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Abstract

The Heckscher-Ohlin theory and the Ricardian theory of international commerce traditionally have been treated as separate conceptual frameworks, but a growing body of empirical work is relying on both simultaneously and calls for an integrated theory. This paper combines the Heckscher-Ohlin model and Ricardian model into a single unified framework and offers supporting evidence for both Heckscher-Ohlin effects and Ricardian effects in OECD specialization patterns.

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Comparative Advantage, Technology Adoption, Trade

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Comments

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This paper combines the Heckscher-Ohlin model and Ricardian model into a single unified framework and offers supporting evidence for both Heckscher-Ohlin effects and Ricardian effects in OECD specialization patterns. The Heckscher-Ohlin theory and the Ricardian theory of international commerce traditionally have been treated as separate conceptual frameworks, but a growing body of empirical work is relying on both simultaneously and calls for an integrated theory.[1] The need for an integrated treatment is made all the more urgent by the dramatic liberalizations that have occurred in Eastern Europe, in Mexico, in South America, in China, in India and so on and so on. These countries that formerly chose economic isolation suffered both Heckscher-Ohlin effects and Ricardian effects. They lost the exchange benefits that would have come from specialization and they also had greatly decreased access to technological improvements. Integration of these formerly isolated regions will involve both technology transfer (Ricardian effects) and also increased specialization (Heckscher-Ohlin effects).

A first goal of this paper is to present a combined framework that will allow clear thinking about the consequences of economic integration of Southern countries which are both very labor-abundant and also technologically backward. The traditional separate treatment of technological differences and factor supply differences leads to the conclusion that economic integration of these formerly isolated regions will have severe consequences for the advanced developed countries if most of the action is Heckscher-

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[1] For example, Bowen, Leamer and Sveikauskus(1987), and Trefler(1993a,b).

Ohlinian, but relatively little effect if most of the action is Ricardian. A Heckscher-Ohlin framework implies great gains from exchange, but also potentially great pressures on wages of the unskilled in the advanced developed world since the effective global supply of unskilled workers has increased greatly with little increase in physical or human capital. A Ricardian framework is less optimistic about the economic gains to the advanced countries but more optimistic about the adjustment problems. According to the Ricardian model, the formerly isolated regions can be expected rapidly to adopt the superior technology. This technology transfer will cause wage convergence mostly from below not from above. Integration can be accomplished with relatively little increased international trade and relatively little disruption in the advanced regions. One might expect that a combined model would lead to conclusions that fall somewhere between these extremes, but actually the combined model suggests that the technology gap creates very strong comparative advantage in the labor-intensive sector regardless of the Southern initial capital abundance. This makes the South more dependent on exports of labor-intensive manufactures in the medium run than even the Heckscher-Ohlin model suggests. Thus in a sense the Ricardian effects and the Heckscher-Ohlin effects interact to create special pressure for wage convergence from above and also special gains from specialization.

In the model presented here, access to a superior Northern technology does not mean immediate and complete adoption by the South. The initial adoption of the new technology is limited by the suitability of current Southern capital to Northern technologies. Further adoption is limited by the rate of Southern investment in suitable inputs. Both the immediate amount and the continuing flow of adoption can be increased if capital is available from Northern sources.

Two extreme assumptions are made about the suitability of Southern capital to the advanced technology. Either the Southern capital is costlessly transferable or it is completely untransferable. The lack of transferability of capital is intended to capture the idea that tools and skills used in the backward technology may be unsuited to use in the advanced technology. This applies in an obvious way to equipment, but it applies also to human capital. Southern managers and workers may perform fairly well with the familiar fuzzy budget constraint characteristic of Southern state-supported organizations, but they may be flustered by the Northern way of doing business including the ever-present threat of bankruptcy.

Flows of capital from the North to the South can substantially affect both the Southern and the Northern economic response to the Southern liberalization. Two extreme assumptions are made here regarding the availability of Northern capital: Either none is available or the supply to Southern Europe equalizes the marginal product of capital in the North and South. In the latter case, the rate of capital flow is limited by the rate at which the South can supply complementary factors of production and also by the negative elasticity of the Northern marginal product of capital with respect to changes in its capital/labor ratio which determines the amount of wage convergence that occurs from above.

An important but fairly obvious lesson from studying the model with untransferable Southern capital is that it is economically inefficient to abandon the backward technology since that would amount to throwing away productive capital. It is not obvious but it is true that if the initial Southern capital/labor ratio is high enough, it is desirable to allocate some of the new entrants in the labor force into backward sector even as all new capital investment is placed in the advanced sector. Generally the South should produce the capital-intensive product using a capital-intensive version of the backward technology and the labor-intensive product using the advanced technology. It is quite possible that the South may initially export the capital-intensive product made with the backward technology. Over time, with capital accumulation and depreciation, the product mix and the trade mix will shift in favor of the labor-intensive product made with the advanced technology.

This combined Heckscher-Ohlin/ Ricardian theory is laid out in Section 1 with a one-product model and in Section 2 with a two-product model. Some empirical support for a combined framework is offered in Section 3 which examines OECD specialization patterns. The Heckscher-Ohlin variable is a characteristic of the country, roughly the country overall value-added per worker. The Ricardian variable is a characteristic of the country and industry: the country's productivity in a sector relative to the country's productivity overall. The Ricardian variable thus identifies the sector in which the country is unusually productive. Textiles, for example, is a strongly HO sector, located especially in low-wage low-productivity countries. Petroleum refining is a strongly Ricardian sector, located in countries with especially high productivity in refining compared with other sectors, namely Turkey, New Zealand, France and Germany. The location of production of machinery is driven by both Ricardian and HO effects. Japan is favored in machinery for both reasons - having high overall productivity (HO effect) and also having unusually high productivity in machinery(Ricardian effect). While the OECD specialization in these and other products is well explained by this simple Ricardian and HO model, the specialization patterns in chemicals, in rubber manufactures and in iron and steel are completely unexplainable using these two simple predictors. The very tentative conclusion that seems appropriate from this cursory examination of this data set is that both sector-specific technological advantages and also capital abundance play a role in determining OECD specialization patterns. It seems probable that both the HO effects and the Ricardian effects are much stronger for North-South trade than for this OECD trade.

1. One-Product Model of Technology Adoption

Figures 1 and 2 offer a graphical analysis of four types of technology adoption scenarios. Each of these figures contains two unit isoquants, one for the advanced technology, labeled AA, and one for the backward technology, labeled BB. These unit isoquants are combinations of capital and labor that are required to produce a unit of GDP. Constant returns to scale is assumed and the appearance of this figure accordingly is not affected by the units used to define output. Note that the backward technology is shifted away from the origin to indicate that relatively more capital and labor is required to produce a unit of output. The shift depicted here is neutral with respect to capital and labor. Nothing that follows is particularly dependent on whether the backward technology is relatively capital- or labor-intensive.

On the backward isoquant is the point labeled E which represents the current supply (*E*ndowment) of Southern inputs suitable to the backward technology. These figures also contain a Northern isocost line which is tangent to the advanced isoquant at a point which selects the Northern capital/labor ratio. The Northern isocost line determines Southern wages when Northern capital is freely mobile into the South. This capital flow equalizes the marginal product of capital in the South and in the North, which implies an equalization of the capital/labor ratios and consequently an equalization of the marginal productivities of labor and thus wage rates.

Figure 1 illustrates the case of completely Southern transferable capital when it is obviously efficient to move all the Southern inputs immediately to the advanced technology. The proportional gain from this transfer is the ratio EG'/EO since G' is the amount of resources under the new technology that can produce the same output as E under the old technology. At G' the ratio of capital to labor is lower in the South than in the North and accordingly the marginal productivity of Southern capital is higher. Northern capital flow of EF will equalize the rate of return and will raise the wage rate of Southern labor to the Northern level. The proportional increase in the earnings of Southern inputs with capital from the North is the ratio EG/EO. This exceeds the gain EG'/EO of simply transferring the inputs to the new technology because the Southern labor is more productive when complemented by capital from the North.

The effects of the liberalization on Southern factor returns are not illustrated in Figure 1 but are straightforwardly determined. Place a straight line tangent to the backward isoquant at the Southern endowment point E. Notice that this intersects the vertical axis at the location 1/r and the horizontal axis well to the right of $1/w_A$. These intersections select the preliberalization factor prices. In the example illustrated in this figure, liberalization has no effect on the rate of return to Southern capital but increases substantially the Southern wage rate of labor.

Figure 2 depicts the case of perfect capital mobility from the North to the south but Southern capital that cannot be transferred from the backward to the advanced technology. After the liberalization, there will be two different kinds of capital operating in the South: old and new. On Figure 2 are drawn two different isocost lines, one applicable to the Northern capital using the advanced technology and the other applicable to the Southern capital using the backward technology. These isocost lines have a common wage rate because of the mobility of labor between the two sectors, but the rate of return to Southern capital is lower. The tangency of the backward isocost with the backward isoquant selects the efficient post-reform capital/labor ratio which is achieved by a transfer of Southern labor EH from the backward sector to the advanced sector. This Southern labor transfer is complemented with a capital flow EF from the North to equate the capital/labor ratio in the advanced sector to the Northern ratio. Note that the percentage gain in factor earnings, EG/EO, is less in Figure 2 when Southern capital is not transferable than in Figure 1 when capital is transferable.

Figures 1 and 2 are drawn as if the North were so large that the capital outflow has no effect on the Northern capital/labor ratio. Wage equalization is then completely from below with Southern wages rising to the Northern levels dictated by the Northern capital/labor ratio. An alternative is that the capital outflow has a noticeable effect on the Northern capital/labor ratio and on Northern wage rates. If so, these first two figures can be thought to represent the "initial" effect which would be mitigated by declining capital abundance and declining wages in the North. The size of these secondary effects would depend on the amount of the capital outflow from the North to the South. As might be expected, the capital inflow EF from the West in Figure 1 with transferable capital is less than the inflow in Figure 2 with untransferable Southern capital. This is the relatively "happy" scenario with much of the wage differences between North and South eliminated by technology transfer. But the ordering of the capital flows in Figures 1 and 2 would reverse if the efficient post-reform capital/labor ratio in the Southern backward sector is less than the efficient post-reform capital/labor ratio in the Southern advanced sector.[2] Suppose, for example, that the Southern technology allowed no substitution between capital and labor as might indeed be a good assumption for already installed capital. Then the Southern isoquant in Figure 2 would be a right angle and there would be no release of Southern labor to the advanced sector. What would happen is an immediate jump of Southern wages to the Northern level, and an offsetting capital loss on existing Southern assets to keep Southern firms at zero profit levels. There would be no capital inflow from the North and no advanced sector in the South Growth of the advanced sector would then be entirely driven by Southern labor force growth after the liberalization. All new laborers would be directed toward the advanced sector and employed together with new capital either from Southern savings or from Northern capital inflow.[3]

2.0 Two Product Model of Technology Adoption

One lesson from the preceding section is that the state-supported relatively unproductive sector should not be immediately disbanded if existing Southern capital is not transferable to the new Northern technology. Another lesson is that the backward sector must operate at an increased level of capital intensity in order for workers to be released to the advanced sector. This increased capital intensity can be accomplished either by increased capital intensity of productive techniques or by a shift of the product mix in favor of the capital intensive products. To make this latter possibility clear, a two-product model is discussed in this section.

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[2] This measurement of capital intensity in the backward sector is evaluating the capital at book value not market value. Tradable claims on existing Southern assets must suffer a capital loss enough to assure the same rate of return as advanced-sector assets. After this adjustment of the capital value of existing Southern assets, the implicit post-liberalization Southern capital/labor ratio is less and can be found by dropping the point E* to the isocost line applicable to the advanced technology. In the figure this selects just about the same capital/labor ratio as in the advanced sector.

[3] An odd possibility occurs if Southern labor force growth is too low to absorb Southern savings in the advanced sector and if Southern saving is not allowed to flee to the North to acquire the higher Northern rate of return. Then existing and new Southern capital compete to hire Southern labor and bid the Southern wage rate up to the point where existing Southern assets have zero market value. (Can you find this point in Figure 2?) The South then has two sectors, an advanced sector with return to capital that is lower than in the North, and a backward sector with a wage bill that full exhausts the sector's earnings leaving nothing for capital.

Figure 3 has two advanced sector *unit value* isoquants, labeled A1 and A2, and two backward sector isoquants labeled B1 and B2. Relative prices are needed to compare the output levels in the different products and an implicit assumption underlying this figure is that the relative prices of the products in the two regions after liberalization are equalized by international trade. There is no assurance that liberalization leaves unchanged the relative price of the products in the South or North and accordingly the unit value isoquants need not be the same before and after the liberalization. For purposes of discussion, we can take this figure to represent an initial situation in which Northern relative prices are adopted by the South as a consequence of free trade. Later we discuss the likely change in relative prices that would come from liberalization of the South.

Figure 3 includes the Northern unit cost line. It also includes a Southern post-liberalization unit cost line that selects the high Northern wage rate and is tangent to one of the backward sector unit value isoquants. Between the two such tangencies, the one selected will have the higher return on capital. To find this one, rotate an isocost line clockwise around the point $1/w_A$ and select the sector whose isoquant is touched first by this rotating line. This generates a preference for the capital intensive product, as in Figure 3, but it is not impossible that the technological inferiority is sufficiently great in the capital intensive sector that the preferred tangency condition selects the labor intensive product.

The equilibrium depicted in Figure 3 is based on the assumption that Southern capital is redeployable between the products but cannot be transferred to the advanced technology. The flow of capital from the North will increase the wage rate to the Northern level w_A and leave only one of the two backward sectors economically viable. All Southern capital is accordingly shifted into this product and is complemented with the efficient amount of Southern labor. The rest of Southern labor is employed in the labor-intensive advanced-technology sector in conjunction with a suitable amount of Northern capital. In the figure, the Southern endowment of productive factors is E, and the labor reallocation to the advanced sector is EH, leaving the appropriate level of the capital/labor ratio in the backward, capital-intensive sector. These laborers in the advanced sector use Northern capital in the amount EF, just enough to get the capital/labor ratio up to the level needed for efficient production in the labor intensive sector using the advanced technology.

In summary then, if Northern capital is available for use in the South, and if Southern capital is not transferable to the advanced technologies but is mobile between the backward sectors, all Southern capital should be concentrated on the one product that yields the highest rate of return when labor is paid the Northern wage. The high Northern wage tends to make this preferred sector the capital intensive product, but the choice depends on the degree of backwardness as well. Southern laborers are employed at the Northern wage both in this preferred backward sector and also in the advanced-technology labor-intensive sector. Depending on the initial endowment of factors in relationship with the post-reform level of the capital/labor ratio in the preferred backward sector, the South may export either the labor-intensive product or the capital-intensive product. When the South accumulates capital suited to the advanced technology, these new investments are used entirely in the labor-intensive advanced-technology sector where they receive the highest rate of return. Since over time there is no addition of capital to the backward sector, no additional labor is allocated there. Thus with growth will come an increase in output of the labor intensive product. Although the South may initially export the capital-intensive product made with the backward technology, this product mix will change as more and more of the labor-intensive product is made and as the Southern backward capital depreciates. To express this differently, in the medium term, **the South has a comparative advantage in the labor-intensive sector that is a consequence of technological obsolescence of its existing capital stock**. Even if the technological deficiency is neutral, affecting both the labor-intensive and the capital-intensive sector proportionately, there is nonetheless a comparative advantage in the labor-intensive sector.[4]

Next we may consider the case illustrated in Figure 4 in which Southern capital is both untransferable to the advanced technology and is also unredeployable between the backward sectors. Northern capital inflows will again bid up the price of Southern labor to the Northern level w_A. At this new wage rate there are three relevant unit-cost lines each selecting a different rate of return on capital. The highest rate of return applies to the advanced sector, next comes the rate of return applicable to the capital-intensive backward sector and last comes the labor-intensive backward sector. All three unit costs are illustrated with solid lines in Figure 4. These higher wage rates force a more capital intensive productive technique in both backward sectors. These are the heavy lines in the figure. Labor must be moved out of both sectors to bring about the indicated increases in capital intensity. Two triangles in the figure represent the transfer of Southern labor out of the backward sectors into the advanced sector and the inflow of complementary Northern capital. The corner of each triangle represents the initial allocation to the sector. These two allocation vectors sum to the total endowment E. As depicted, the initial product mix favors the labor-intensive sector and most of the labor is released from it. But more generally, the reform has a greater impact on the rate of return in the labor-intensive sector, unless the substitution possibilities are much greater in the capital-intensive sector, and therefore the proportion of the workforce released from the labor-intensive sector will exceed the proportion released in the capital-intensive sector.[5]

[4] If Northern capital is not available, the Southern lower level of wages continues to be applicable. At this lower level of wages, the sector with the highest rate of return on new investments is the labor-intensive advanced-technology sector, which accordingly attracts all new investment. This new capital must be accompanied by a suitable amount of labor which may come from labor force growth or may have to be extracted from the backward sectors though a competition that will raise wages. The slightest increase in wages will render the labor-intensive backward sector uneconomical and all backward capital should shift to the capital-intensive product. This creates an equilibrium that is very much like the one that applies when Northern capital is available. Here all new Southern investments go to the labor-intensive advanced-technology sector and all existing Southern capital is concentrated on the capital-intensive sector.

