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FACTOR PROPORTIONS, RELATIVE EFFICIENCY AND DEVELOPING COUNTIES' TRADE

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Factor proportions, relative efficiency and developing countries' trade

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Abstract: This study attempts to assess the extent to which LDC trade in manufactures can be explained by the factor proportions theory and the economies-of-scale account on the one hand, and by commodity characteristics that affect relative efficiency on the other. Among the relative efficiency characteristics that affect trade patterns are R&D intensity, total factor productivity in the more developed countries, factory size, and some input–output measures of the degree to which the industry interacts with the rest of the economy.

1. Introduction

There is a rather well defined pattern of trade in manufactured goods between less developed countries (LDCs) and more developed countries (MDCs). The LDCs tend to export goods that are intensive in unskilled labor and they tend to import from the MDCs goods that are intensive in physical and human capital [e.g. Kirkpatrick et al., (1984, p. 24)]. Thus the pattern of trade can be explained to some extent by the factor proportions (or Heckscher–Ohlin) theory. It also seems clear that the levels of total factor productivity are considerably lower in LDCs than in MDCs and it seems quite likely that the differences in total factor productivity are not uniform across commodities. Consequently trade patterns should also be affected by the levels of total factor productivity or efficiency. The present paper attempts to clarify the extent to which manufactured goods trade between LDCs and MDCs can be explained by the factor proportions theory on the one hand and some commodity characteristics that affect relative efficiency on the other.

In the empirical international trade literature, there is a fairly long tradition of running cross-commodity regressions to test the factor propor-

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tions theory. In these studies a measure of trade performance (such as net exports) of a particular country is regressed on some variables suggested by the theory, such as physical capital per worker and human capital per worker [see the list of studies cited in Deardorff (1984), and the ones by Hilton (1984) and Balassa (1986)]. The present paper falls within this tradition, but it differs from previous studies in that it makes use of data on factor prices in MDCs and LDCs; the factor price data permit the calculation of predicted relative costs, which are then used as an explanatory variable in regressions explaining net exports. Inasmuch as the factor proportions theory is quite precise about the way in which relative factor prices and factor shares of commodities determine predicted relative costs, the incorporation of these theoretical considerations affords a more precise test of the factor proportions theory than the free-form regressions that have traditionally been run.

Since economies of scale are an important phenomenon in many manufacturing industries, the predicted relative costs variable incorporates an adjustment for the effects on unit costs of the differences in factory size between LDCs and MDCs. Once the influences of factor intensities and relative factory size have been taken into account, the study examines whether other commodity characteristics, which are thought to affect the relative efficiency of LDCs compared to MDCs, can help to explain the patterns of trade.

Motivating this study is the hypothesis that productive efficiency is affected by the institutional context within which production takes place. One of the important differences between LDCs and MDCs is that large organizations in both the private and the public sectors seem to function better in the latter group of countries than in the former group.[1] In MDCs there exist many large organizations (corporations, government agencies) in which most of the members behave like 'organization men', that is, they internalize the goals of the organization and attempt to carry out their assigned duties according to the organizational chart. A management trainee entering such an organization would find it quite sensible to adopt this pattern of behavior, since he or she is likely to be well rewarded for doing so and is likely to be penalized (perhaps by being fired) for violating the stated rules. The successful evolution of large organizations in MDCs has been reinforced by the evolution of cultural values that support them. In LDCs, on the other hand, there has been much less experience with large organizations, and cultural values support other kinds of loyalties (such as loyalties based on family, ethnic group, or friendship). A management trainee entering a corporation or government agency in an LDC would probably not find it as sensible to play by the rules as would his MDC counterpart. Thus the

[1]See Olson (1987) for explanations of this phenomenon.

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difference in functioning of organizations is quite compatible with individual rationality [Sah (1987)].

An implication of this hypothesis is that LDC relative efficiency (compared to MDCs) will be affected by the degree to which a commodity relies on the efficiency of large organizations. The hypothesis predicts that LDC relative efficiency will be higher in production that can be carried out in small organizations than in activities that benefit from large organizations in the private sector or from supporting services from the government.

A well functioning economy relies on the government to construct and maintain physical infrastructure, to provide or regulate the provision of public utilities such as electricity, telephone, mail, and transportation services, and to refrain from inefficient over-regulation of private markets. Governmental deficiencies in these areas will impinge especially on efficiency in activities that make heavy use of the economy's transportation and communication systems. The hypothesis thus implies that LDC relative efficiency would be lower in goods that draw inputs from many other sectors of the economy (thereby making extensive use of the transportation and distribution systems) than in goods whose production is self-contained. For these reasons the hypothesis is called the Self-Containment Hypothesis [for fuller exposition, see Clague (1991)].

A related consideration is that technological transfer from an MDC to an LDC is likely to be easier (and hence more profitable) if the activity in question is self-contained than if the activity requires new kinds of performance (such as the delivery of high-quality intermediate products in a timely manner) by actors over whom the innovator has no direct control. This consideration reinforces the prediction that LDC relative efficiency should be higher in self-contained activities than in interdependent ones.

There are other theories relating to commodity characteristics that might affect LDC relative efficiency, notably the technology-based theories of trade [see, for example, Vernon (1966) and Hirsch (1967)]. A number of variables will be employed as proxies for the various hypotheses relating to LDC relative efficiency. Included among these variables are research and development as a percent of sales, total factor productivity growth in the MDCs, the share of professional workers in total employees, average factory size, and some measures of the degree to which the industry relies heavily on other sectors of the economy.

Since net exports are being used as an indicator of LDC relative efficiency, the present study is related to the literature on total factor productivity (TFP) comparisons between MDCs and LDCs, which is surveyed by Horton and King (1981) and by Pack (1988, pp. 358–365). The number of such studies is not large (due to the difficulty of making careful TFP comparisons), and many of the variables considered there are not particularly

study by Pack (1984), who compares TFP in two-digit manufacturing industries in Israel and the Philippines with that in the United States. Pack's findings will be compared with ours later in the paper.