[5] Incidentally, it is quite possible that the post-reform implicit rate of return in one or both of these sectors is negative, which calls for complete scrappage of the Southern capital and the transfer of all of the labor

If there are no substitution possibilities in either sector, as might be the case for capital already deployed, there can be no release of workers from either sector unless the wage rate is bid up to the point at which a sector is no longer economically viable. This possibility is illustrated in Figure 5. Here as the possible isocost lines are rotated around the $1/w_A$ point, the unit isoquant for the labor-intensive sector cannot be reached without twisting the isocost line to select a negative return on capital. This means that the labor-intensive Southern capital is completely scrapped and the associated Southern labor is employed at Northern wages levels in the labor-intensive advanced sector together with Northern capital.

Last we need to be clear what impact these changes have on the North. If there are no changes in relative product prices then Northern earnings are completely unaffected by the Southern liberalization and the technology transfer. Relative product price reductions of the labor-intensive product can be expected to occur because of change in the relative supply of the two products, first because the South will specialize according to its labor-based comparative advantage, second because of the technology transfer to the South and third because of capital outflow from the North to the South. The effect of the capital outflow is the easiest to predict since it increases the relative supply of the labor-intensive good in both the North and the South. This increase in global supply will lower the price of the labor-intensive good, and then through the usual Stolper-Samuelson effects, will lower the real wage rate and raise the real return on capital. This capital flow will not occur unless there is also technology transfer since the existing Southern technology as depicted generates both lower wages and a lower return to capital. Even if there is no capital flow and no technology transfer, Southern abundance of labor would create a comparative advantage in the labor-intensive product which would have the effect of lowering its price and thus lowering wages in both North and South. Even if the South has been historically capital abundant (think of Eastern European human capital), it may have committed itself to the wrong kind of capital that has little value after liberalization, thus creating a global shortage of the Northern (good) capital.

force to the advanced technology. In the figure, this occurs when a unit cost line has to be rotated beyond the vertical to get to the sectoral unit value isoquant.

3.0 Evidence: Heckscher-Ohlin and Ricardian Effects in OECD patterns of specialization.

The foregoing theory combines Ricardian technological advantages with Heckscher-Ohlin factor supply differences to explain international flows of products, capital and knowledge. This section provides some support for this theory of international specialization by showing that both Ricardian effects and Heckscher-Ohlin effects seem to be present in the specialization patterns of OECD countries. No evidence is provided here regarding the predicted international flows of factors or the flows of knowledge.

An OECD trade data base is not an ideal place to look for either Heckscher-Ohlin effects or Ricardian effects. The Heckscher-Ohlin effects may be minor because these OECD countries have similar factor supply mixes. The Ricardian effects may be minor because technology may be rather fluid among these OECD countries. Nonetheless, it appears as though both Ricardian effects and Heckscher-Ohlin effects are present in the data in the sense that both factor abundance and technological superiority help explain the specialization patterns of these OECD countries.

The basic data are reported in Tables 1 -3. The revealed comparative advantage numbers in Table 1 indicate the extent of specialization in value added data, after correcting for country size and for commodity size. Using the notation

V_{ic} = value added in Sector i for Country c ,

$V_{i.} = \sum_i V_{ic}$ = total OECD value added in Sector i ,

$V_{.c} = \sum_c V_{ic}$ = total value added in Country c ,

$V_{..} = \sum_{ic} V_{ic}$ = total OECD value added ,

a traditional measure of revealed comparative advantage is $[V_{ic}/V_{i.}] / [V_{.c}/V_{..}]$ which is equal to the country's share of world value-added in this sector compared with its share overall. The measure of **Revealed Comparative Advantage** used here is slightly different:

$$\mathbf{RCA}_{ic} = \log_2 \{[V_{ic}/(V_{i.} - V_{ic})] / [(V_{.c}/(V_{..} - V_{.c})]\}.$$

The use of rest-of-OECD value-added instead of total OECD figures corrects for country size effects which limit apparent specialization patterns of large countries, particularly the United States. The base-2 logarithmic function makes the data a symmetric measure of specialization: $\mathbf{RCA}_{ic} = 1$ means that the sector is twice as large as expected after controlling for country and commodity size, $\mathbf{RCA}_{ic} = -1$ means that the sector is twice as small as expected.

The revealed comparative advantage ratio equal to 1.16 in the upper left corner of Table 1 indicates that Portugal has $2^{1.16} = 2.23$ times more footwear value added than would be predicted based on the size of the apparel sector and the size of Portugal. Some of the other extreme specializations RCA figures are Portuguese and Italian footwear (2.65, 2.70), and Portuguese and Italian pottery (2.95, 3.07) . In the opposite direction, Greece has a value of RCA of -4.15 for professional equipment with value-added only equal to $2^{-4.15}$ = .06% of that predicted from country and commodity size. The U.S. has a very strong RCA=2.04 in professional equipment, and also an RCA >1 in tobacco and in petroleum refining. Oddly, the U.S. has a postive RCA = .36 in wearing apparel. Keep in mind that these RCA numbers use OECD value-added patterns as the norm, not world value-added patterns. The positive RCA for the U.S. in wearing apparel means that, in comparison with other OECD countries, the U.S. has clung to its apparel sector as it has moved out of the OECD into the third world. The biggest negative RCA for the U.S. is pottery and china, with RCA = -1.09. The next is iron and steel, with RCA = -.82. Specialization in iron and steel is led by Japan, Austria and Turkey, and will be shown below not to be well explained using either Heckscher-Ohlin or Ricardian variables.

Commodities are ordered in these tables by the overall OECD value added per worker. First is wearing apparel with value added per worker of $30,000 and last is petroleum refining with value added per worker of $437,000. Countries are sorted by the country factors reported in the last row of Table 2. Country and commodity factors are found by regressing the logarithm of value added per worker on country dummies and commodity dummies:

$$\ln(V_{ic}/E_{ic}) = \alpha_i + \beta_c$$

with the normalization that $\exp(\alpha_{petrol}) = 1$. The estimated country factors $\exp(\beta_c)$ and commodity factors $\exp(\alpha_i)$ are reported in the last column and last row of Table 2 and they can be seen to closely correlate with value added per worker. The one exception is tobacco which has a substantial downward adjustment of $\exp(\alpha_i)$ compared with value-added per worker.

The estimated country factors will be used here to represent the capital abundance that drives the Heckscher-Ohlin model :

$$\mathbf{HO}_c = \hat{\beta}_c \,.$$

The HO effect $\exp(\beta)$ is highly correlated with overall productivity in manufacturing and will be taken here to be an (imperfect) indicator of the country capital/labor abundance ratio. Although, in fact, these country factors are highly correlated with capital abundance, in theory, they should not vary at all since productivities should be identical across countries for each commodity. Total value added per worker could vary across countries, but only because of differences in product mix. This strict HO viewpoint is obviously at variance with the facts. Kotlikoff and Leamer(1987) and Dollar, Baumol and Wolff(1988) find substantial and persistent differences in productivities across countries at the two-digit level of commodity aggregation. Bowen, Leamer and Sveikauskus(1987) and Trefler(1993,1994) make the point that the HO model works well only if factor supplies are corrected for neutral technological differences. One possible explanation of these anomalies is that the substantial apparent productivity differences across countries come entirely from aggregation over commodities. If, for example, commodities were aggregated into a single composite called GDP, the HO model would predict that GDP per worker would vary across countries and would perfectly correlate with capital abundance per worker. More on aggregation below.

It is apparent from Table 1 that some commodities and some countries have highly specialized production patterns while others are more uniformly dispersed. Industry and country specialization averages are reported in Tables 3 and 4 using value-added weights. These indices are averages of the absolute values of the RCA (remembering that RCA = 0 means no specialization.) :

$$S_i = \sum_c |RCA_{ic}| \ w_c \quad , \qquad w_c = \sum_i V_{ic} / \sum_{ic} V_{ic}$$

$$S_c = \sum_i |RCA_{ic}| \ w_i \quad , \qquad w_i = \sum_c V_{ic} / \sum_{ic} V_{ic}$$

From Table 3 it is seen that transportation equipment is the least concentrated commodity; next is plastics and then industrial chemicals. The most concentrated commodity is professional equipment, mostly because the United States has an extremely large share of the market and because the low-wage developing countries in the sample are substantially underrepresented in this category. Tobacco and petroleum refining are also highly concentrated. According to the indices reported in Table 4, the UK and France have the least specialized patterns of value-added; Turkey and Greece have the most specialized patterns.

One might have expected that there would be a relationship between value-added per worker and these specialization numbers. This idea is explored in the graphs at the bottom of each of these tables. Across commodities (Table 3) there is very little relationship between specialization and value-added, but there is some negative association between specialization and total value added in the sector. This is very a disturbing finding since it suggests that the results of this empirical exercise may be influenced greatly by the level of aggregation. The high value-added commodities like machinery, electrical machinery, and transportation equipment may in fact just be combinations of many different products each of which is just as specialized internationally as is professional equipment.

The association between specialization and both productivity and also total value added is more clear across countries, as can be seen in the displays at the bottom of Table 4. Large countries with high levels of productivity are much less specialized. The negative association between country size and specialization is suggestive of scale economies. The negative association between value-added per worker and specialization is suggestive of technological differences. These features of the data clearly demand more careful attention. They are reminiscent of Leamer's(1987) finding that small SMSA's (cities) in the United States have more concentrated manufacturing than large ones, even though there is no overall tendency for any industry to locate mostly in small or large SMSA's.

Table 5 reports indicators of productivity advantage. With

E_{ic} = employment in industry i in country c,

$P_{ic} = V_{ic} / E_{ic}$ = productivity in industry i in country c,

the **Ricardian Productivity Advantage** is

$$\mathbf{RIC}_{ic} = \log_2([P_{ic} / P_{i\bar{c}}]/[P_c / P_{\bar{c}}])$$

where

$P_c = \sum_i V_{ic} / \sum_i E_{ic}$ = country c's average productivity

$P_{i\bar{c}} = \sum_{j\neq c} V_{ij} / \sum_{j\neq c} E_{ij}$ = industry i's average productivity, excluding country c

$P_{\bar{c}} = \sum_{j\neq c} \sum_i V_{ij} / \sum_{j\neq c} \sum_i E_{ij}$ = value added per worker, excluding country c

Using this index a country is said to have a Ricardian technological advantage in a sector if its productivity in that sector is high after adjusting for the commodity and country general levels of productivity.[6] According to the numbers in Table 5, the United States is particularly productive in tobacco, professional instruments and industrial chemicals, but particularly unproductive in petroleum refinining, and furniture. Japan has a Ricardian advantage in iron and steel, France and Germany and the U.K. have a Ricardian advantage in petroleum refining. Some of these Ridardian advantages translate into RCA, but others do not.

Table 6 reports estimates of equations explaining the revealed comparative advantage for each commodity with both the Heckscher-Ohlin and the Ricardian variables. The equations take the form

$$RCA_{ic} = \alpha_i + \delta_i HO_c + \theta_i RIC_{ic} \quad i = 1,2,....,$$

one equation for each 2-digit ISIC commodity aggregate. Keep in mind that both dependent variable and explanatory variables are logarithmic by definition.. For each commodity the estimates are reported both in terms of the "economic significance" of the effect and also the "statistical significance" of the effect The economic significance is measured by the product of the estimated coefficient times the range of the data. This number indicates by how much the predicted revealed comparative advantage changes over the range of the data. (For the HO variable, the range is the same for every commodity but the Ricardian

[6] An alternative would be to find the extremes, not the averages, and to define the Ricardian advantage as

$$RIC^*_{ic} = (P_{ic} / \max_c P_{ic} \max_i P_{ic})(P_{..})$$

range differs by commodity.) Also in these tables are the traditional measures of "statistical significance": t-values and adjusted R^2's.

The commodities in Table 6 are sorted into four subgroups, depending on the relative size of the t-values of the HO and Ricardian variables. First are the HO products with high t-values for the HO variable; then are the Ricardian products with high t-values for the Ricardian variable. After that are three "combined" classes, the first leaning in favor of the HO effect, the second toward the Ricardian model, and the third neutral. Last are two commodities (industrial chemicals and rubber manufactures) that defy explanation and allow only a negative adjusted R^2. Within each subgroup, commodities are ordered by the adjusted R^2. Scatter diagrams corresponding to these simple regressions are depicted in Figures 2.1 to 2.11. It is very clear from these figures that many of these associations are broadly supported by the data and are not driven by one or two outliers.

The first HO commodity is textiles, with a predicted HO effect over the range of this sample equal to -2.73, meaning that the value-added decreases to $2^{-2.73} = 15$ % of its initial value as one ranges from the country at the lowest stage of development to the highest. Similar numbers apply for wearing apparel, pottery and footwear. Comparative advantage goes the opposite direction for electrical machinery and printing and publishing which tend to be located in the advanced countries. In this class, both footwear and printing/publishing have fairly strong Ricardian effects.

The top Ricardian commodity is petroleum refining. The estimate times the Ricardian range equal to 3.10 means that output increases by a factor of $2^{3.10} = 8.6$ as one ranges from the least to the most productive country. Furniture and wood and lumber are also Ricardian commodities, although this is probably only because we haven't given the HO model a fair "shake" by including softwood forests as a source of comparative advantage. Note that iron and steel is placed in this Ricardian category since it has a t-value in excess of one, but the adjusted R^2 is nonetheless negative. For this category and several of the others with very low R^2's one suspects that trade barriers and government interventions are an important part of the explanation of the OECD specialization pattern.

The adjusted R^2 exceeds 0.3 in sixteen of twenty-seven commodity aggregates. Particularly good fits are obtained for professional equipment, leather products and machinery. For eleven of the commodities the adjusted R^2 is less than 0.2. Out of the sixteen products with adjusted R^2 exceeding 0.3, four are HO or HO leaning, seven are Ricardian or Ricardian leaning, and five are combined. Thus the Ricardian model wins this Olympics, but keep in mind that the HO model that is running this race is a particularly weak representative.

Next, in Table 7, the possibility of nonlinearities is explored. A multi-cone Heckscher-Ohlin model suggests that these specialization patterns may be nonlinear, with value-added especially high for countries in the middle of the range not the extremes. The possibility of nonlinearities is formally explored by including in the model a quadratic HO term. The t-values of the quadratic HO term are reported in Table 7 together with the value within the HO range (from 0 to 1) at which the extreme predicted specialization occurs. Commodities are ordered by the estimated location of the extreme. Most commodities have extreme specialization estimated to be either at the lowest value of the range or at the highest value. Nonlinearities that favor countries in the middle of the range do seem to be detectable for tobacco, food manufactures, beverages, furniture, and printing and publishing

Last, Table 8 reports the estimated residuals with country and commodity R^2's on the edges. Countries and commodities are sorted by their residual sum-of-squares, thus placing problem observations at the lower right. Although the United States is a problem country in the sense of having a low R^2 (.15), it is not a problem country in the sense of contributing to the overall lack of fit. The low R^2 of the U.S. comes from its diverse mix of products and thus lack of variability of RCA across commodities. The problem countries in terms of additions to the overall lack of fit are Iceland, Norway and Italy. The problem commodities are footwear, wood and pottery/china.

In conclusion, the OECD specialization pattern does seem to be driven by both Heckscher-Ohlin factor endowment differences and by Ricardian technological superiorities, although the measurements here of both endowment differences and technological differences are primitive.

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APPENDIX

List of Figures

Allocation of Factors
100% Transferable Capital

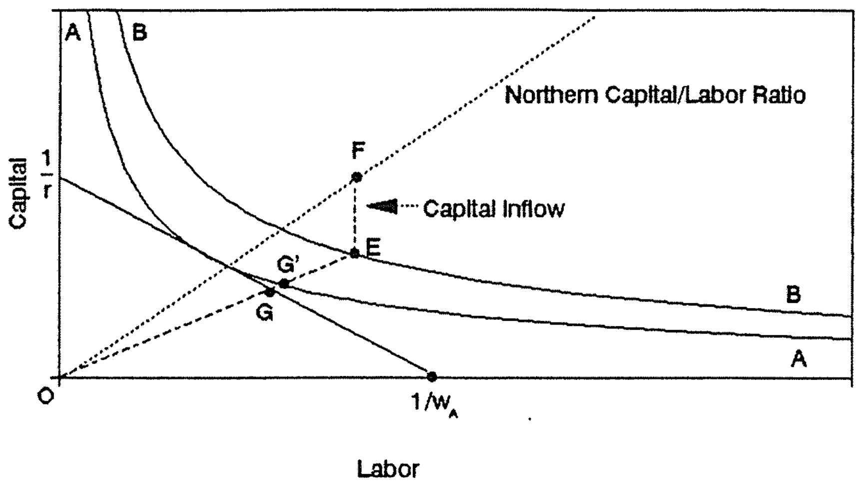


Figure 1

Allocation of Factors
0% Transferable Capital

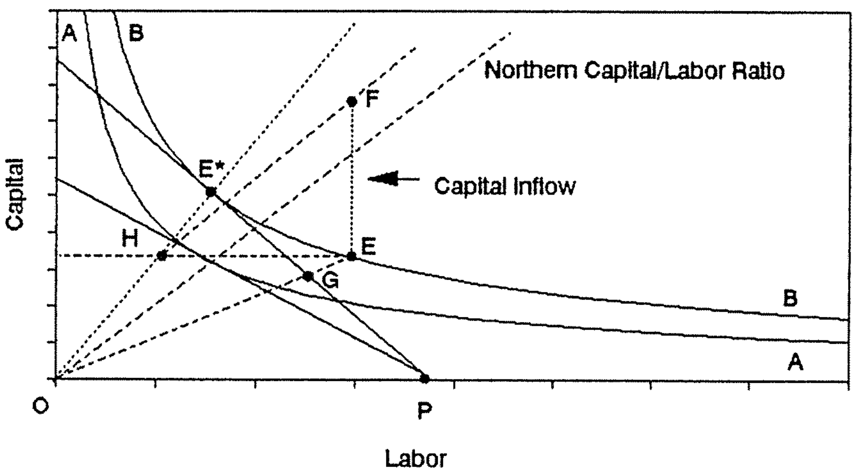


Figure 2

Liberalization with Two Sectors

0% Transferability, Sectoral Mobility

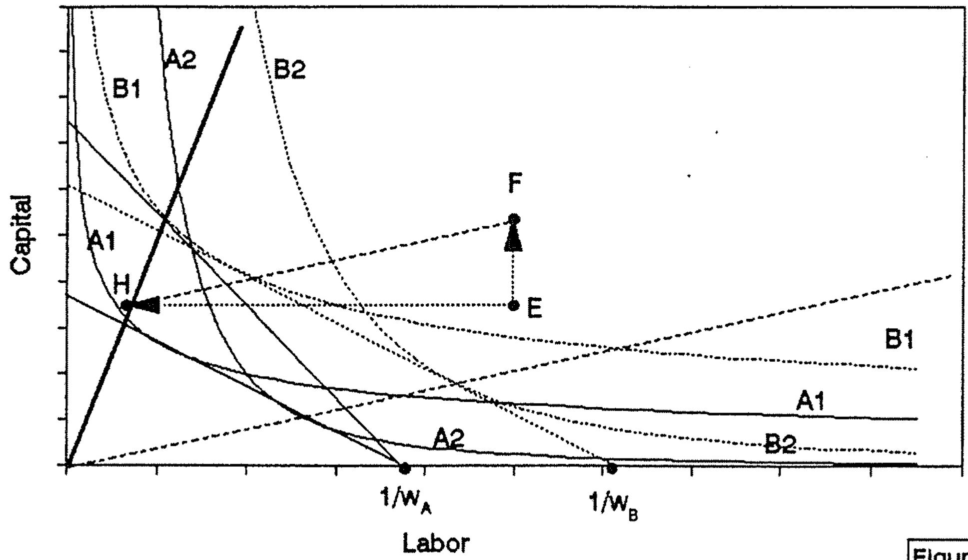


Figure 3

Liberalization with Two Sectors

0% Transferability, Sectoral Immobility

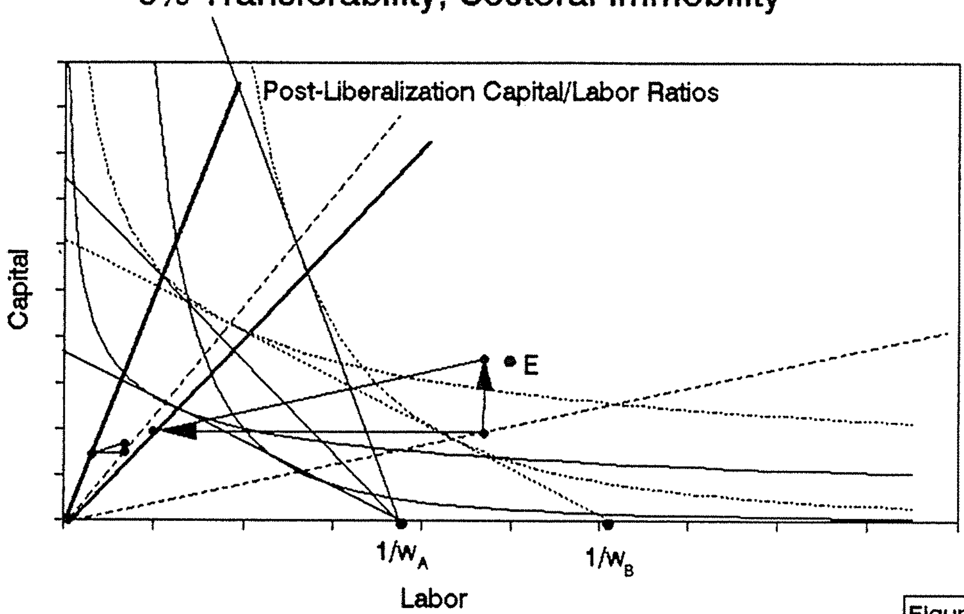


Figure 4

Liberalization with Two Sectors
Completely Committed Southern Capital

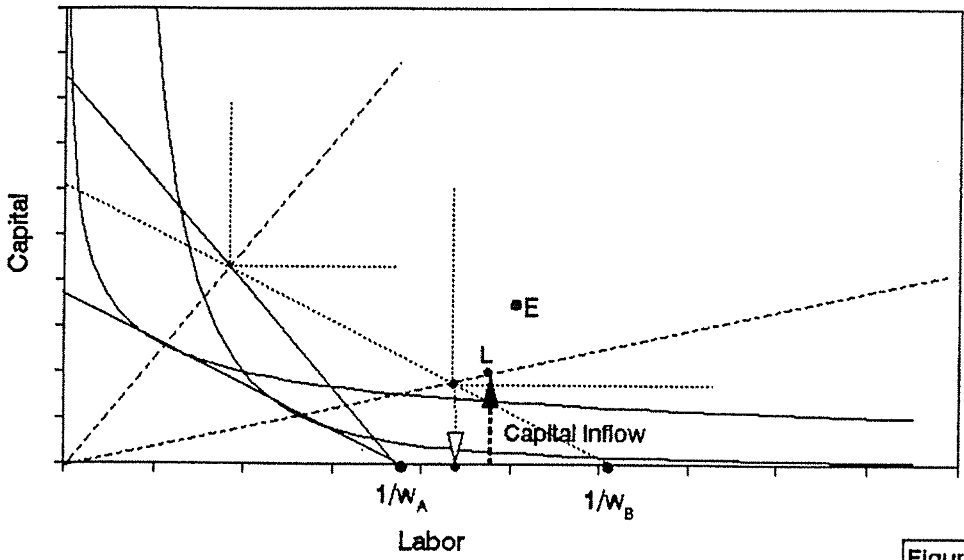
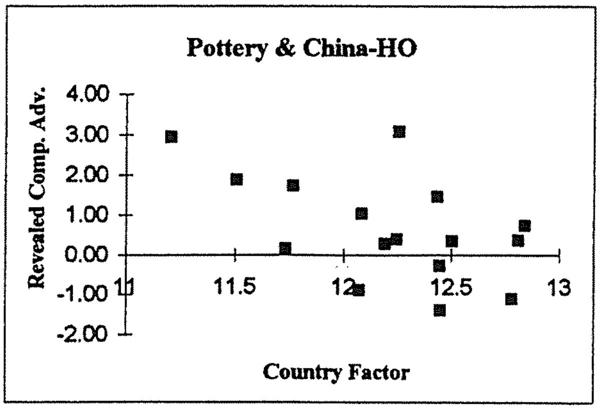