The theoretical framework of this paper is a world in which commodity prices are not equalized through trade, because of transport costs, governmentally imposed trade barriers, and possibly private market imperfections. Since it is assumed that there are efficiency differences among countries, it is clear that factor prices and costs of production of particular commodities may differ among countries in the trading equilibrium. Some empirical tests in the paper will consist of comparisons of net exports between two economies and the predicted relative costs in the two economies. The validity of these tests rests on the assumption that larger differences in relative costs will lead to larger net exports by the lower-cost economy. This assumption is not a proposition that follows from standard trade theory, but it does not seem to be an unreasonable empirical assumption. A similar assumption underlies the traditional cross-commodity regressions testing the factor proportions theory.[2]

Cross-commodity regressions have come under severe theoretical attack from the proponents of the 'AT methodology' in which one calculates the factor content of trade [Anderson (1981), Leamer and Bowen (1981) Leamer (1984, pp. 54–58)]. One of the points of these critics is that in a multi-factor world, the theory does not predict any simple relationships between trade flows and factor intensity ratios for a *subset* of the relevant factors. (That is, in a multi-factor world the theory does not predict that a country with a higher capital–labor endowment ratio than its trading partner will necessarily export goods with higher capital–labor ratios.) The theoretical objections would largely disappear, however, under the following circumstances: the subset of factors being studied is raw labor, human capital, and physical capital; the sample of commodities is limited to resource-free manufactured products; and it is assumed that the raw materials and intermediate products (e.g. cotton, leather, steel, fuel) are available everywhere at similar prices. This last assumption is not correct, of course, but the problem constitutes an empirical qualification to be kept in mind in interpreting the results rather than a theoretical objection to cross-commodity regressions.

An alternative way of assessing the relative importance of factor intensities,

[2]Deardorff (1984, pp. 471–473) comments on the absence of a well articulated theory of the relationship between trade flows and autarky prices. There is a similar lack of theory relating trade flows to actual relative costs, but in both cases it seems reasonable to posit a strong relationship.

It must be recognized of course that exports and (especially) imports are influenced by tariffs, subsidies, and non-tariff barriers, but data limitations preclude introducing these variables into the analysis. In ignoring these influences we are following a long tradition in empirical studies of

relative factory size, and differences in relative efficiency is to compare predicted relative costs with actual relative prices instead of with net exports. This method of analysis has considerable theoretical advantages (in particular there is no need to rely on an assumed relationship between relative costs and net exports), but the relative price data have certain practical shortcomings: they are collected at the retail rather than at the factory level and there is doubt about whether proper adjustments have been made for product quality. Nevertheless, it is useful to bring the net export data and relative price data together to see whether they can both be explained by the same independent variables.

The paper is organized in the following way. Section 2 explains the design of the tests with the trade data and with the relative price data. The variables used to describe commodity characteristics that affect LDC relative efficiency are discussed in section 3. The data sources and procedures are described in section 4, and the adjustment for economies of scale is explained in section 5. Section 6 contains the empirical results, and some concluding observations are presented in section 7.

2. The design of the tests

Trade flows are measured by net normalized exports (NNX), defined as

$$NNX_i = (X_i - M_i)/(X_i + M_i),$$

where i refers to the commodity category and X_i and M_i refer to exports from a particular LDC to all MDCs and imports into that LDC from all MDCs. NNX_i is bounded by -1 and $+1$.

In choosing this measure I am following Balassa (1986). An obvious alternative is a measure based on exports alone, such as Balassa's 'revealed comparative advantage' [Balassa (1979)], which is the ratio of a country's share in world exports of a particular commodity to its share in world exports of all manufactured goods. This measure seemed to have the disadvantage that the regressions would be dominated by very large values for a few commodities; by contrast, the limits on the range of net normalized exports (-1 and 1) make it unlikely that a small number of commodities would dominate the regression.[3,4]

[3]The regressions were run by ordinary least squares. It was thought that estimation by nonlinear least squares to limit the predicted values to the appropriate range (-1, $+1$) would not alter the substantive results. Balassa and Bauwens (1988, p. 64) report that the two sets of results were very similar in their study.

[4]The measure NNX_i bears a superficial resemblance to one measure of inter-industry trade (IIT)

The variable NNX_i will be regressed on the log[5] of predicted relative costs (PRC_i) of the LDC compared to that of MDCs as a group. The predicted relative costs depend on two sets of influences: relative factory size in the LDC on the one hand, and factor shares and relative factor prices on the other. Denoting LDC relative factory size in commodity i by RS_i, and the share of factor k in commodity i by T_k^i, and the LDC relative factor price by r_k, we may write predicted relative costs as

$$PRC_i = f(T_1^i, T_2^i, \ldots; r_1, r_2, \ldots)\phi(RS_i),$$

where $\phi(RS_i)$ measures the proportional increase in unit cost resulting from the difference in factory size, and $f(\cdot)$ is a function that depends on the production function.[6] In the case of the Cobb–Douglas production function, the f function turns out to be Cobb–Douglas in form, and we may write

$$PRC_i = \phi(RS_i) \prod_{k=1}^{5} (r_k)^{T_k^i}$$

for the case of five factors of production [for derivation, see Clague (1989)]. For ease of notation we shall refer to the Cobb–Douglas expression above as the weighted factor price index ($WFPI$), and since the factor prices r_k are invariant across commodities, we may write

$$PRC_i = \phi(RS_i) WFPI_i(T_1^i, T_2^i \ldots T_5^i).$$

Now the difference between our theoretically constrained regression and the traditional cross-commodity regression may be explained with the following equations:

$$NNX_i = a + b \log[\phi(RS_i) WFPI_i(T_1^i, \ldots, T_5^i)] + \sum_j c_j Z_j + u_i, \tag{1}$$

$$NNX_i = A + B_1 T_1^i + B_2 T_2^i + \cdots + B_5 T_5^i + \sum_j C_j Z_j + u_i'. \tag{2}$$

$$IIT_i = |X_i - M_i|/(X_i + M_i),$$

which lies between 0 and 1. The presence of intra-industry trade may simply reflect the heterogeneity of commodities within a category, or it may also reflect the influence of advertising, product differentiation, and other forms of non-price competition. For the purposes of this study, it would be desirable to purge the NNX_i measure of the trade that is based on non-price influences. That is unfortunately not possible, but the problem does not seem to be a very serious one. The presence of two-way trade based on product differentiation merely adds a positive quantity to the numerator and the denominator of NNX_i and moves the measure closer to zero. But most of the action in NNX_i comes from the values being positive or negative and the sign of NNX_i would not be altered by the removal of a portion of two-way trade.