Figure 5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2.00
1.00
0.00
-1.00
-2.00
11
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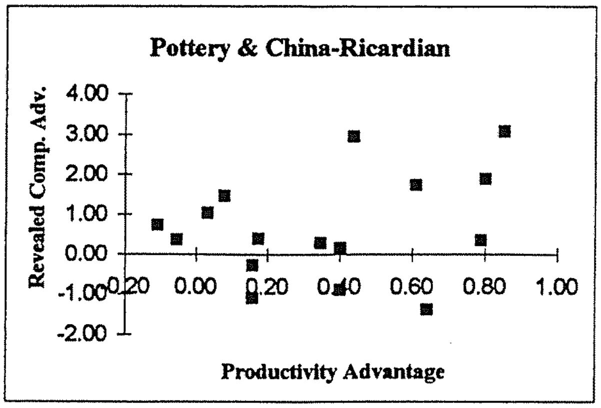
12
12.5
13
Country Factor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0.80
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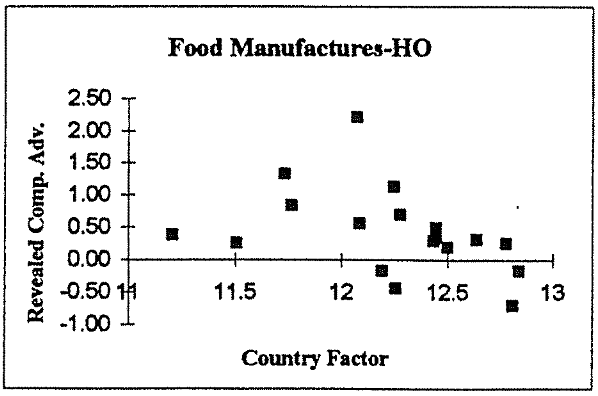
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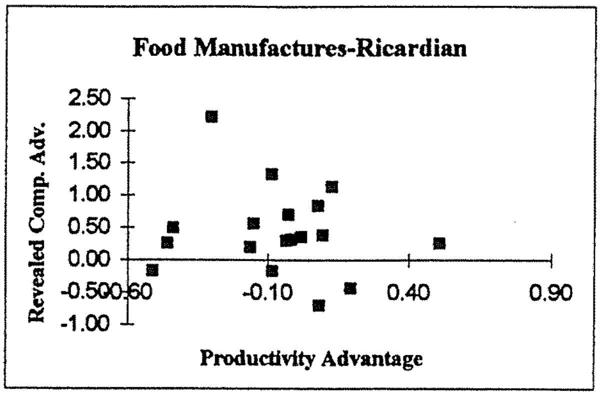
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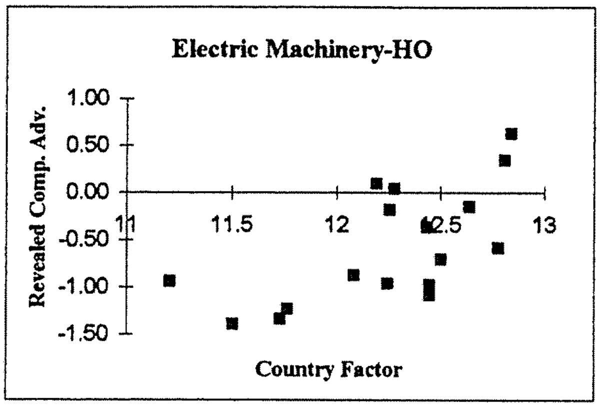
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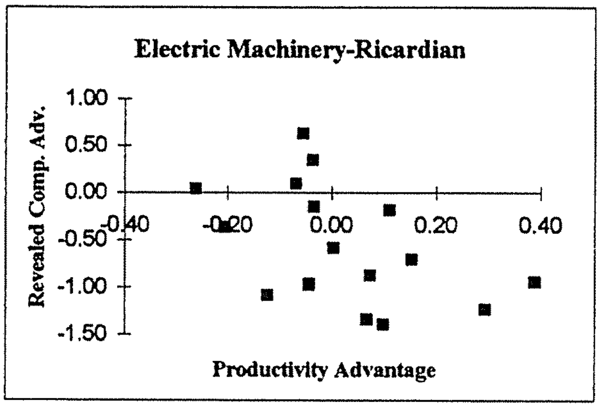
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0.40
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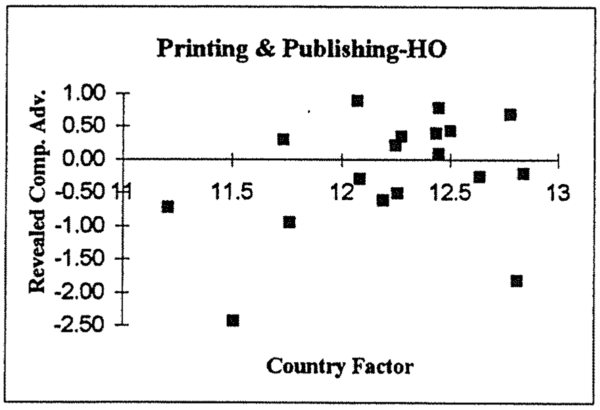
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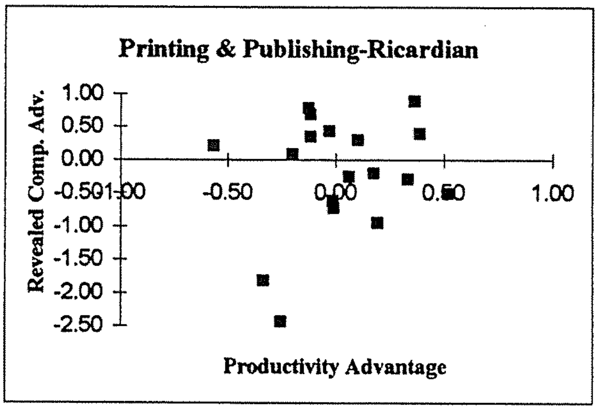
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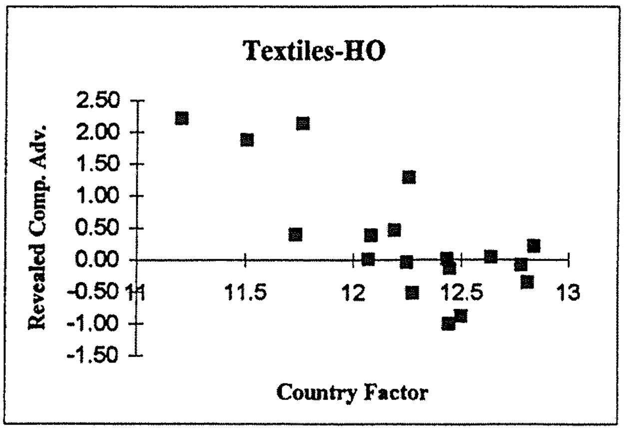
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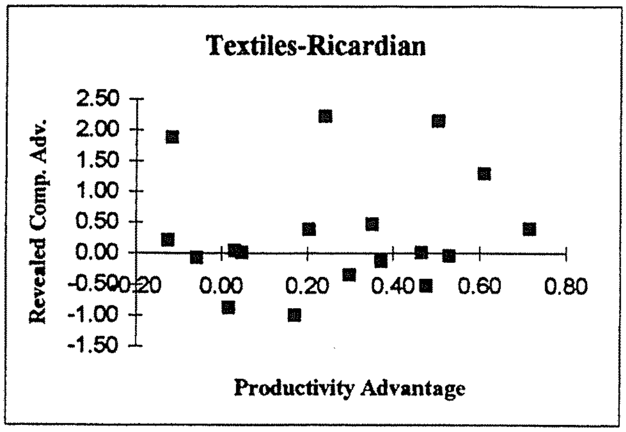
Country Factor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0.80
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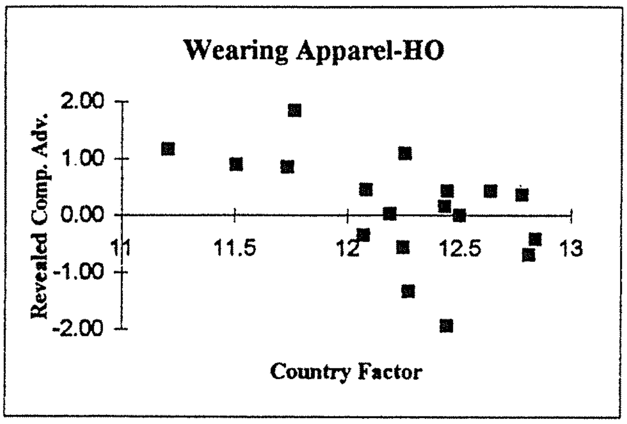
Productivity Advantage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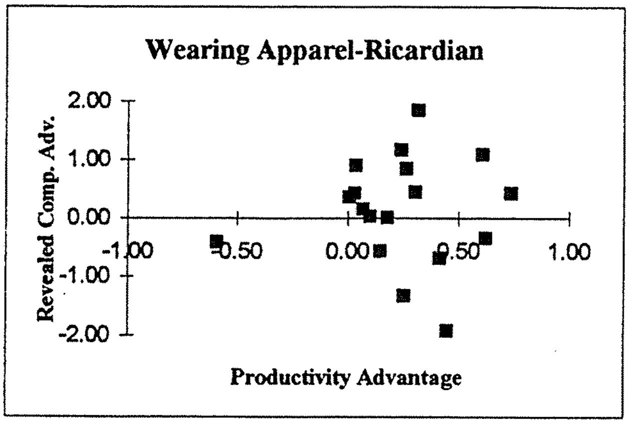
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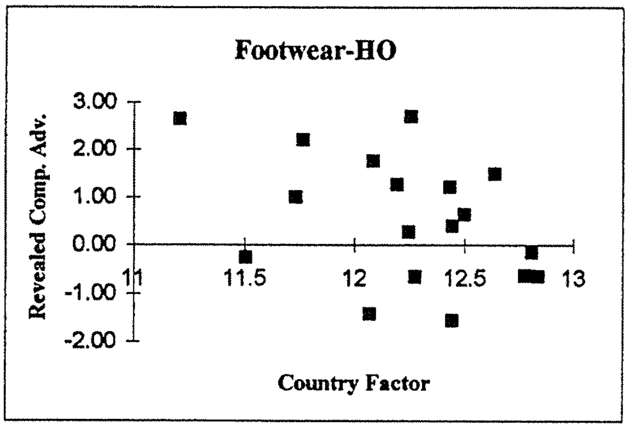
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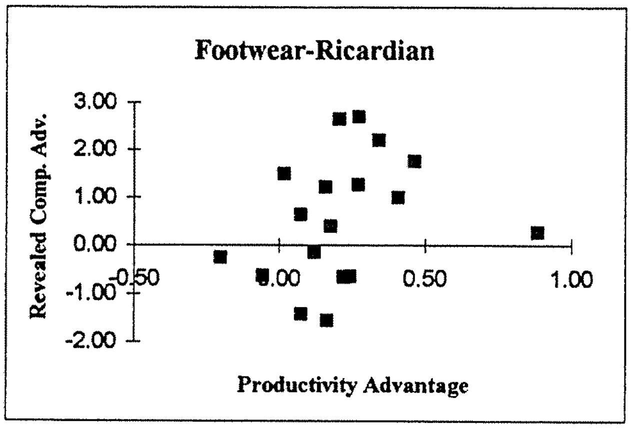
Country Factor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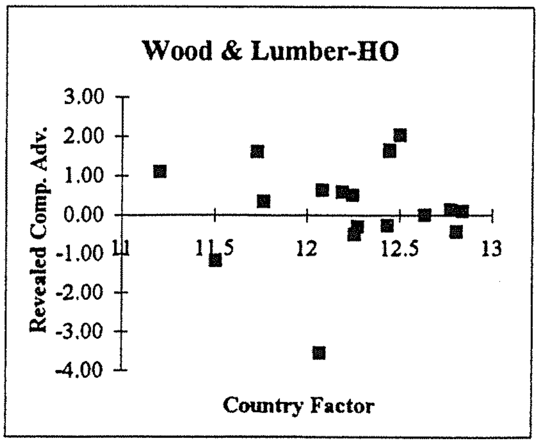
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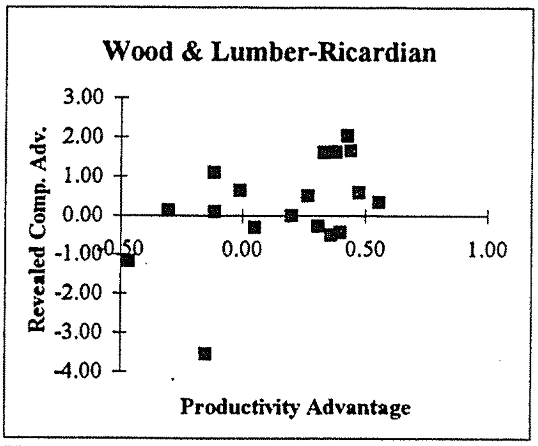
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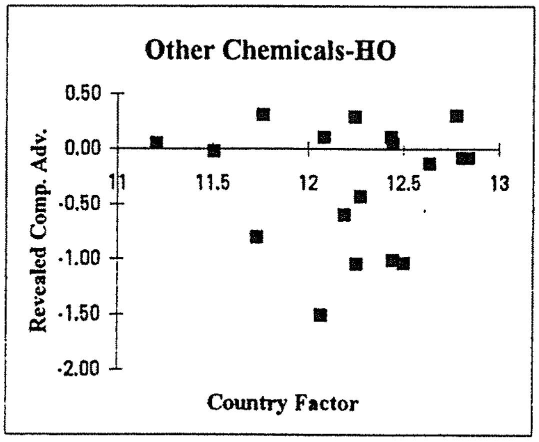
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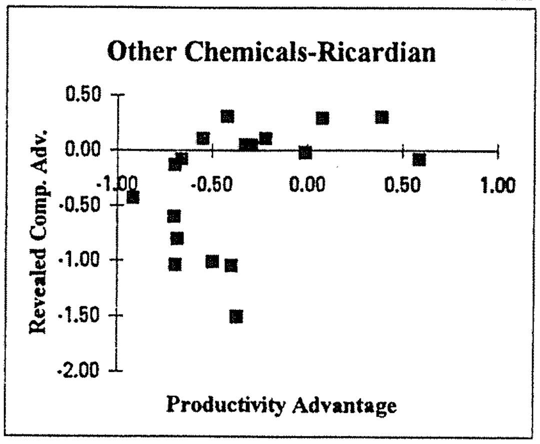
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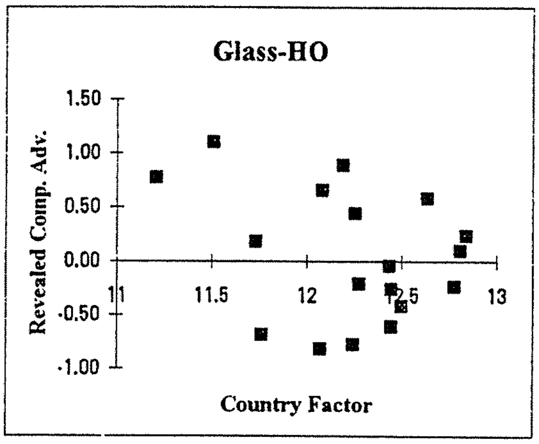
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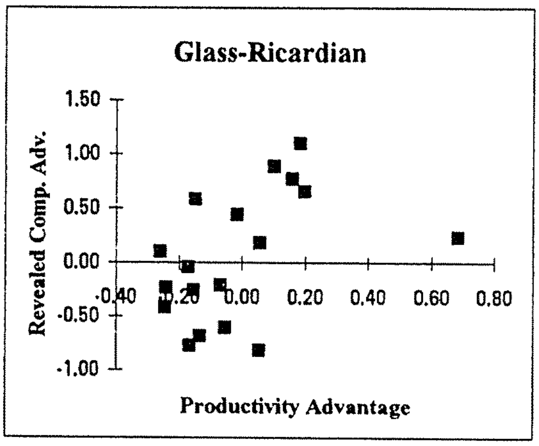
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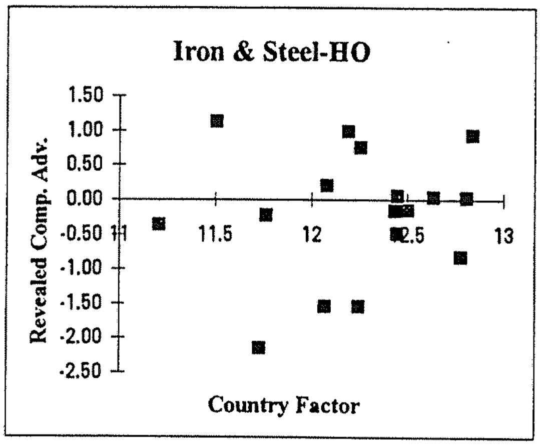
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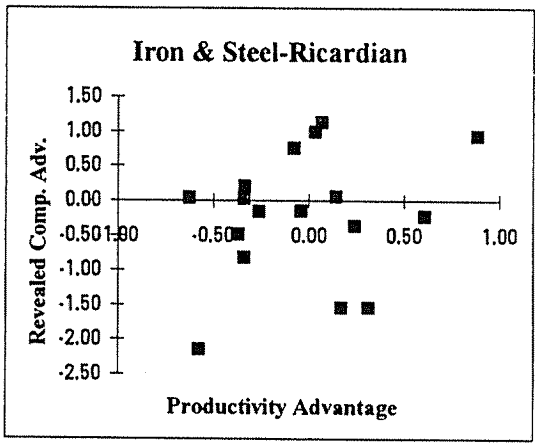
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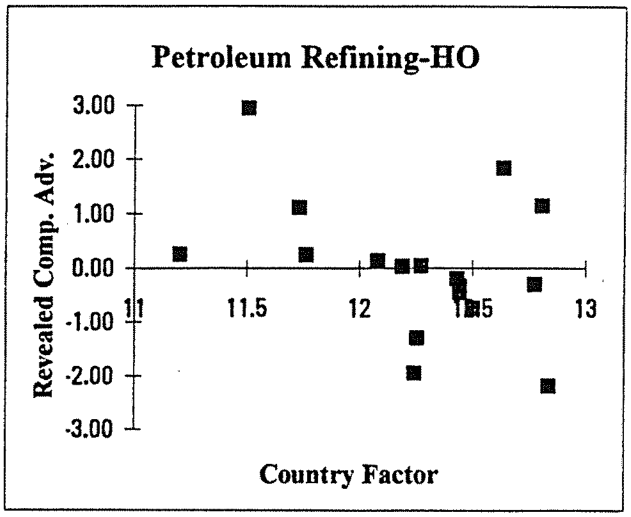
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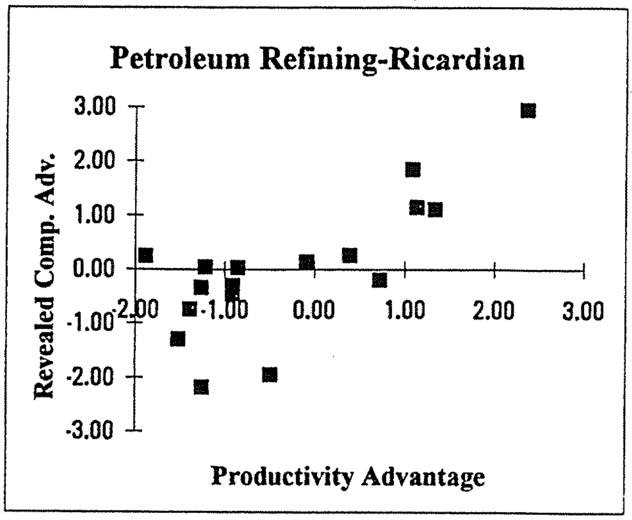
13
Country Factor


Petroleum Refining-Ricardian
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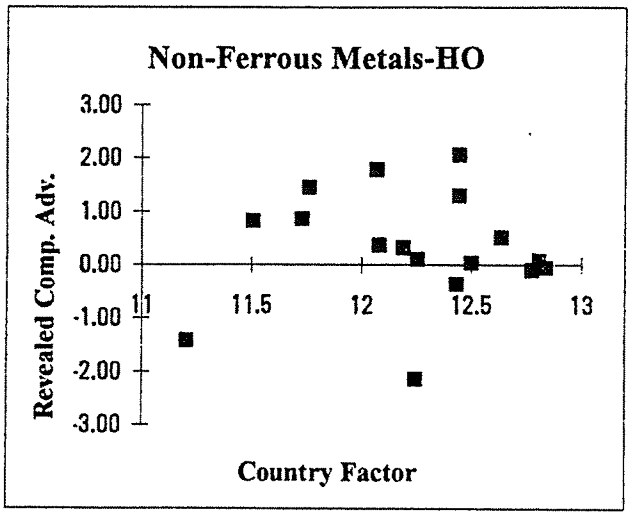
Productivity Advantage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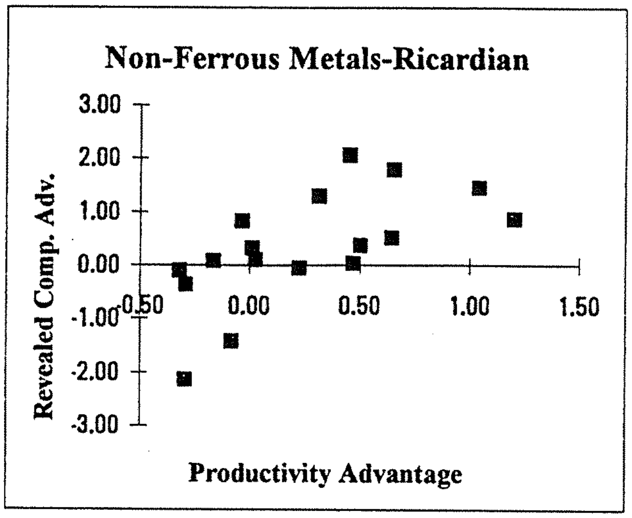
Country Factor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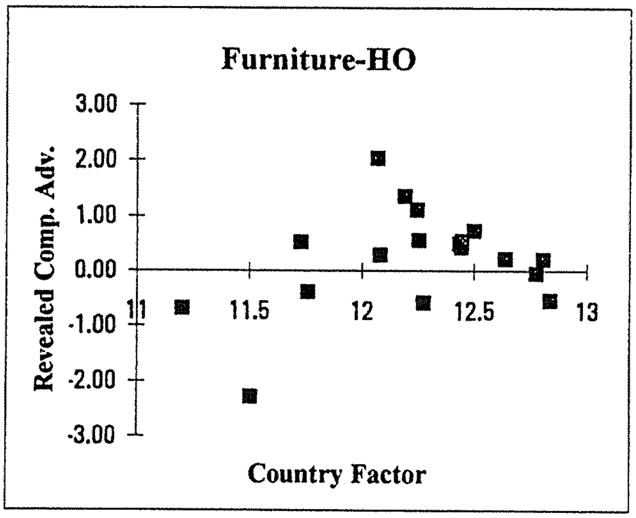
1.50
Productivity Advantage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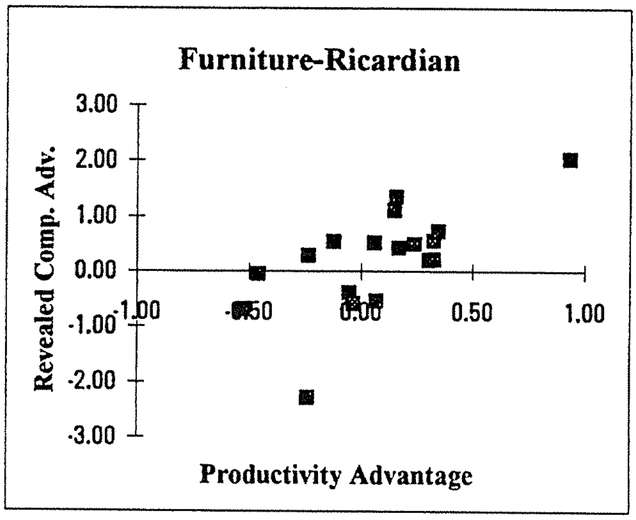
Country Factor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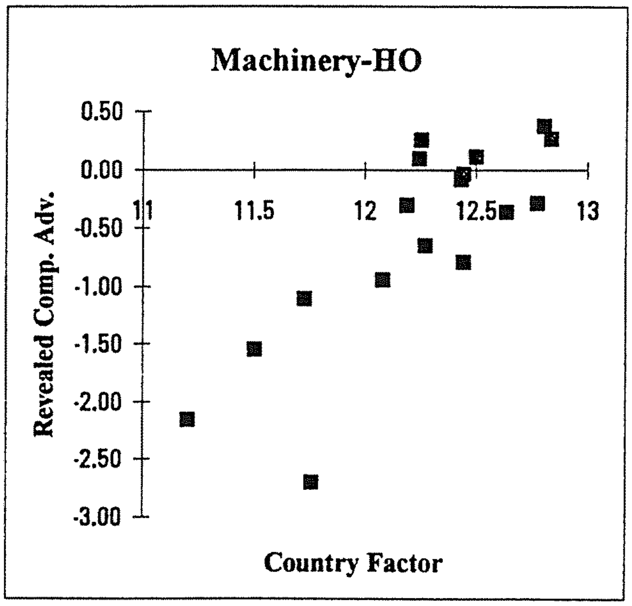
Productivity Advantage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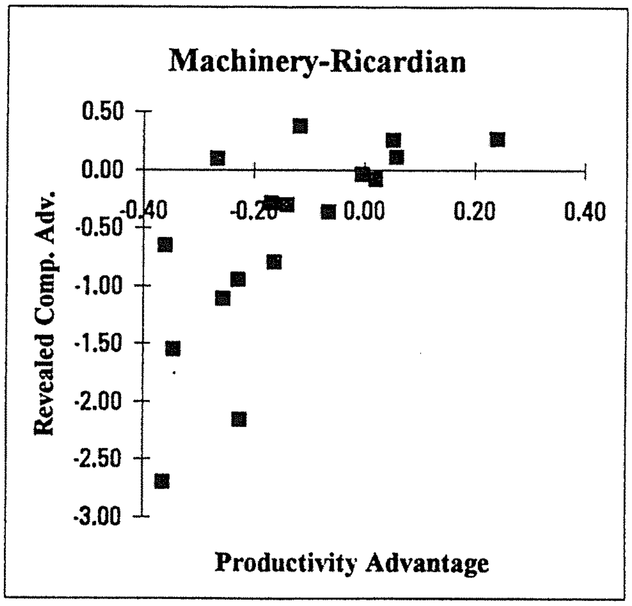
Country Factor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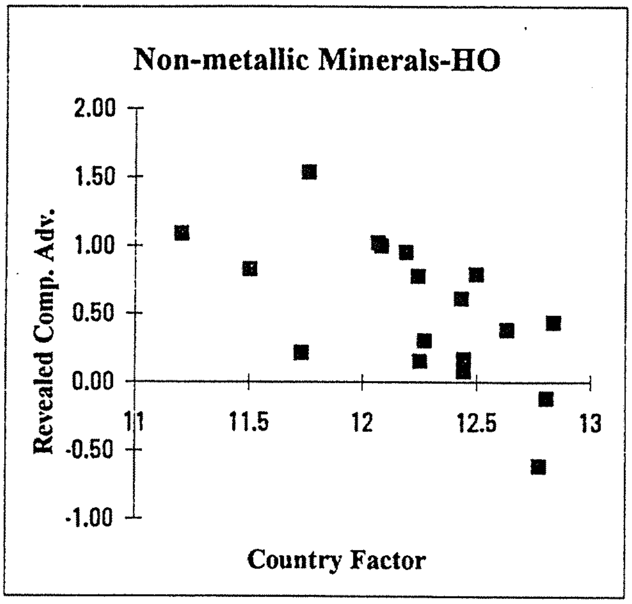
Productivity Advantage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13
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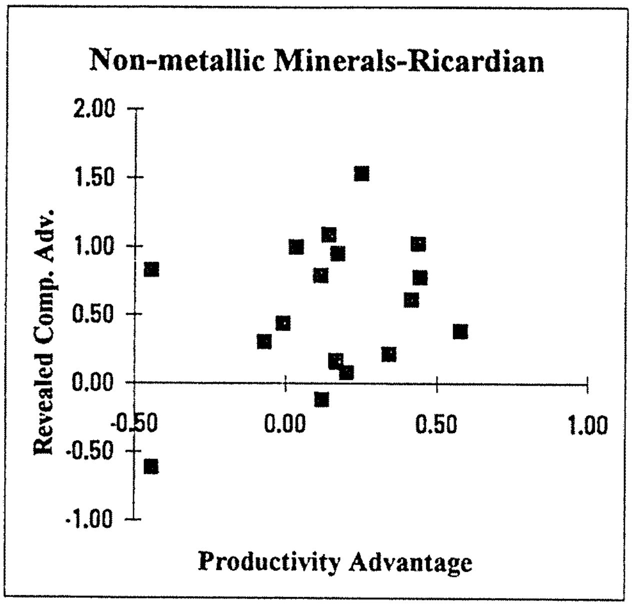
Country Factor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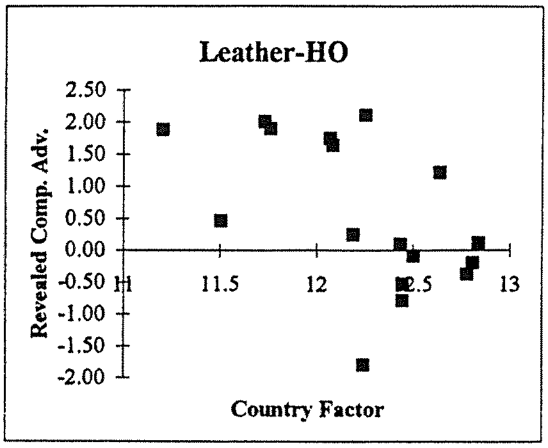
Productivity Advantage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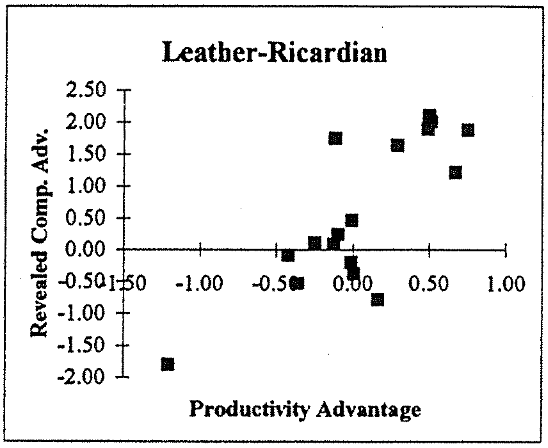
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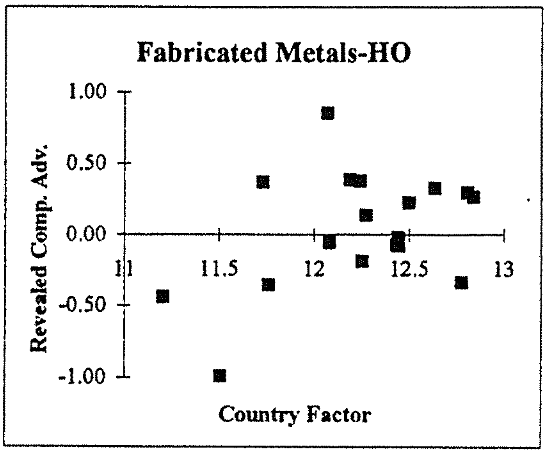
Fabricated Metals-HO
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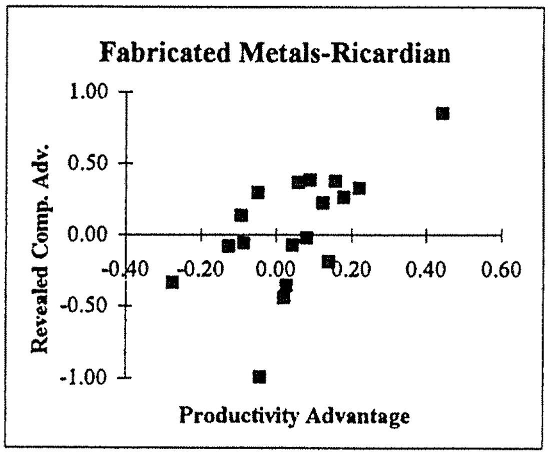
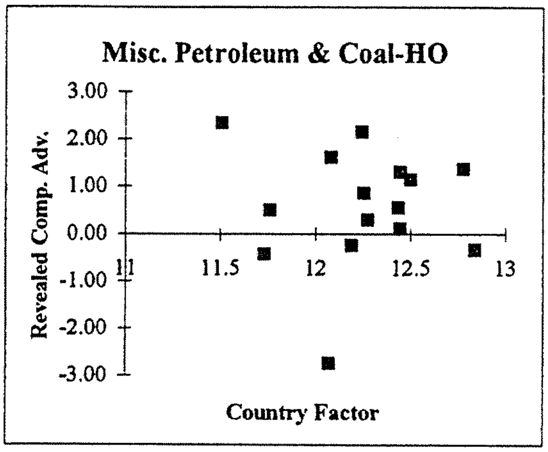
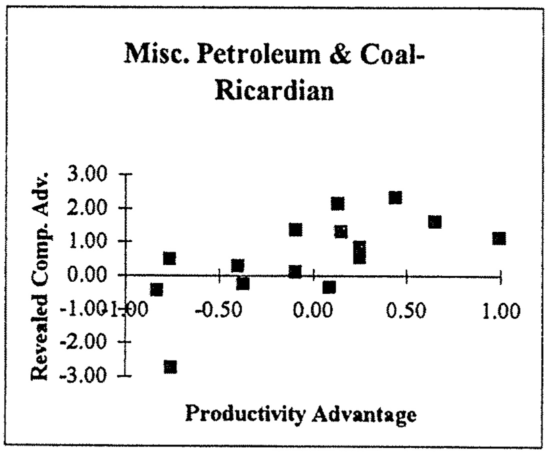
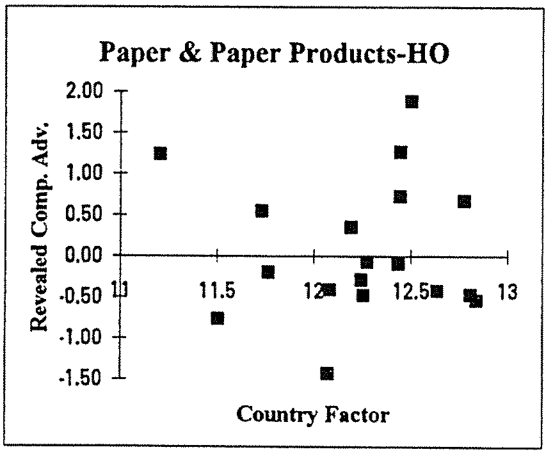
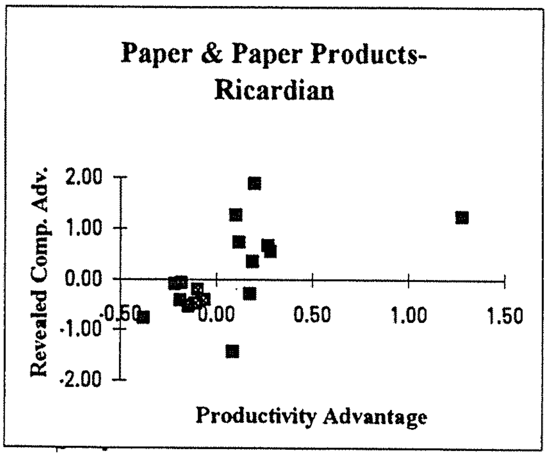
Country Factor


Fabricated Metals-Ricardian
Revealed Comp. Adv.
Productivity Advantage

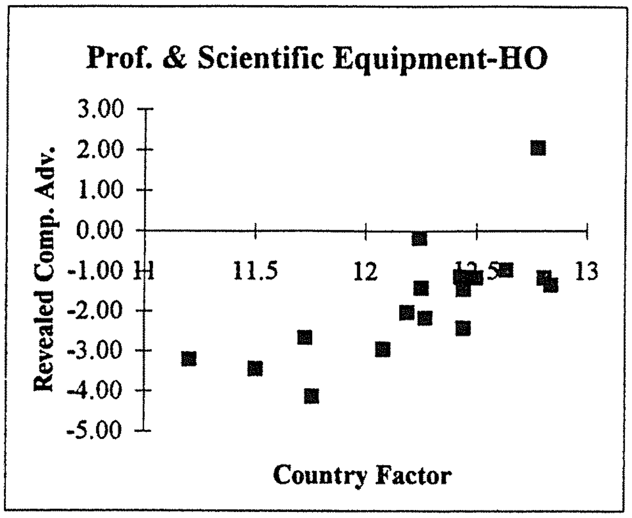

Misc. Petroleum & Coal-HO
Revealed Comp. Adv.
Country Factor


Misc. Petroleum & Coal-Ricardian
Revealed Comp. Adv.
Productivity Advantage


Paper & Paper Products-HO
Revealed Comp. Adv.
Country Factor


Paper & Paper Products-Ricardian
Revealed Comp. Adv.
Productivity Advantage

Combined


Prof. & Scientific Equipment-HO
Revealed Comp. Adv.
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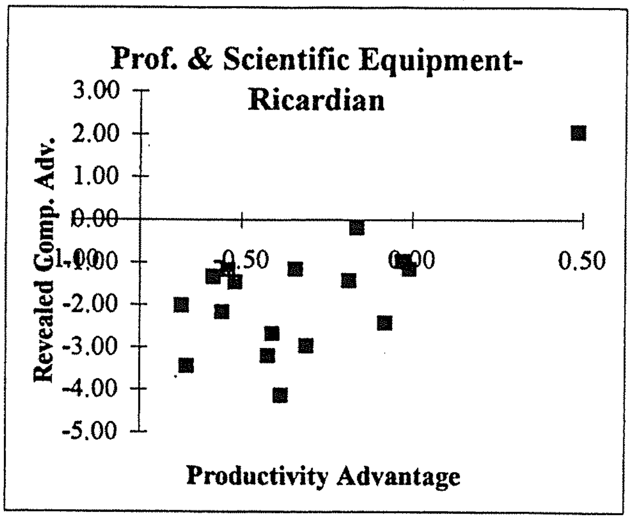
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
11
11.5
12
12.5
13
Country Factor


Prof. & Scientific Equipment-Ricardian
Revealed Comp. Adv.
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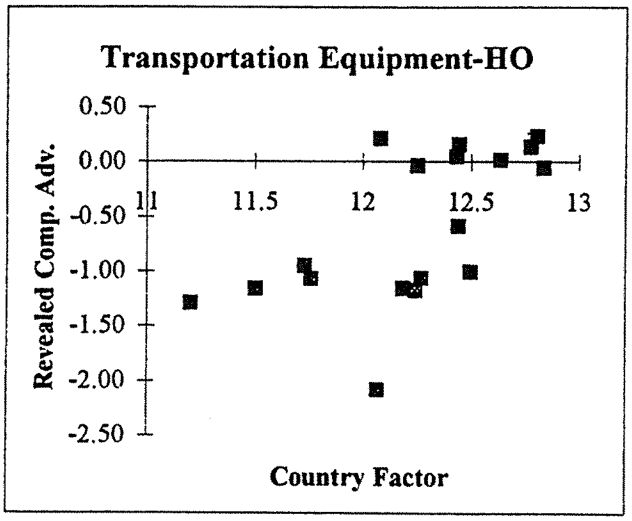
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-1.00
-0.50
0.00
0.50
Productivity Advantage


Transportation Equipment-HO
Revealed Comp. Adv.
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-1.50
-2.00
-2.50
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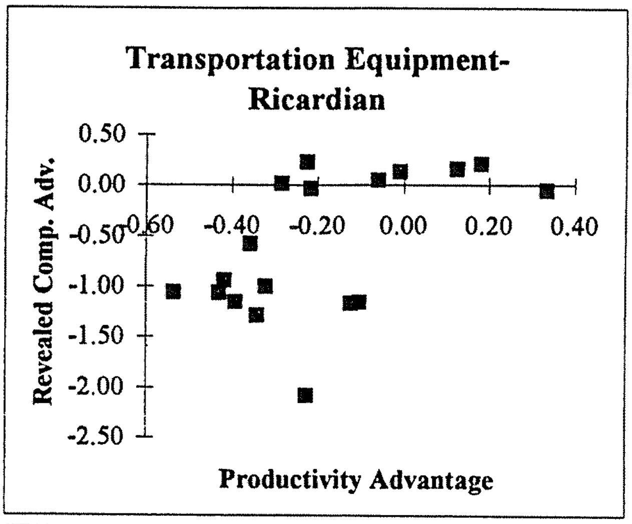
12
12.5
13
Country Factor