[5]The reason for taking the log of PRC_i is explained in footnote 8 below.

[6]The Cobb–Douglas assumption is used for simplicity of exposition. Experiments were also run with the CES production function, but the choice makes no substantive difference in the empirical results.

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Eq. (1) represents the theoretically constrained test, where the factor shares and the relative size variable are combined according to theoretical considerations. Eq. (2) is an example of the traditional regression where here the factor shares are used as the independent variables. Factor proportions (e.g., capital–labor ratios) have often been used rather than the factor shares [see the comment on this practice by Deardorff (1984, pp. 486–487)]. The Z_j will be called the *supplementary* variables, and they represent the commodity characteristics that are thought to affect relative efficiency.

Suppose for the moment that we leave out the supplementary variables (the Z_j) from both (1) and (2) and we omit the relative factory size term $\phi(RS_i)$ from (1). Under these conditions it is clear that the R^2 must be higher for the free-form regression (2) than for the theoretically constrained regression (1), because the same variables (the factor shares T) are entering both equations and the regression program is free to select the weights in (2) but not in (1). Despite the lower R^2, to the present researcher the theoretically constrained regression represents a conceptually superior method; it isolates the mechanisms captured by the factor proportions theory, while the factor-share variables in the free-form regression may also be capturing some of the determinants of LDC relative efficiency.

As mentioned in the introduction, an alternative way of analyzing the data is to compare predicted relative costs with actual relative prices instead of with net exports. The theory underlying these tests will now be explained. Under the hypothesis that LDC relative efficiency is the same for all commodities, the predicted relative price (PRP_i) in the LDC would be

$$PRP_i = A^* \phi(RS_i) WFPI_i.$$

The actual relative price ($PRICE_i$) in the LDC may be written

$$PRICE_i = A_i \phi(RS_i) WFPI_i + e_i,$$

where e_i is a random error term and the relative efficiency parameter A_i is allowed to vary across commodities. The deviation of the actual price from the predicted price is then

$$PDEV_i = PRICE_i - PRP_i = (A_i - A^*) WFPI_i \phi(RS_i) + e_i.$$

Dividing by PRP_i gives

$$RDEV_i = PDEV_i / PRP_i = [A_i - A^*)/A^*] + e_i / PRP_i. \tag{3}$$

$RDEV_i$ is the proportional deviation of the observed price from the predicted price, which according to (3) is equal to the proportional deviation [illegible]

from A^*.[7] Since the efficiency parameter A_i is a function of the supplementary variables, the variable $RDEV_i$ will be regressed directly on these supplementary variables.[8]

For reasons given below we shall assume that the error term e_i is heteroscedastic of the form $\mathrm{var}(e_i)=s^2VAR_i$ where VAR_i is an exogenous variable. Hence $\mathrm{var}(e_i/PRP_i)=s^2(VAR_i/PRP_i^2)=s^2v_i$ where $v_i=VAR_i/PRP_i^2$. To correct for heteroscedasticity the observations in the regression will be weighted by $1/v_i$.

3. Relative efficiency variables

The supplementary variables were selected to measure commodity characteristics that were thought to affect LDC relative efficiency. Some variables were chosen to capture the influences represented in the Self-Containment Hypothesis described in the introduction. Other variables were designed to represent the technology-based theories of trade.

The technology-based variables are research and development as a percent of sales (R&D) and the rate of growth of total factor productivity (TFP) in the particular industry in the MDCs. Both of these variables are designed to capture the degree of technological progressiveness of the product in the MDCs and are therefore conceptually correctly measured with MDC data.

The variables representing the Self-Containment Hypothesis include first the absolute size of factories in the particular industry. Industries in which factories are large are ones in which there are benefits from large organizations. This variable was measured by taking an average of factory size in an MDC (the U.S.) and the LDC (Korea). This absolute size variables ($SIZE$) is not to be confused with the relative size of factories in LDCs which is used in the economies-of-scale adjustment. The relative size variable incorporates the idea that LDC average costs should be high in industries in which LDC factories are small relative to factories in MDCs (the adjustment also depends on the magnitude of economies of scale), while the absolute size variable ($SIZE$) tests the hypothesis that LDC relative costs are high in industries that benefit from large organizations. (Not surprisingly, absolute and relative size are correlated; our main focus is an absolute size, which we test *after* correcting for the influence of relative size.)

The Self-Containment Hypothesis is also tested by constructing two variables from the 480-sector U.S. input–output table; these variables are designed to measure the degree to which a product depends on inputs from other sectors of the economy and therefore depends on the functioning of the

[7] A^* is calculated from $A^*=\overline{PRICE}/\overline{PRC}$.

[8] The reason for taking the log of PRC_i in eq. (1) instead of using PRC_i itself is that net exports are taken to be a function of A_iPRC_i, where A_i is a function of the supplementary

economy's transportation and distribution system.[9] The first of these variables is the number of input sectors into the product in question; the second is the dispersion of input shares (or one minus the Herfindahl index of the concentration of input shares). It would be useful to have the input–output data for both MDCs and LDCs but for practical reasons only the U.S. data were employed. It is assumed therefore that the ranking of products by these measures would be similar of LDC data were available.[10]

The next two supplementary variables are designed to capture the degree to which the product requires information processing. It was thought that LDCs have not developed institutions for the efficient transmission of information both within organizations and across sectors. The two variables employed to capture the extent of information processing required for a product are the share of professional and technical workers among all employees (*PROF*) and the share of college graduates among all employees (*COLL*). These variables have been used in prior trade studies in free-form regressions; in such regressions they can be interpreted either as factor-intensity variables (according to the factor-endowments theory) or as technology variables (according to technology-based theories). Our use is closer to the latter interpretation, but our study differs from the prior literature in that the influence of these variables through the mechanism of the factor proportions theory has already been taken into account through the variable *PRC*. Thus these variables in our regressions can be interpreted as representing some aspect of relative efficiency influences. These variables were measured with MDC data; this procedure is appropriate because these variables capture the degree to which information processing is useful in countries where the appropriate institutions function effectively.