Transportation Equipment-Ricardian
Revealed Comp. Adv.
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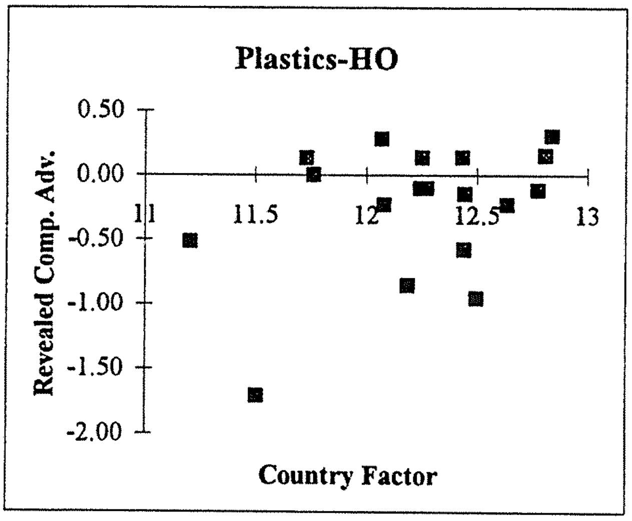
0.40
Productivity Advantage


Plastics-HO
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-0.50
-1.00
-1.50
-2.00
11
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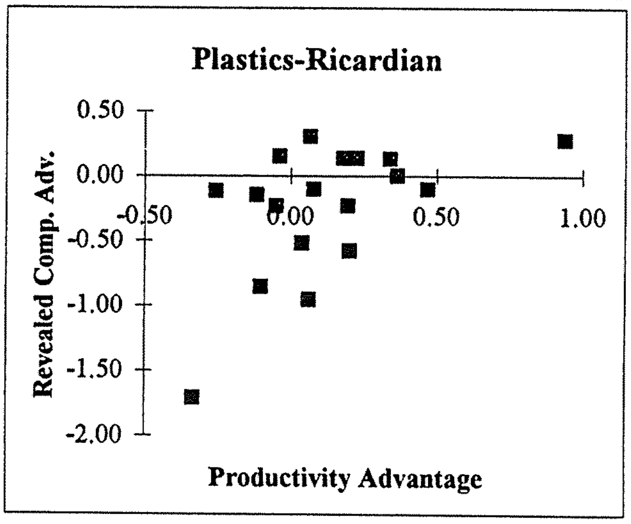
12
12.5
13
Country Factor


Plastics-Ricardian
Revealed Comp. Adv.
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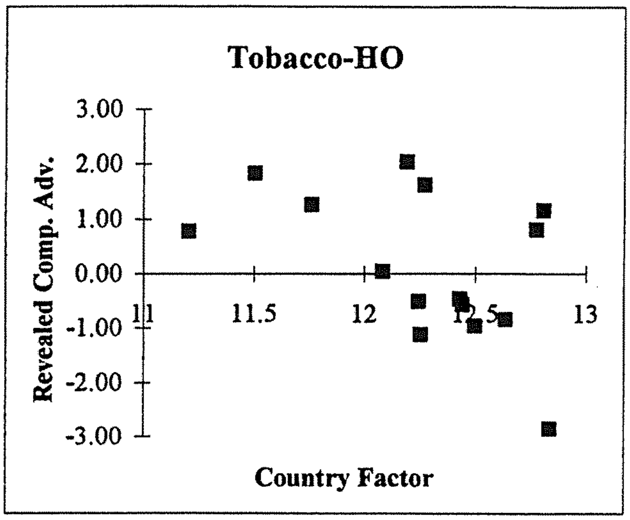
-0.50
-1.00
-1.50
-2.00
-0.50
0.00
0.50
1.00
Productivity Advantage

Combined


Tobacco-HO
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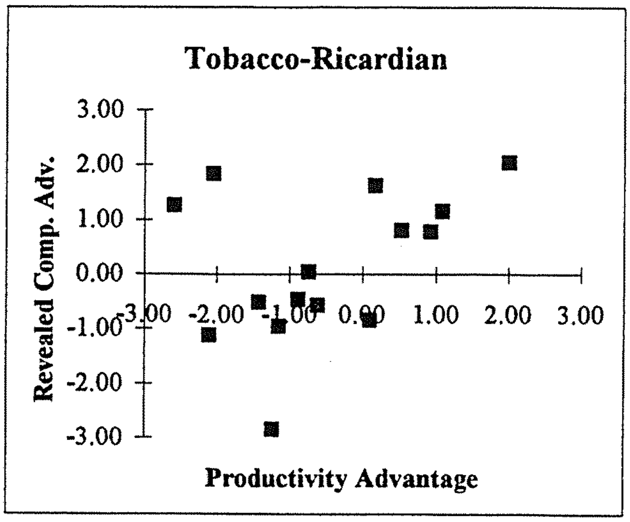
-1.00
-2.00
-3.00
11
11.5
12
12.5
13
Revealed Comp. Adv.
Country Factor


Tobacco-Ricardian
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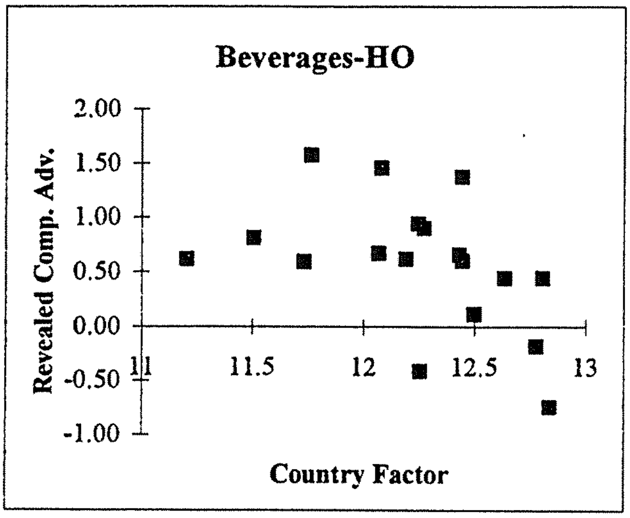
1.00
0.00
-1.00
-2.00
-3.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
Revealed Comp. Adv.
Productivity Advantage


Beverages-HO
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0.00
-0.50
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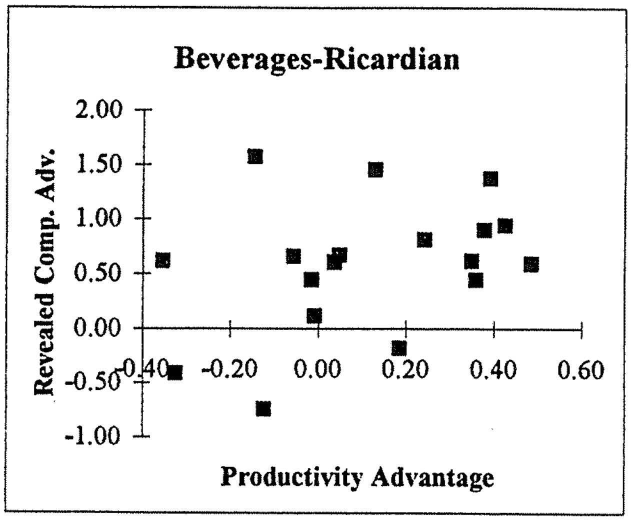
12
12.5
13
Revealed Comp. Adv.
Country Factor


Beverages-Ricardian
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0.00
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-1.00
-0.40
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0.00
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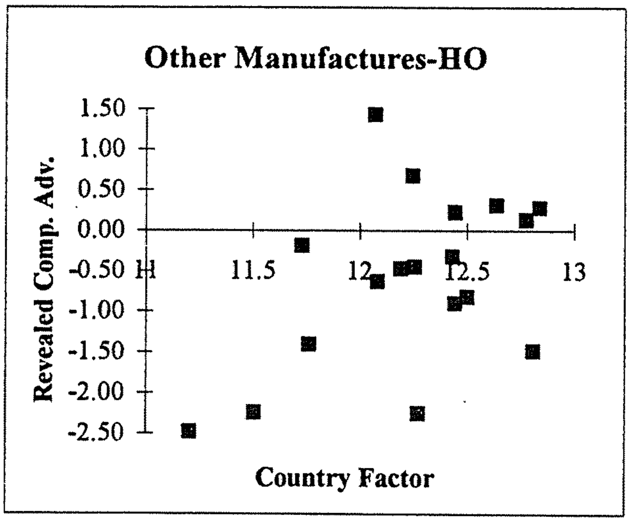
0.40
0.60
Revealed Comp. Adv.
Productivity Advantage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0.50
0.00
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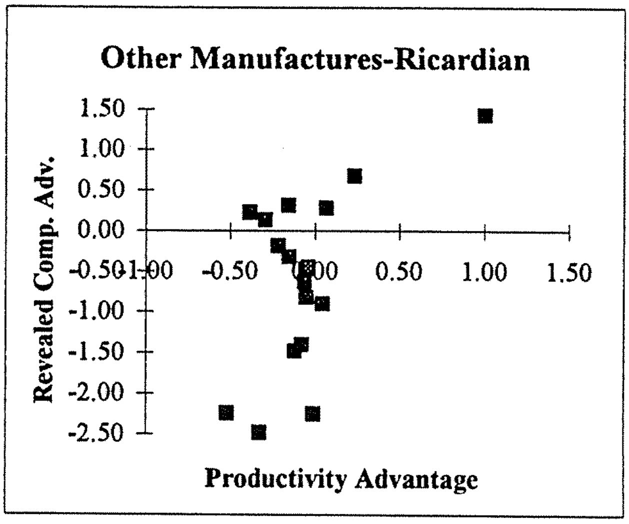
-1.00
-1.50
-2.00
-2.50
11
11.5
12
12.5
13
Revealed Comp. Adv.
Country Factor


Other Manufactures-Ricardian
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0.50
0.00
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-1.50
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0.00
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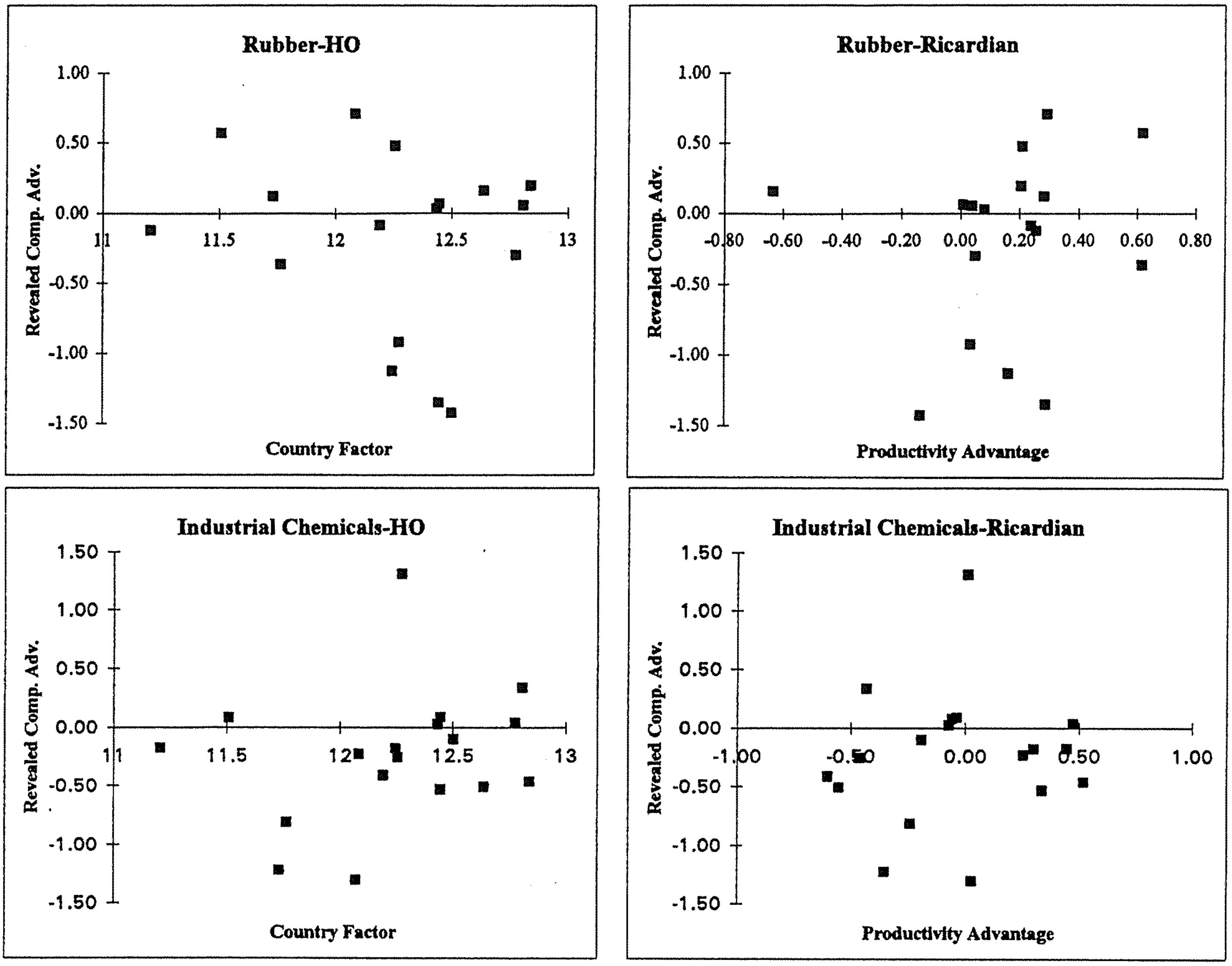
Revealed Comp. Adv.
Productivity Advantage


Rubber-HO
Revealed Comp. Adv.
Country Factor
Rubber-Ricardian
Revealed Comp. Adv.
Productivity Advantage
Industrial Chemicals-HO
Revealed Comp. Adv.
Country Factor
Industrial Chemicals-Ricardian
Revealed Comp. Adv.
Productivity Advantage

List of Tables

Table 2. Value Added per Worker
(All Figures in thousand $)