4. The data

The trade data for six Asian LDCs (India, Pakistan, Sri Lanka, the Philippines, Thailand, and Korea) were taken from the OECD Statistics of Foreign Trade, Series C for 1975. The figures include only exports to and imports from the OECD countries. The price data for the same year were taken from Kravis, Heston, and Summers (KHS) (1982); this source gives the purchasing-power parity (PPP) vis-à-vis the U.S. dollar for some 150 categories of commodities and services. The PPPs for each Asian LDC were divided by the exchange rate (vis-à-vis the dollar) to give the price relative to the U.S. price. The prices for a group of seven high-income[11] MDCs were

[9]To avoid relying on uncertain deliveries, factory managers in LDCs frequently maintain facilities for producing their own intermediate inputs or even their own electricity. These facilities are typically operated with low rates of capital utilization.

[10]LDCs, however, do not have such detailed input–output tables as the U.S. does.

[11]The Netherlands, Belgium, France, Luxembourg, Denmark, Germany, and the U.S.

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averaged and the price in each Asian LDC was taken as a ratio of this MDC average price.

The sample consists of 45 resource-free manufactured commodities for which reasonable matches could be made with U.S. production statistics. [For a description of the sample and a more detailed description of the data, see Clague (1991).] The factor shares for the five factors (raw production labor, production labor skill, non-production labor, producer durables, and construction) were taken from U.S. data. Conceptually it would be preferable to use average factor shares for MDCs and LDCs but this change in procedure would be unlikely to make much difference to the results, first because researchers have generally found that the rankings of commodities by factor intensities are quite similar across countries, and second because out main focus is on the supplementary variables; these variables are quite robust to alternative procedures for claculating *PRC* (see below).

The supplementary variables are as follows:

PROF = share of professional and technical workers among all employees [Source: U.S. Bureau of Labor Statistics (1981)];
COLL = share of college graduates among all employees [U.S. Census of Population (1970)];
R&D = research and development expenditures as a percent of sales [U.S. Federal Trade Commission (1982)].

The rates of growth of total factor productivity (1960–1979) in Japan and the United States were available in Jorgenson et al. (1985). Rates of *TFP* growth in the U.S. for 1950–1957 were available in Massell (1961). The variables used are:

TFP = average of U.S. and Japanese rates of growth of *TFP*, 1960–1979;
TFP2 = U.S. rate of growth of *TFP*, 1950–1957.

The two input–output variables are:

VRTY = variety of inputs, or number of input sectors;
DISP = dispersion of input shares, or one minus the Herfindahl index of concentration of input shares.

The following factor price data were collected from the International Comparison Project (ICP) [KHS (1982, pp. 176–179 and 208–215)]. The numbers are averages of the six Asian LDCs relative to the seven high-income countries in the ICP sample.

Labor costs:	blue collar – unskilled	0.075
	– skilled	0.089
	white collar	0.090
	[illegible]	0.124

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Capital costs:	producer durables	0.849
	construction	0.328

For each country the PPP was divided by the exchange rate to obtain the price (or wage). The wages are all for government workers. (These may not be representative of the labor market in the private sectors, but one can see from the figures above that precision is hardly necessary for present purposes.) Blue-collar employees are divided into unskilled and skilled according to whether they have primary or secondary education. White-collar employees have secondary education and professionals have post-secondary education. The producer durables and construction prices are averages of some 22 categories of producer durables and 14 categories of structures. The rate of return to capital was assumed to be the same in LDCs and MDCs.[12]

The next task is to translate the ICP relative labor cost data into the three labor costs used in this study: raw labor, production labor, and non-production labor. Some alternative ways of doing this are listed in table 1.

Alternative 1 is a straightforward approach that takes the unskilled blue collar wage as the cost of raw labor (0.075), the simple average of white-collar and professional salaries as the cost of non-production labor (0.112), and a suitable figure for production skill (0.103) such that the relative earnings of skilled production workers will come out to the observed figure (0.089), on the assumption that these workers' earnings are divided equally between raw labor and return to skill.

Alternatives 2 and 3 were selected rather arbitrarily in such a way as to increase the relative cost in the LDCs of the more skilled labor categories. We shall perform a sensitivity analysis on these variations. Alternative 2 uses the relative wages of professional workers (0.134) for both production skill and non-production labor, and Alternative 3 arbitrarily doubles the relative cost of non-production labor (to 0.268).

Table 1

Alternative ways of translating ICP relative labor cost data.

	Raw labor	Production skill	Nonproduction labor
Alternative 1	0.075	0.103	0.112
Alternative 2	0.075	0.134	0.134
Alternative 3	0.075	0.134	0.268

[12]A study by Harberger (1978) found no systematic difference in the rate of return to capital in developed and less-developed countries.

5. Adjustment for economies of scale

The adjustment for economies of scale is adapted from a procedure used by Pack (1984). The adjustment is based on the relative size of factories in the LDC compared to the MDCs and on the degree of economies of scale.

We assume that the relation of total cost (C) to output (X) is

$$C = BX^{1-\alpha},$$

where $0<\alpha<1$. Hence average cost (c) is

$$c = C/X = BX^{-\alpha}.$$

The ratio of average cost in the LDC to that in the MDC's is

$$c^{\mathrm{LDC}}/c^{\mathrm{MDC}} = (X^{\mathrm{LDC}}/X^{\mathrm{MDC}})^{-\alpha} = (X^{\mathrm{MDC}}/X^{\mathrm{LDC}})^{\alpha}, \tag{4}$$

where $X^{\mathrm{LDC}}/X^{\mathrm{MDC}}$ is LDC relative factory size.