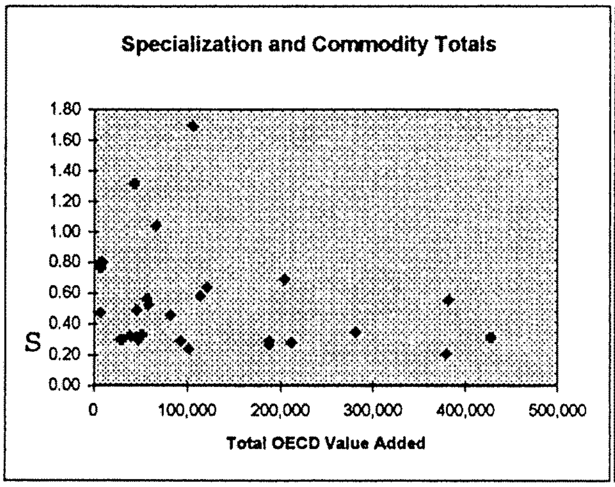
Commodity	OECD '90 Avg. VA/ Worker	Portugal 1987	Turkey 1989	NZ 1986	Greece 1990	Iceland 1990	Spain 1988	Aut 1989	Denmark 1990	Italy 1989	Neth 1989	UK 1990	Norway 1990	Canada 1986	Finland 1990	France 1990	US 1990	Germany 1990	Japan 1990	ommodit Factor
Wearing Apparel	30	6	9	10	14	21	19	18	20	27	24	23	31	20	27	41	32	41	24	0.10
Footwear	33	6	8	11	16	16	22	21	37	23	24	28	28	21	28	29	35	38	43	0.11
Textiles	41	12	13	15	23	18	26	22	11	37	0	29	36	19	26	55	46	45	42	0.13
Pottery, china	41	8	12	18	22	26	24	29	35	37	38	31	34	32	33	35	42	52	43	0.14
Leather	43	5	11	13	16	39	19	28	30	34	29	38	37	26	45	46	39	56	52	0.14
Wood	44	8	10	16	25	18	23	36	32	36	32	39	45	37	47	42	41	59	46	0.15
Furniture	44	8	12	13	20	50	27	29	38	33	37	36	42	27	42	42	51	53	62	0.15
Other manf.	54	10	23	13	24	25	22	31	28	46	0	33	34	36	57	0	48	42	43	0.16
Fabricated metal	58	10	17	16	23	36	28	34	39	39	37	44	40	37	51	57	54	59	71	0.18
Plastics nec	59	10	15	16	22	0	31	27	40	41	35	43	52	33	59	61	85	56	59	0.18
Rubber	60	13	15	17	28	25	31	35	45	47	45	49	38	43	49	58	90	76	59	0.19
Printing, publishin	67	11	14	21	29	52	30	31	49	42	43	48	51	35	49	57	56	60	68	0.19
Food manf.	68	10	17	16	21	0	31	36	36	46	38	53	53	39	59	58	70	70	90	0.19
Elec. machinery	68	12	18	21	29	39	42	38	27	60	44	63	46	39	52	59	67	57	83	0.20
Machinery	71	13	28	20	36	0	38	39	41	42	41	47	55	38	44	35	66	65	75	0.20
Professional equip.	74	15	22	19	32	0	37	36	40	45	39	44	47	41	61	57	73	70	73	0.20
Glass	75	10	18	15	22	30	43	40	42	41	36	54	45	50	49	54	80	71	103	0.20
Non-metal mineral	76	15	26	22	26	36	46	45	40	46	49	49	54	43	51	59	71	68	121	0.22
Transport	76	15	28	12	50	44	34	50	63	52	0	53	49	47	66	49	77	74	144	0.24
Non-ferrous metals	77	15	17	26	35	47	41	48	62	52	49	73	64	53	66	94	66	87	84	0.25
Paper	83	35	20	27	30	40	42	55	56	49	52	53	68	55	77	63	97	83	87	0.26
Iron and Steel	85	12	24	44	61	55	59	46	38	51	0	47	79	54	85	98	71	74	97	0.27
Misc. pet. & coal	109	19	40	21	39	48	47	46	86	62	48	87	72	64	67	75	169	98	211	0.31
Beverages	132	0	49	19	25	29	91	50	72	85	60	93	90	74	171	0	110	0	128	0.33
Other chemicals	135	30	41	25	45	65	83	52	103	64	97	98	102	92	98	83	183	115	213	0.39
Industrial chemical	139	26	45	43	46	62	67	54	106	61	109	95	130	72	105	141	153	138	139	0.40
Tobacco	430	79	25	0	30	0	78	594	98	42	208	180	0	87	156	388	550	814	223	0.74
Petroleum refining	437	78	601	238	47	0	180	123	188	88	118	512	175	95	135	705	317	855	231	1.00
Country Factor		74	100	125	129	175	177	197	208	210	214	251	254	255	269	308	354	366	377	
VA/worker		12	22	19	27	33	36	40	43	44	48	52	53	43	57	61	76	75	80	

Table 1. Revealed Comparative Advantage

Commodity	OECD '90 Avg. VA/ Worker (1000s $)	Portugal 1987	Turkey 1989	NZ 1986	Greece 1990	Iceland 1990	Spain 1988	Aut 1989	Denmark 1990	Italy 1989	Neth 1989	UK 1990	Norway 1990	Canada 1986	Finland 1990	France 1990	US 1990	Germany 1990	Japan 1990
Wearing Apparel	30	1.16	0.89	0.84	1.84	-0.35	0.45	0.02	-0.57	1.09	-1.33	0.15	-1.93	0.42	0.00	0.43	0.36	-0.69	-0.41
Footwear	33	2.65	-0.25	1.00	2.21	-1.43	1.76	1.27	0.27	2.70	-0.66	1.21	-1.56	0.39	0.63	1.49	-0.63	-0.14	-0.64
Textiles	41	2.22	1.88	0.39	2.14	0.02	0.39	0.47	-0.04	1.29	-0.52	0.02	-1.00	-0.13	-0.88	0.04	-0.07	-0.35	0.21
Pottery, china	41	2.95	1.89	0.16	1.73	-0.88	1.03	0.28	0.39	3.07		1.47	-0.28	-1.37	0.35		-1.09	0.36	0.73
Leather	43	1.88	0.46	2.01	1.89	1.75	1.64	0.25	-1.80	2.10		0.09	-0.79	-0.52	-0.09	1.21	-0.37	-0.19	0.11
Wood	44	1.09	-1.18	1.60	0.34	-3.54	0.63	0.58	0.50	-0.50	-0.30	-0.27	1.66	1.62	2.02	-0.01	0.12	-0.44	0.09
Furniture	44	-0.69	-2.29	0.51	-0.39	2.03	0.28	1.35	1.10	0.55	-0.59	0.49	0.42	0.53	0.72	0.21	-0.06	0.20	-0.55
Other manf.	54	-2.48	-2.24	-0.19	-1.41	1.43	-0.63	-0.47	0.67	-0.46	-2.25	-0.33	-0.90	0.22	-0.83	0.31	0.13	-1.49	0.27
Fabricated metal	58	-0.44	-0.99	0.36	-0.36	0.85	-0.06	0.38	0.37	-0.19	0.13	-0.08	-0.08	-0.02	0.22	0.33	-0.34	0.29	0.26
Plastics nec	59	-0.52	-1.71	0.13	0.00	0.28	-0.23	-0.86	-0.10	0.13	-0.11	0.13	-0.58	-0.15	-0.95	-0.23	-0.12	0.15	0.30
Rubber	60	-0.12	0.57	0.12	-0.37		0.71	-0.09	-1.13	0.48	-0.93	0.03	-1.35	0.06	-1.43	0.16	-0.30	0.05	0.19
Printing, publishing	67	-0.72	-2.43	0.30	-0.95	0.89	-0.29	-0.62	0.21	-0.51	0.34	0.40	0.78	0.08	0.44	-0.25	0.69	-1.82	-0.21
Food manf.	68	0.38	0.25	1.33	0.83	2.22	0.55	-0.17	1.13	-0.44	0.69	0.29	0.49	0.35	0.19	0.31	0.25	-0.71	-0.17
Elec. machinery	68	-0.94	-1.39	-1.34	-1.23		-0.87	0.09	-0.96	-0.18	0.04	-0.36	-1.08	-0.97	-0.70	-0.15	-0.58	0.35	0.63
Machinery	71	-2.16	-1.55	-1.11	-2.70		-0.95	-0.31	0.09	0.25	-0.65	-0.08	-0.04	-0.80	0.11	-0.37	-0.29	0.37	0.26
Professional equip.	74	-3.21	-3.45	-2.68	-4.15		-2.97	-2.03	-0.19	-1.44	-2.18	-1.17	-2.44	-1.47	-1.18	-1.00	2.04	-1.18	-1.36
Glass	75	0.78	1.10	0.18	-0.68	-0.82	0.66	0.89	-0.77	0.44	-0.21	-0.05	-0.61	-0.26	-0.42	0.59	-0.23	0.10	0.23
Non-metal minerals	76	1.08	0.83	0.21	1.53	1.02	0.99	0.95	0.77	0.15	0.30	0.61	0.16	0.08	0.79	0.38	-0.62	-0.12	0.44
Transport	76	-1.29	-1.16	-0.95	-1.07	-2.08	0.21	-1.16	-1.17	-0.04	-1.06	0.04	-0.59	0.15	-1.00	0.01	0.13	0.23	-0.06
Non-ferrous metals	77	-1.43	0.81	0.85	1.44	1.78	0.36	0.32	-2.14	0.09		-0.37	2.05	1.28	0.03	0.51	-0.11	0.07	-0.06
Paper	83	1.24	-0.77	0.55	-0.19	-1.43	-0.40	0.35	-0.29	-0.48	-0.07	-0.09	0.73	1.27	1.88	-0.42	0.67	-0.47	-0.54
Iron and Steel	85	-0.36	1.13	-2.14	-0.23	-1.54	0.20	0.99	-1.54	0.76		-0.16	-0.49	0.05	-0.15	0.03	-0.82	0.03	0.93
Misc. pet. & coal	109		2.34	-0.44	0.50	-2.74	1.62	-0.25	2.15	0.85	0.28	0.55	1.31	0.11	1.15		1.37		-0.35
Beverages	132	0.61	0.81	0.59	1.57	0.66	1.45	0.61	0.94	-0.42	0.90	0.65	1.37	0.60	0.11	0.44	-0.18	0.44	-0.74
Other chemicals	135	0.05	-0.02	-0.80	0.31	-1.51	0.11	-0.60	0.29	-1.05	-0.43	0.10	-1.01	0.05	-1.04	-0.13	0.30	-0.08	-0.08
Industrial chemicals	139	-0.18	0.08	-1.22	-0.81	-1.30	-0.23	-0.41	-0.18	-0.26	1.31	0.03	0.09	-0.53	-0.10	-0.51	0.04	0.34	-0.46
Tobacco	430	0.77	1.82		1.26		0.03	2.04	-0.52	-1.12	1.62	-0.47		-0.57	-0.96	-0.84	0.79	1.15	-2.86
Petroleum refineries	437	0.25	2.95	1.10	0.24		0.12	0.02	-1.96	-1.31	0.04	-0.20	-0.46	-0.35	-0.75	1.84	-0.30	1.14	-2.19
		72,632	99,523	124,643	128,687	174,871	176,966	197,235	208,385	210,271	214,363	251,485	254,290	254,515	268,912	308,116	354,385	365,577	377,053
		63,782	98,532	95,438	128,687	174,871	175,280	195,270	208,385	208,176	212,228	251,485	254,290	194,880	268,912	308,116	354,385	365,577	377,053

Table 3. Specialization Indices by Commodity

	1990 OECD Value Added Total ($m) 1990	Share	OECD '90 Avg. VA/ Worker (1000s $)	Specialization Index Value-Added Weights
Transport	378,449	11.0%	76.40	0.20
Plastics nec	101,792	3.0%	58.68	0.23
Industrial chemicals	187,439	5.5%	139.08	0.26
Fabricated metal	211,933	6.2%	57.92	0.28
Textiles	93,473	2.7%	40.78	0.28
Other chemicals	187,426	5.5%	135.15	0.29
Non-ferrous metals	47,529	1.4%	76.76	0.29
Glass	28,953	0.8%	74.96	0.30
Machinery	427,007	12.5%	71.33	0.31
Furniture	44,978	1.3%	44.15	0.31
Rubber	39,762	1.2%	60.43	0.32
Wood	51,399	1.5%	43.90	0.33
Food manf.	280,639	8.2%	68.13	0.34
Non-metal minerals	82,601	2.4%	76.30	0.45
Leather	6,768	0.2%	43.10	0.47
Other manf.	46,068	1.3%	54.09	0.49
Beverages	59,375	1.7%	132.03	0.52
Elec. machinery	380,740	11.1%	68.16	0.55
Wearing Apparel	57,100	1.7%	29.86	0.56
Paper	114,526	3.3%	83.35	0.58
Iron and Steel	120,950	3.5%	85.20	0.63
Printing, publishing	205,204	6.0%	66.67	0.69
Misc. pet. & coal	7,105	0.2%	108.56	0.76
Footwear	8,024	0.2%	33.29	0.80
Pottery, china	8,092	0.2%	41.25	0.81
Petroleum refineries	67,725	2.0%	437.39	1.04
Tobacco	43,306	1.3%	429.60	1.31
Professional equip.	106,162	3.1%	73.76	1.69
Total	3,427,934			



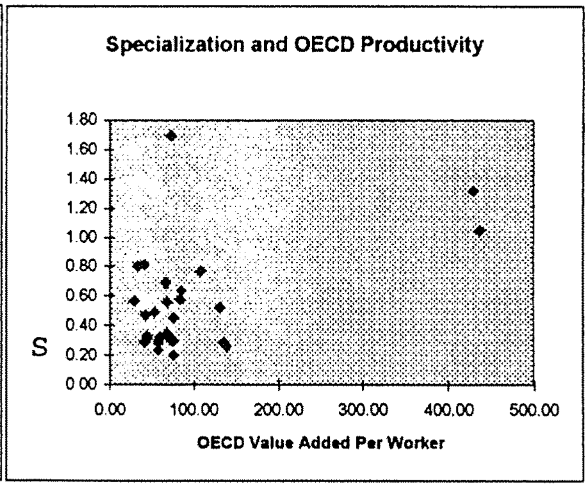
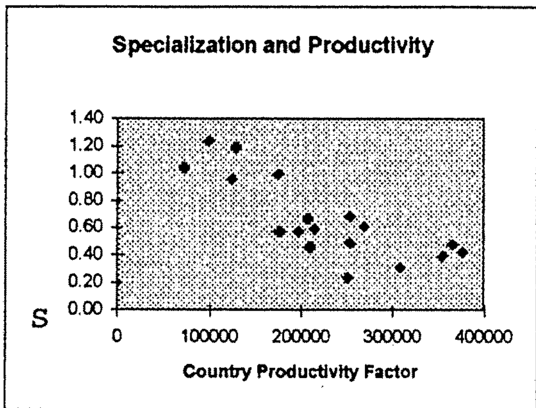


Table 4. Specialization Indices by Country

Country	Country Factor	Total Value-Added $ Millions	Share	Specialization Index
UK	251,485	253550	6.9%	0.23
France	308,116	255648	6.9%	0.31
US	354,385	1322052	35.8%	0.40
Japan	377,053	891794	24.1%	0.42
Italy	210,271	122646	3.3%	0.46
Germany	365,577	535531	14.5%	0.48
Canada	254,515	77423	2.1%	0.48
Spain	176,966	65924	1.8%	0.57
Austria	197,235	25148	0.7%	0.57
Netherlands	214,363	39959	1.1%	0.59
Finland	268,912	26427	0.7%	0.61
Denmark	208,385	22979	0.6%	0.67
Norway	254,290	14472	0.4%	0.68
New Zealand	124,643	5553	0.2%	0.95
Iceland	174,871	758	0.0%	0.99
Portugal	72,632	7509	0.2%	1.04
Greece	128,687	9293	0.3%	1.19
Turkey	99,523	20981	0.6%	1.24
AVG/TOT	224,551	3697647		