Pack (1984) measured relative factory size by relative employment size. This procedure biases upward the size of factories in LDCs to the extent that there is substitution of labor for capital. As an alternative, factory size was measured by a Cobb–Douglas composite of inputs. This procedure yields the following expression:

$$\frac{X^{\mathrm{MDC}}}{X^{\mathrm{LDC}}} = \frac{L^{\mathrm{MDC}}}{L^{\mathrm{LDC}}}\left(\frac{RCC}{RLC}\right)^{T}, \tag{5}$$

where the first fraction on the right is the ratio of employment size of factory in MDCs and the LDC, and the second fraction is the ratio of relative LDC capital costs (RCC) to relative LDC labor costs (RLC), raised to the capital share.[13] Since the second fraction is greater than one, this adjustment for capital–labor substitution increases the measured relative size of the MDC factories.

The employment size of factories in an industry is measured by a Niehans

[13] In an obvious notation factory size in the MDC and the LDC is given by

$$X^{\mathrm{MDC}} = K^{T}L^{1-T}, \qquad X^{\mathrm{LDC}} = k^{T}l^{1-T}.$$

From the first-order conditions we have

$$\frac{K/L}{k/l} = \frac{(w/r)^{\mathrm{MDC}}}{(w/r)^{\mathrm{LDC}}} = \frac{r^{\mathrm{LDC}}/r^{\mathrm{MDC}}}{w^{\mathrm{LDC}}/w^{\mathrm{MDC}}} = \frac{RCC}{RLC}.$$

Hence

$$\frac{X^{\mathrm{MDC}}}{X^{\mathrm{LDC}}} = \left(\frac{L}{l}\right)\left(\frac{K/L}{k/l}\right)^{T} = \left(\frac{L}{l}\right)\left(\frac{RCC}{RLC}\right)^{T}.$$

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Index, which is a weighted average of the employment size in different size classes [see Pryor (1973) for a discussion of different indexes used to make international comparisons of factory size]. Specifically, the Niehans Index of employment size is

$$\lambda = \sum_j \lambda_j \left(L_j \Big/ \sum_j L_j \right),$$

where λ_j is the average employment size in size class j and $L_j/\sum_j L_j$ is the relative share of employment in factories of this size in the particular industry.

The Niehans Index of employment size could be calculated only for those countries and industries for which a size distribution of factories could be located. From the libraries of the IMF–World Bank, Inter-American Development Bank, the U.S. Bureau of the Census, and the Maryland Inforum Project, I was able to collect size distributions by two-digit industry for 17 countries.[14] These data are printed in Table A.1 in the appendix, and the reader is invited to peruse that table, since the numbers are interesting in their own right. The numbers tend to support Pryor's (1973) finding that factory size is positively related to the market size of the country, and the highly successful exporters (Taiwan, Korea, Singapore) tend to have larger factory size than would be expected on the basis of market size. Another interesting feature of the data is that really large differences in factory size between LDCs and the United States appear only in industries that can be characterized as machinery producing sectors (non-electrical machinery, electrical machinery, transportation equipment, and instruments). These are industries in which LDCs tend to have a strong comparative disadvantage, as measured by either net exports or relative prices; thus it is possible that this comparative disadvantage may be partly attributable to economies of scale.

It is obvious that factory size is an endogenous variable in this context, in that successful exporters will tend to have larger factory size. The data set does not appear to be sufficiently rich to support a simultaneous-equation approach to the analysis of net exports and factory size (in particular we have factory size data on only one of the six Asian LDCs in the study). Moreover, since our interest is primarily in the supplementary variables measuring relative efficiency, we shall adopt the following procedure. We shall calculate a generous adjustment for economies of scale, one that tends to overstate the importance of relative factory size. Then we shall run the regressions both with and without this adjustment. Since the relative

[14]Korea, Taiwan, Singapore, Colombia, Mexico, Venezuela, Ecuador, El Salvador, Costa Rica, Panama, Cyprus, Italy, Austria, the Netherlands, Belgium, Japan, U.S.

Table 2

Factory size variables.[a]

	No. workers	L^{LDC}/L^{MDC}	X^{LDC}/X^{MDC}	$SCALE$
India	710	0.724	0.547	1.067
Pakistan	461	0.503	0.382	1.103
Sri Lanka	265	0.328	0.252	1.157
The Philippines	456	0.498	0.379	1.104
Thailand	454	0.496	0.378	1.104
Korea	460	0.598	0.464	1.114
U.S.	1,239			

[a]For explanation of variables, see text.

efficiency variables tend to be quite significant in both cases, we can have some confidence in our conclusions with respect to these variables.

For the 171 industry observations in the 17 countries, the following regression was estimated (t-ratios in parentheses):

$$NIEH = \underset{(4.66)}{223} + \underset{(2.36)}{42}\log(MKT) + \underset{(0.16)}{13}\,MACH + \underset{(5.10)}{157}(MACH \cdot \log(MKT))$$

$$+ \underset{(2.04)}{212}RUBB + \underset{(1.42)}{161}KOR + \underset{(3.36)}{419}\,TAI, \qquad \bar{R}^2 = 0.3743, \quad S.E.E. = 364.$$

where $NIEH$ is the Niehans Index of factory employment size, $MACH$ and $RUBB$ are industry dummies for machinery sectors and rubber products, KOR and TAI are dummies for Korea and Taiwan, and MKT is the market size of the country (real per capita income multiplied by population). From this regression equation, factory employment size was imputed to each industry in India, Pakistan, Sri Lanka, the Philippines, and Thailand. The U.S. was taken as the representative country for the MDCs.

The results of these calculations are shown in table 2. All the entries are averages across the 45 products in our sample. The number of workers is the Niehans index of employment. The next column gives relative employment size (L^{LDC}/L^{MDC}), and the next gives relative factory size (X^{LDC}/X^{MDC}), which is relative employment size adjusted for factor substitution.

It remains to explain the selection of the values of α used in the economies-of-scale adjustment in eq. (4). The industrial organization literature contains some estimates of the 'minimum efficient scale' (MES) of factories and of the percentage increase in average costs resulting from producing at half the size of the MES instead of at the MES. Let us denote this 'cost elasticity' by Ecx. I took estimates of the cost elasticity primarily from Scherer (1980). The values selected are listed in the appendix.

From the definition of Ecx and the exponential cost function used in (4), we have

Table 3

Correlation matrix of supplementary variables.[a]

	PROF	*R&D*	*SIZE*	*TFP*	*TFP2*	*VRTY*	*DISP*
PROF	1.000						
R&D	0.753	1.000					
SIZE	0.515	0.271	1.000				
TFP	0.478	0.120	0.498	1.000			
TFP2	0.502	0.199	0.676	0.768	1.000		
VRTY	0.368	0.348	0.602	−0.103	0.291	1.000	
DISP	0.521	0.463	0.562	0.310	0.533	0.410	1.000
Mean	0.8467	1.729	6.488	1.311	2.072	0.5160	0.8975
S.D.	0.6449	1.901	0.433	0.817	1.038	0.1950	0.0670

[a]Key: *PROF* = share of professional workers in industry employment, *R&D* = research and development expenditures as a percent of sales, *SIZE* = log of Nichans index of establishment employment, *TFP* = average growth of total factor productivity in the U.S. and Japan, 1960–79, *TFP2* = rate of growth of total factor productivity in the U.S., 1950–57, *VRTY* = variety of number of input sectors, *DISP* = dispersion of input shares.

$$1+Ecx=2^{\alpha} \quad \text{or} \quad \alpha=\ln(1+Ecx)/\ln 2. \tag{6}$$

Eq. (6) was used to infer a value of α from the value of Ecx and it was assumed in accordance with (4) that this value of α applies through the range of factory sizes between the average size in the LDC and that in the U.S.

The variable *SCALE* is defined as

$$SCALE=(\text{LDC relative factory size})^{-\alpha}.$$

Average values for the six countries are shown in table 2. This is very similar to the scale variables constructed by Pack (1984), the only difference lying in our adjustment for factor substitution.

The correction for economies of scale was thought to be generous for two reasons. First, the choice of the U.S. as the representative MDC exaggerates the employment factory size in the MDCs. Second, the use of the Cobb–Douglas production function exaggerates the correction for capital–labor substitution if, as many believe, the elasticity of substitution is less than unity. A factor working in the other direction is that LDC plants tend to produce a wider range of products than their counterparts in MDCs [e.g. Pack (1987)].

6. Empirical results

Regressions were run on the pooled sample of six Asian LDCs of the price deviations according to (3) and of net exports according to (1). The correlation matrix of the supplementary variables is shown in table 3. where

it is seen that there is a good deal of multicollinearity among these variables. (To save space the college share *COLL* has been omitted; it is highly correlated with *PROF* and did not perform as well as *PROF* in the regressions.)

The base case for the analysis is the one in which factor prices are selected according to Alternative 3 and predicted relative costs incorporate the adjustment for economies of scale. It turns out that the use of alternative assumptions strengthens the supplementary variables.

As expected net exports (*NNX*) and relative prices (*PRICE*) are negatively correlated, but far from perfectly; the correlation is −0.54 for the whole sample and ranges from −0.46 in Thailand to −0.68 in Pakistan. The *PRICE* variable appears to contain a good deal of noise; the standard derivation in the pooled sample is 0.5343, and the standard error of the regression when *PRICE* is regressed on the six country dummies is 0.5329. When price has been corrected for factor proportions alone, the standard error falls to 0.4839, and when the economies-of-scale adjustment is incorporated the standard error falls to 0.4680. Since all the price regressions were run with six intercept dummies for the countries, the standard errors indicate the variation left to be explained by the supplementary variables.

The price deviation regressions are shown in table 4. Recall that the dependent variable is the ratio of the price deviation to predicted relative price. There is good reason to believe that the error variance differs across product categories; the categories contain somewhat heterogeneous goods and the individual items are priced in some countries and not in others. To correct for different degrees of product heterogeneity across categories, I first calculated the variance of prices (VAR_i) across all 34 countries in the KHS (1982) sample. The observations were then weighted by $1/v_i$, where $v_i = VAR_i/PRP^2$, as required by eq. (3). Panel A of table 4 shows the regressions with a single independent variable, and it can be seen that each of the seven supplementary variables comes in with the expected positive sign and a highly significant t-ratio.

Some multiple regressions are shown in Panel B. As a result of the high degree of multicollinearity, the variables interfere with another. The two input–output variables *VRTY* and *DISP* are very strong and together greatly weaken most of the others. In the absence of these two variables, the strong ones are *R&D* and the two *TFP* variables.

We turn next to the net export regressions, which are displayed in table 5. Six country intercept dummies are included in each regression but are not shown in the table. In all of these regressions, the first regressor in the table is the log of predicted relative costs, which is always highly significant. In this study the variable capturing the factor proportions theory performs better than in many cross-commodity studies of trade. The success of this variable is not primarily due to the incorporation of the economies-of-scale

Table 4

Price deviation regressions.

PROF	*R&D*	*SIZE*	*TFP*	*TFP2*	*VRTY*	*DISP*	
A. Regressions with a single independent variable							
0.2779	0.7403	0.3245	0.1826	0.1685	0.8807	3.063	
(6.66)	(5.70)	(4.67)	(4.19)	(5.26)	(5.85)	(8.58)	
B. Multiple regressions							$\bar{R}^2$/S.E.E.
	0.5974	0.2150					0.1531
	(4.38)	(3.00)					(0.4256)
	0.6446		0.1332				0.1551
	(4.91)		(3.11)				(0.4251)
	0.5903			0.1267			0.1731
	(4.47)			(3.92)			(0.4205)
	0.5686	0.1521	0.0982				0.1646
	(4.18)	(1.97)	(2.13)				(0.4227)
	0.5427)	(0.1129		0.1035			0.1764
	(4.00)	(1.43)		(2.87)			(0.4197)
					0.4522	2.584	0.2581
					(2.95)	(6.66)	(0.3983)
0.0884					0.3584	2.236	0.2642
(1.77)					(2.22)	(5.16)	(0.3967)
	0.1910				0.3847	2.379	0.2602
	(1.32)				(2.38)	(5.70)	(0.3978)
		−0.0420			0.5037	2.638	0.2558
		(−0.49)			(2.70)	(6.53)	(0.3989)
			0.1093		0.4617	2.335	0.2767
			(2.75)		(3.05)	(5.94)	(0.3933)