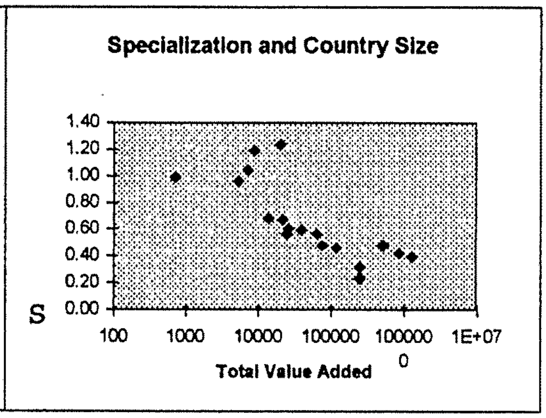


Table 5. Ricardian Productivity Advantage

Commodity	OECD '90 Avg. VA/ Worker	Portugal 1987	Turkey 1989	NewZ 1986	Greece 1990	Iceland 1990	Spain 1988	Aut 1989	Denmark 1990	Italy 1989	Neth 1989	UK 1990	Norway 1990	Canada 1986	Finland 1990	France 1990	US 1990	Germany 1990	Japan 1990	ommodit Factor
Wearing Apparel	30	0.24	0.04	0.27	0.32	0.62	0.31	0.10	0.15	0.61	0.26	0.07	0.45	0.03	0.18	0.74	0.01	0.42	-0.59	0.10
Footwear	33	0.21	-0.20	0.41	0.34	0.08	0.46	0.27	0.88	0.27	0.22	0.16	0.17	0.18	0.08	0.02	-0.06	0.12	0.24	0.11
Textiles	41	0.24	-0.12	0.72	0.50	0.47	0.21	0.35	0.53	0.61	0.48	0.05	0.17	0.37	0.02	0.03	-0.06	0.30	-0.12	0.13
Pottery, china	41	0.44	0.80	0.40	0.61	0.40	0.03	0.35	0.17	0.85		0.08	0.16	0.64	0.79		0.16	-0.05	-0.11	0.14
Leather	43	0.75	-0.01	0.51	0.49	-0.12	0.29	-0.10	-1.21	0.50		-0.13	0.17	-0.36	-0.42	0.67	0.01	-0.01	-0.25	0.14
Wood	44	-0.12	-0.46	0.33	0.56	-0.15	-0.01	0.47	0.27	0.36	0.05	0.31	0.44	0.38	0.43	0.20	-0.30	0.40	-0.11	0.15
Furniture	44	-0.52	-0.24	0.06	-0.05	0.93	-0.23	0.16	0.15	0.33	-0.03	0.24	0.17	-0.12	0.35	0.33	-0.46	0.31	0.07	0.15
Other manf.	54	-0.33	-0.52	-0.22	-0.07	1.01	-0.06	-0.05	0.23	-0.04	-0.01	-0.15	0.05	-0.38	-0.05	-0.16	-0.29	-0.12	0.07	0.16
Fabricated metal	58	0.02	-0.04	0.06	0.03	0.44	-0.09	0.09	0.16	0.14	-0.09	0.04	-0.13	0.08	0.12	0.22	-0.28	-0.05	0.18	0.18
Plastics nec	59	0.04	-0.33	0.34	0.37	0.94	-0.05	-0.10	0.47	0.23	0.08	0.18	0.20	-0.11	0.06	0.20	-0.25	-0.04	0.07	0.18
Rubber	60	0.26	0.62	0.28	0.62		0.29	0.24	0.16	0.21	0.03	0.08	0.29	0.01	-0.13	-0.63	0.05	0.04	0.21	0.19
Printing, publishin	67	-0.01	-0.25	0.10	0.19	0.37	0.33	-0.01	-0.57	0.52	-0.11	0.39	-0.12	-0.20	-0.03	0.06	-0.12	-0.33	0.17	0.19
Food manf.	68	0.09	-0.46	-0.09	0.08	-0.30	-0.15	-0.08	0.13	0.19	-0.03	-0.03	-0.44	0.02	-0.16	-0.01	0.51	0.08	-0.51	0.19
Elec. machinery	68	0.39	0.10	0.07	0.29		0.07	-0.07	-0.04	0.11	-0.26	-0.21	-0.12	-0.04	0.15	-0.03	0.00	-0.04	-0.05	0.20
Machinery	71	-0.22	-0.34	-0.25	-0.36		-0.23	-0.14	-0.26	0.05	-0.36	0.02	0.00	-0.16	0.06	-0.06	-0.17	-0.12	0.24	0.20
Professional equip.	74	-0.42	-0.66	-0.41	-0.38		-0.31	-0.67	-0.16	-0.18	-0.56	-0.34	-0.08	-0.52	-0.01	-0.03	0.49	-0.54	-0.58	0.20
Glass	75	0.16	0.18	0.06	-0.13	0.06	0.20	0.10	-0.17	-0.01	-0.07	-0.17	-0.05	-0.15	-0.24	-0.15	-0.24	-0.26	0.69	0.20
Non-metal mineral	76	0.14	-0.44	0.34	0.25	0.44	0.04	0.17	0.44	0.17	-0.07	0.42	0.17	0.20	0.12	0.58	-0.44	0.12	-0.01	0.22
Transport	76	-0.34	-0.39	-0.42	-0.43	-0.22	0.18	-0.10	-0.12	-0.22	-0.53	-0.06	-0.36	0.13	-0.32	-0.28	-0.01	-0.22	0.33	0.24
Non-ferrous metals	77	-0.08	-0.03	1.21	1.05	0.66	0.50	0.01	-0.29	0.03		-0.29	0.45	0.32	0.47	0.65	-0.32	-0.16	0.23	0.25
Paper	83	1.28	-0.38	0.28	-0.10	0.09	-0.06	0.19	0.17	-0.11	-0.18	-0.22	0.12	0.10	0.20	-0.19	0.27	-0.10	-0.14	0.26
Iron and Steel	85	0.24	0.07	-0.58	0.61	0.17	-0.33	0.04	0.31	-0.08		-0.26	-0.37	0.14	-0.04	-0.63	-0.34	-0.34	0.89	0.27
Misc. pet. & coal	109		0.44	-0.83	-0.76	-0.76	0.65	-0.37	0.13	0.25	-0.40	0.25	0.15	-0.09	0.99		-0.09		0.09	0.31
Beverages	132	0.35	0.24	0.49	-0.15	0.05	0.13	-0.35	0.42	-0.32	0.38	-0.06	0.39	0.04	-0.01	0.36	0.19	-0.01	-0.12	0.33
Other chemicals	135	-0.29	-0.01	-0.68	-0.42	-0.36	-0.55	-0.70	0.08	-0.40	-0.91	-0.22	-0.49	-0.32	-0.69	-0.69	0.39	-0.66	0.59	0.39
Industrial chemical	139	0.45	-0.06	-0.35	-0.24	0.03	0.26	-0.60	0.30	-0.46	0.01	-0.07	-0.04	0.34	-0.19	-0.55	0.47	-0.43	0.52	0.40
Tobacco	430	0.93	-2.04		-2.58		-0.74	2.01	-1.42	-2.10	0.17	-0.88		-0.61	-1.14	0.10	0.53	1.09	-1.23	0.74
Petroleum refining	437	0.40	2.37	1.34	-1.88		-0.08	-0.85	-0.48	-1.51	-1.21	0.73	-0.91	-1.25	-1.38	1.09	-0.91	1.14	-1.24	1.00
Country Factor		74	100	125	129	175	177	197	208	210	214	251	254	255	269	308	354	366	377	

Table 6. Combined Regressions by Commodity

Commodity	OECD '90 Avg. VApw (1000s $)	HO Slope times range	HO t-value	Ricardian Slope times range	Ricardian t-value	Adj. R-sq.	Best Model
Textiles	41	-2.73	-4.54	-0.44	-0.81	0.53	HO
Elec. machinery	68	1.27	2.27	-0.20	-0.32	0.34	HO
Wearing Apparel	30	-1.78	-2.42	-0.19	-0.20	0.19	HO
Pottery, china	41	-2.32	-1.92	0.15	0.15	0.17	HO
Footwear	33	-1.86	-1.72	1.41	0.99	0.12	HO
Food manf.	68	-0.91	-1.58	-0.29	-0.45	0.05	HO
Printing, publishing	67	1.10	1.46	0.81	0.99	0.05	HO
Petroleum refining	437	-0.77	-0.96	3.10	3.98	0.54	Ricardian
Furniture	44	0.34	0.50	2.54	3.11	0.38	Ricardian
Non-ferrous metals	77	0.69	0.90	2.39	3.30	0.36	Ricardian
Glass	75	-0.47	-0.95	0.96	1.69	0.14	Ricardian
Wood	44	-0.37	-0.34	2.17	2.14	0.13	Ricardian
Other chemicals	135	-0.14	-0.30	0.90	1.81	0.07	Ricardian
Iron and Steel	85	0.56	0.67	0.94	1.07	-0.04	Ricardian
Machinery	71	1.94	3.53	0.94	1.67	0.68	Combined(HO)
Non-metal minerals	76	-1.18	-3.39	0.60	1.67	0.41	Combined(HO)
Leather	43	-1.14	-1.81	3.33	4.52	0.67	Combined(R)
Fabricated metal	58	0.65	2.57	1.18	3.67	0.50	Combined(R)
Misc. pet. & coal	109	-1.41	-1.18	3.19	3.41	0.41	Combined(R)
Paper	83	0.83	1.25	2.71	3.14	0.32	Combined(R)
Professional equip.	74	2.79	3.57	2.53	2.90	0.66	Combined
Plastics nec	59	0.80	2.28	1.30	3.06	0.40	Combined
Transport	76	1.14	2.13	0.87	1.57	0.39	Combined
Other manf.	54	1.52	2.07	2.54	2.64	0.39	Combined
Tobacco	430	-2.61	-2.55	2.25	2.15	0.35	Combined
Beverages	132	-0.86	-1.72	0.49	1.09	0.16	Combined
Industrial chemicals	139	0.49	0.95	0.19	0.43	-0.06	??
Rubber	60	-0.33	-0.45	0.19	0.20	-0.10	??

Table 7. Quadratic HO Model

Regression with Quadratic HO Term

Commodity	OECD '90 Avg. VApw (1000s $)	t-value for quadratic term	value for HO at max
Wood	44	1.52	0.00
Textiles	41	1.30	0.00
Glass	75	1.09	0.00
Other chemicals	135	0.93	0.00
Pottery, china	41	0.89	0.00
Misc. pet. & coal	109	0.71	0.00
Non-metal mineral	76	-0.67	0.00
Rubber	60	0.64	0.00
Wearing Apparel	30	0.54	0.00
Footwear	33	0.42	0.00
Tobacco	430	-1.27	0.22
Petroleum refining	437	-0.41	0.25
Leather	43	-1.51	0.38
Food manf.	68	-1.82	0.39
Beverages	132	-2.38	0.39
Furniture	44	-1.44	0.60
Printing, publishing	67	-1.30	0.74
Non-ferrous metals	77	-0.64	0.74
Paper	83	-0.62	0.88
Fabricated metal	58	-1.08	0.90
Other manf.	54	-0.71	0.96
Elec. machinery	68	1.44	1.00
Machinery	71	-1.15	1.00
Plastics nec	59	1.00	1.00
Transport	76	0.91	1.00
Professional equip.	74	0.91	1.00
Iron and Steel	85	0.52	1.00
Industrial chemical	139	0.43	1.00

Table 8. Residuals for Combined Model

Countries and Commodities Sorted by Residual Sum-of-Squares

	Spain	Austria	UK	France	Canada	US	Portugal	Finland	NZ	Germany	Japan	Neth	Greece	Turkey	Denmark	Italy	Norway	Iceland	RSS	R-Sqd.
Fabricated metal	0.21	0.32	-0.30	-0.13	-0.17	-0.03	0.01	-0.02	0.53	0.21	-0.21	0.33	-0.16	-0.57	0.17	-0.36	0.11	0.26	1.34	0.50
Plastics nec	0.27	-0.36	0.06	-0.26	0.23	0.24	0.32	-0.77	0.40	0.28	0.31	0.16	0.23	-0.64	-0.21	0.26	-0.51	-0.22	2.34	0.40
Non-metal minerals	0.41	0.37	0.30	-0.12	-0.34	-0.42	-0.20	0.46	-0.80	-0.23	0.43	-0.08	0.59	0.12	0.07	-0.39	-0.24	0.19	2.45	0.41
Elec. machinery	-0.11	0.72	-0.23	0.14	-0.53	-0.39	0.61	-0.25	-0.31	0.51	0.76	0.54	-0.16	-0.18	-0.37	0.45	-0.67	0.00	3.53	0.34
Machinery	0.01	0.38	-0.33	-0.34	-0.38	-0.25	-0.15	0.12	0.30	0.30	-0.42	0.29	**-1.16**	0.27	0.90	0.57	0.13	0.00	3.61	0.68
Transport	0.50	-0.66	0.09	0.37	0.24	0.13	0.14	-0.50	0.19	0.41	-0.45	-0.19	0.05	0.10	-0.69	0.53	-0.01	**-1.38**	4.31	0.39
Other chemicals	0.52	-0.09	0.38	0.42	0.36	0.21	0.23	-0.51	-0.34	0.46	-0.28	0.22	0.62	0.02	0.34	-0.71	-0.60	**-1.21**	4.37	0.07
Glass	0.37	0.73	0.24	0.82	-0.09	0.13	0.27	-0.14	-0.07	0.49	-0.34	-0.17	-0.73	0.66	-0.63	0.41	-0.54	-0.97	4.68	0.14
Beverages	0.78	0.27	0.45	-0.07	0.17	-0.52	-0.66	-0.26	-0.47	0.23	-0.87	0.18	0.89	-0.23	0.19	-0.74	0.74	0.03	4.74	0.16
Industrial chemicals	0.00	-0.06	0.11	-0.31	-0.42	0.03	0.29	0.08	-0.78	0.47	-0.50	1.53	-0.39	0.54	0.00	0.04	0.27	**-1.02**	5.36	-0.06
Leather	0.56	-0.09	0.20	-0.13	-0.24	-0.49	-0.61	0.33	0.31	-0.25	0.48	0.00	0.24	-0.52	-0.22	0.78	**-1.41**	**1.36**	6.36	0.67
Food manf.	0.01	-0.63	0.16	0.11	0.06	0.28	-0.59	-0.12	0.61	-0.79	-0.40	0.29	0.17	-0.70	0.76	-0.79	0.06	**1.63**	6.49	0.05
Rubber	0.86	0.08	0.35	0.55	0.32	0.02	-0.15	**-1.14**	0.20	0.38	0.50	-0.71	-0.34	0.55	-0.93	0.67	**-1.13**	0.00	6.54	-0.10
Textiles	-0.28	0.05	0.42	0.20	-0.11	0.28	0.08	-0.95	-0.60	0.24	0.63	-0.73	**1.09**	0.08	-0.27	**1.12**	**-1.09**	-0.53	6.62	0.53
Paper	-0.17	0.11	0.04	-0.27	**1.05**	0.00	-0.26	**1.47**	0.40	-0.55	-0.57	0.25	0.26	0.27	-0.52	-0.26	0.48	**-1.44**	7.09	0.32
Furniture	0.62	0.99	-0.13	-0.54	0.60	0.54	0.34	-0.03	0.42	-0.55	-0.89	-0.64	-0.29	**-1.81**	0.75	-0.12	-0.01	0.36	8.18	0.38
Professional equip.	-0.92	0.62	-0.23	-0.51	0.42	**1.16**	0.61	-0.50	0.19	0.13	-0.01	0.09	**-1.40**	0.35	**1.26**	0.03	**-1.51**	0.00	9.68	0.66
Non-ferrous metals	-0.26	0.42	-0.04	-0.57	0.79	0.26	-0.77	-0.71	-0.73	0.18	-0.57	0.00	0.10	**1.26**	**-1.59**	0.14	**1.36**	0.92	10.11	0.36
Petroleum refining	-0.09	0.42	-0.68	**1.03**	0.46	0.42	-0.73	0.18	-0.31	0.38	**-1.20**	0.74	1.19	0.68	**-1.80**	-0.40	0.10	0.00	10.21	0.54
Other manf.	0.06	0.10	-0.13	0.65	**1.11**	0.56	-0.51	-0.54	**1.10**	**-1.37**	0.04	**-1.82**	-0.40	-0.24	0.73	0.04	-0.73	0.35	10.35	0.39
Wearing Apparel	0.19	-0.15	0.61	0.84	0.52	0.82	-0.08	0.18	0.20	-0.14	0.03	**-1.38**	**1.24**	-0.03	-0.67	**1.06**	**-1.77**	-0.57	10.68	0.19
Printing, publishing	-0.21	-0.36	-0.03	-0.35	0.31	0.63	0.21	0.50	0.79	**-1.74**	-0.52	0.62	-0.55	**-1.53**	0.85	-0.69	0.95	0.95	11.03	0.05
Misc. pet. & coal	-0.26	-0.26	-0.03	0.00	-0.16	**1.38**	0.00	-0.96	-0.04	0.00	-0.60	0.40	0.80	0.33	**1.32**	-0.18	0.62	**-2.17**	11.13	0.41
Iron and Steel	0.62	**1.14**	-0.02	0.44	0.05	-0.63	0.01	-0.06	**-1.45**	0.21	0.33	0.00	-0.29	**1.49**	**-1.58**	0.96	-0.17	**-1.43**	12.34	-0.04
Tobacco	-0.23	0.60	0.44	-0.63	-0.32	**1.02**	**-1.74**	-0.36	0.00	**1.15**	**-1.67**	**1.22**	**1.39**	**1.27**	-0.19	-0.44	0.00	0.00	14.66	0.35
Pottery, china	0.18	-0.46	**1.60**	0.00	**-1.80**	-0.97	0.77	-0.02	**-1.24**	0.56	0.98	0.00	0.34	0.10	-0.25	**2.34**	-0.63	**-1.80**	19.68	0.17
Wood	0.75	-0.30	-0.67	-0.21	0.99	**1.02**	**1.25**	**1.30**	0.92	**-1.03**	0.60	-0.26	-0.82	-0.23	0.06	**-1.13**	0.91	**-3.12**	21.31	0.13
Footwear	0.75	0.63	**1.38**	**1.68**	0.16	-0.18	0.95	0.59	-0.34	0.12	-0.50	**-1.14**	0.99	**-1.06**	**-1.09**	**2.13**	**-1.78**	**-1.96**	23.55	0.12
Sum of Squares	5.78	6.84	7.15	8.42	9.65	9.82	10.02	10.42	10.58	10.78	11.50	13.76	15.03	15.80	19.03	19.63	20.25	38.28		
R-Squared	0.78	0.63	0.03	0.23	0.30	0.15	0.83	0.50	0.66	0.11	0.41	0.36	0.75	0.77	0.34	0.42	0.37	0.33		

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