[a]t-ratios in parentheses below coefficients. Key: see table 2.

adjustment ($\bar{R}^2$ for log *PRC* alone is 0.6275 with and 0.5074 without this adjustment), but seems mainly to be the result of the choice of countries. The pattern of trade of these six Asian countries does fit the predictions of the factor proportions theory pretty well, probably better than the trade patterns of most other LDCs. Nevertheless, the supplementary variables also perform quite well. The upper part of the table shows the supplementary variables entered singly; all have the expected negative signs and are quite significant.[15] (To save space the *TFP2* variable is not shown, since *TFP* is the more appropriate variable conceptually.) As in the price regressions multicollinearity makes the supplementary variables interfere with one another,

[15]There is reason to believe that the coefficients of the self-containment variables (*VRTY*, *DISP*, and *PROF*) would be strengthened if it were possible to remove the component of two-way trade based on product differentiation from the *NNX* variable. The products in which self-containment is low (and *VRTY*, *DISP*, and *PROF* are high) tend to be those in which product differentiation is high and in which *NNX* for the LDCs is negative. Removing part of the two-way trade always moves *NNX* away from zero (see footnote 4 above), and in this case it would reduce *NNX*, thereby strengthening the negative association between *NNX* and the variables *VRTY*, *DISP*, and *PROF*.

Table 5

Net export regressions.[a]

Log *PRC*	*PROF*	*R&D*	*SIZE*	*TFP*	*VRTY*	*DISP*	$\bar{R}^2$/S.E.E.
−2.618 (−20.57)							0.6275 (0.5051)
−2.285 (−14.85)	−0.2146 (−3.68)						0.6445 (0.4935)
−2.392 (−15.60)		−0.5084 (−2.58)					0.6354 (0.4998)
−2.028 (−14.11)			−0.5712 (−7.05)				0.6857 (0.4640)
−2.088 (−14.77)				−0.1353 (−3.54)			0.6431 (0.4944)
−1.835 (−11.22)					−0.6801 (−4.02)	−2.897 (−5.05)	0.6835 (0.4656)
−1.888 (−12.03)	−0.1218 (−2.16)		−0.5240 (−6.29)				0.6901 (0.4608)
−1.722 (−10.39)		−0.6315 (3.51)	−0.5968 (−7.49)				0.6988 (0.4543)
−1.7558 (−10.96)				−0.1507 (−4.02)	−0.8978 (−5.12)	−2.279 (−3.94)	0.7009 (0.4527)
−1.445 (−8.24)		−0.4812 (−2.68)	−0.4686 (−5.22)		−0.2296 (−1.27)	−2.146 (−3.81)	0.7144 (0.4423)

[a]Key: *PRC* = predicted relative costs. See also table 2.

but the two input–output variables *VRTY* and *DISP* are quite strong and reasonably robust. The *SIZE* and *R&D* variables are also quite robust.

To check for differences in regression coefficients among the countries, a number of regressions were run with a complete set of country slope dummies as well as intercept dummies. In almost all cases the country slope dummies were not significant as a group; that is, the *F*-test did not reject the assumption of common slopes at the 5 percent level.[16]

Regressions were also run for the price deviations and for net exports under alternative assumptions; specifically, the adjustment for economies-of-scale was omitted and factor prices were selected under Alternative 2. Table 6 shows the effects of these changes in assumptions; the price regressions there each contain a single independent variable; the net export regressions contain log *PRC* and one other independent variable (except in the case of *VRTY* and *DISP*, which are entered together). Almost without exception the changes in assumptions strengthen the supplementary variables. The improvement is especially pronounced for *PROF* and *R&D* under Alterna-

[16]In the net export regression of *VRTY* and *DISP*, the country slope dummies were barely significant at the 5% level.

Table 6

Regressions under alternative assumptions.[a]

	PROF	*R&D*	*SIZE*	*TFP*	*VRTY*	*DISP*
Price regressions						
Base case	0.2779	0.7403	0.3245	0.1826	0.8807	3.063
	(6.66)	(4.67)	(4.67)	(4.19)	(5.85)	(8.58)
No scale adjustment	0.3288	0.8386	0.4392	0.2181	1.094	3.489
	(7.62)	(6.17)	(6.15)	(4.78)	(7.05)	(9.46)
Alternative 2	0.3528	0.8908	0.3314	0.2044	0.9083	3.140
	(8.14)	(6.64)	(4.77)	(4.61)	(6.05)	(8.77)
Export regressions						
Base case	−0.2146	−0.5084	−0.5712	−0.1353	−0.6801	−2.897
	(−3.68)	(−2.58)	(−7.05)	(−3.54)	(−4.02)	(−5.05)
No scale adjustment	−0.3731	−0.8411	−0.8421	−0.2275	−0.9788	−3.921
	(−6.23)	(−3.80)	(−11.42)	(−5.43)	(−5.67)	(−6.84)
Alternative 2	−0.3658	−1.0230	−0.6344	−0.1700	−0.7194	−3.606
	(−6.73)	(−5.44)	(−7.26)	(−4.19)	(−4.00)	(−6.07)

[a]Price regressions are each with a single independent variable. Net export regressions contain log *PRC* and one other independent variable (except for *VRTY* and *DISP*, which were entered together).

tive 2 and for *SIZE* when the scale adjustment is omitted. In brief, the supplementary variables are quite robust to alternative assumptions.

A methodological point of some interest is that the results are quite strongly influenced by the manner in which the elements of the factor proportions theory and the economies-of-scale account are incorporated into the analysis. Specifically, if one regresses net exports on the factor shares and the *SCALE* variable in free form (instead of combining them according to theory into *PRC*), these variables explain net exports better than log *PRC* does and leave less opportunity for the supplementary variable to enter the regression significantly. This is exactly what one would expect if the factor-share variables and the *SCALE* variable are picking up commodity characteristics that affect relative efficiency.

It is interesting to compare the results of this study with those of Pack (1984). Although his dependent variable is relative total factor productivity (*TFP*) (compared with the U.S.) in Israel and the Philippines, whereas my dependent variables are net exports and relative prices, both studies are addressing the explanation of the patterns of LDC relative efficiency across industries. Pack's findings that are relevant to this study are as follows. In regressing LDC relative efficiency on product characteristics he found a significant negative coefficient on his *SCALE* variable, a significant positive coefficient on LDC industry average wage rate, and a very insignificant coefficient on U.S. *TFP* growth (the same variable as *TFP2*). The present study has confirmed the existence of a strong negative relationship between

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SCALE and LDC relative efficiency (as reflected in either net exports or relative prices),[17] but our results differ with respect to *TFP2*, which was a very successful variable in this study.

With respect to industry wages, our results again appear to differ. I found a very strong negative relationship between LDC relative efficiency (as reflected in either net exports or relative prices) and U.S. average wages.[18] Inasmuch as interindustry wage structures seem to be rather similar across countries, I would expect similar relationships of net exports and relative prices with LDC industry wages.

7. Concluding observations

The results of this study provide substantial evidence that LDC relative efficiency levels differ across industries and are related to the commodity characteristics measured in this study. The strong performance of the *R&D* variable and of the *TFP* growth variables support the product cycle and other technology-based theories of trade. The *SIZE* variable, which also performed quite well, supports the hypothesis that LDCs are deficient in managing large organizations. The two input–output variables, number of input sectors (*VRTY*) and dispersion of input shares (*DISP*), support the hypothesis that LDCs are especially inefficient in industries that require intensive interaction with other sectors of the economy. The good performance of the professional share variable indicates that LDCs are relatively weak in information-intensive activities. The *SCALE* variable indicates that relative factory size probably has an important influence on relative costs in some industries.

The size, professional share, and input–output variables tend to support the proposition that productive efficiency is affected by the institutional context within which production takes place. That is, productive inefficiencies are importantly related to the interactions among sectors in the economy and among people within an organization; thus my interpretation of productivity differences is the opposite of that of Clark (1987), who attributes these differences to labor quality, and my interpretation of income differences is quite different from that of the many economists who stress the differences in endowments of physical and human capital. In a broad sense my interpretations are consistent with those of Stiglitz (1988), who stresses the limitations of the factor endowments approach and the importance of recognizing the inefficiencies in both market and non-market mechanisms in LDCs.

[17]The simple correlations of *SCALE* in the pooled sample are −0.715 with net exports and 0.242 with price deviations.

[18]The simple correlation of U.S. average earnings in the pooled sample are −0.794 with net exports and 0.677 with price deviations.

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One of the puzzles in the development literature is why cross-country studies of growth have found that in recent decades high rates of economic growth have been associated with large and rapidly growing exports [Feder (1983)]. A modeling effort based on a dynamic compatible general equilibrium model suggests some of the mechanisms by which export success can increase the overall growth rate, but the difference in growth experience between export-oriented and import-substituting countries remained larger than could be accounted for in the model (Chenery et al. (1986, p. 339)]. The results of this study suggest two interpretations of this puzzle. The first is that LDCs that are successful in industrial exports have evolved or are evolving institutions that permit effective coordination of individual activities within organizations and across sectors. The second is that the ability to purchase imports freely on the world market is one way to get around the unreliability of local suppliers.

Appendix: Factory size data

Table A.1 lists the Niehans Index of factory employment size by two-digit industry for the 17 countries in the sample. The industry names are largely self-explanatory; fab refers to fabricated metal, nonel to non-electrical machinery, elmch to electrical machinery, trans to transportation equipment, and instr to instruments. The index values were calculated from the employment size distributions given in the primary sources, which are listed below. Factories of less than 10 workers were excluded, but this exclusion makes little difference to the Niehans Index (although it strongly affects the ratio of industry employment to number of factories). A minus 1 indicates missing data.

The population and real income variables were taken from Summers and Heston (1984) and Clague (1986). In the regressions, Belgium and the Netherlands were assigned the market size of the Benelux Union.

Values of *Ecx* were as follows:

Ecx	Sectors
1%	Apparel
2%	Footwear, printing, furniture
5%	Textiles, tires, fabricated metal
7%	Non-electrical machinery, transportation equipment, instruments, household electrical goods
10%	Electrical machinery, electronic goods

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Table A.1

Niehans index of factory employment size.

Country	Text	App.	Ftwr.	Furn.	Prin.	Fab.	Nonel.	Elmch.	Trans.	Instr.	Rubb.
Korea	738	699	590	196	344	330	364	833	1,123	376	1,086
Taiwan	1,078	812	−1	583	597	561	724	1,513	1,159	−1	308
Singapore	466	407	−1	356	279	355	334	474	437	435	296
Colombia	541	179	173	99	279	173	213	259	332	96	616
Mexico	351	178	415	159	289	464	242	419	1,008	120	1,091
Venezuela	376	117	56	43	87	97	139	161	387	48	400
Ecuador	327	327	−1	186	158	234	234	234	234	−1	−1
El Salvador	437	237	2,047	42	125	120	245	278	83	33	56
Costa Rica	212	205	162	105	162	178	123	209	179	17	170
Panama	−1	100	94	55	126	130	−1	−1	−1	−1	−1
Cyprus	86	143	86	33	112	49	108	47	44	−1	34
Italy	194	110	85	72	319	276	405	1,781	3,351	284	958
Austria	517	297	297	296	233	735	735	735	735	−1	−1
The Netherlands	688	412	200	257	358	425	581	1,357	1,023	507	570
Belgium	685	235	235	176	502	624	753	926	671	−1	945
Japan	484	152	192	122	343	202	532	935	1,134	586	469
U.S.	774	339	338	457	636	664	1,100	1,545	2,699	1,399	757

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