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# How Pervasive Is the Product Cycle? The Empirical Dynamics of American and Japanese Trade Flows

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**Abstract**

This paper looks for dynamic patterns in international trade flows using comprehensive multilateral American and Japanese data disaggregated to the four-digit SITC level. Little evidence is found of product-cycle dynamics between 1962 and 1988. Rather, goods that begin the sample in surplus (deficit) almost always remain in surplus (deficit) throughout the sample.

## I: Introduction and Motivation

This paper uses disaggregated data to determine whether most international trade flows are essentially static or dynamic. More precisely, we seek to discover whether a trade surplus (or deficit) in a given commodity is likely to be persistent for a long period of time. The chief empirical finding is a remarkably high degree of persistence in disaggregated international trade balances.

The motivation for this exercise is that different theories of international trade have different implications for the time-series patterns of trade flows. The standard factor-proportions (Heckscher-Ohlin) theory argues that trade flows are determined by relative endowments of factors of production, which change only slowly over time. Hence, goods that are net exports in one year (because of a country's factor proportions), also tend to be net exports in subsequent years.[1] Alternative "technological" theories, such as the "product cycle" theory of Posner (1961), imply more dynamic patterns. The product-cycle theory states that goods go through a life cycle. During the initial development stage a good is produced only in a rich country, which also exports some production. After the good matures into a standardized commodity, its production migrates abroad to take advantage of lower production costs; at this stage, the country that first developed the commodity becomes a net importer. That is, goods that are net exports because of product-cycle reasons become net imports later. Alternatively, Ethier (1988) states in his popular textbook that "the actual export mix [of a rich country such as the United States] would have to constantly change in order for ... 'advanced' products to continue to be exported".

The primary goal of this paper is to use the most finely disaggregated comprehensive data available to search for evidence of dynamics in international trade flows that might be related to product cycles. We ask the question: "what fraction of total trade is composed of goods that exhibited at least some of the characteristics of a product cycle over the past three decades?" Thus, this paper should be viewed as a contribution to the relatively sparse empirical literature on the product cycle.

Our study exploits a comprehensive data base of American and Japanese multilateral trade flows disaggregated to the four-digit SITC level from 1962 through 1988. Goods at the four-digit SITC level include: "unmilled rye" (0451); "porcelain or china household ware" (6664); and "aircraft engines" (7114). We normalize the data and find that relatively few goods that were net exports (imports) at the beginning of our sample become net imports (exports) at *any* time subsequently. Instead, most goods are either net exports or net imports throughout the entire period. Alternatively, there is a high probability that a good that is a net export at the beginning of our sample is still a net export at the end of our sample. We conclude that there is little empirical evidence of product cycles of reasonable duration; the quantitative importance of this theory of international trade appears to be limited. Rather, our findings are supportive of theories of international trade that imply sluggish trade patterns, such as the factor-proportions theory.

The following section briefly reviews the existing literature; our data are described in section III. Section IV contains our results, and the final section concludes.

## II: Literature

Deardorff (1984) provides a recent survey of the extant empirical literature in international trade, including studies concerned with the product cycle. There is relatively little empirical work concerned with dynamic patterns in international trade. While there is a small body of research that seeks to test the product-cycle theory of international trade, most existing studies (e.g., Wells (1969), Finger (1975), and Hirsch (1975)) provide rather indirect evidence. This evidence primarily takes the form of moderately disaggregated (to the two-digit or sometimes three-digit SITC level) cross-sectional regressions of (net) exports on technological variables (such as R&D expenditures or the age of a product), and more traditional explanatory variables (such as capital and labor). The typical finding of significant dependence of exports on R&D or product age is taken as evidence for the product cycle.

In addition to being somewhat oblique, the empirical literature has a number of other shortcomings. These studies have difficulty in discriminating between the product-cycle theory and the factor-proportions theory augmented to include human capital as a factor of production. Much of the existing work uses a relatively narrow span of (now-dated) data, typically only for the United States (Finger (1975) is the exception). However, product-cycle theories which have empirical implications for the trade patterns of rich countries also have clear ramifications for their trading partners. More serious is the fact that few of the studies are comprehensive; instead, much existing work uses anecdotal evidence or the case-study approach. The more comprehensive studies also tend to rely on relatively highly aggregated data.

Finally, studies of the more traditional theories of trade rarely look at the time-series patterns of trade flows. For instance, the excellent monograph by Leamer (1984) explicitly ignores dynamics of the type generated by product-cycle theories, while working with data aggregated to approximately the two-digit SITC level. Similarly, Deardorff's survey also contains few references to empirical work on the dynamics of trade patterns.

In this paper, we ignore a debate in the literature that is concerned with the reason why a product-cycle good is initially produced only in the rich country. Posner (1961) and Hufbauer (1966) argue that there is a "*technology gap*" between rich countries and poor countries, allowing only the former to build new goods; Grossman and Helpman (1991a,b) recently have provided a rigorous formalization of this notion (also see Krugman (1979) and Dollar (1990)). Hirsch (1967) argues that production of new goods requires large quantities of *skilled labor*, which is available only in rich countries; hence production of new goods does not migrate instantly to poor countries where production costs are lower. Vernon (1966) argues that comparative costs are essentially irrelevant, since new products can be developed only in proximity to large bases of sophisticated customers who constitute the *initial demand impetus*, although Vernon (1979) argues that product-cycle dynamics have accelerated considerably because of the proliferation of large multi-national corporations and the increased importance of raw materials costs. Our interest in this paper is the *existence*, rather than the *nature*, of product-cycle phenomena. In any case, the absence of (at the very least) disaggregated price and quantity data precludes a resolution of this issue; thus we mention the dispute only in passing.

**III: Data**

Our data are taken from the United Nations data base, and are disaggregated to the four-digit ("subgroup") level of Revision 1 of the Standard International Trade Classification (SITC) Index. The data are annual flows and span 1962 through 1988. For each category and year, the nominal dollar values of both imports and exports are available. For both Japan and the United States there are 507 categories of goods with non-zero trade flows for at least one year.[2] There are seven categories that do not overlap both countries.

Throughout the paper, we make an important assumption, namely that our choice of the subgroup level of aggregation is appropriate. That is, we assume that the subgroup corresponds to the theoretical concept of "a good" to which the product-cycle theory might apply. In this context, it is clear that more finely disaggregated data are always preferable to more aggregated data. To the best of our knowledge, a comprehensive data set that is more finely disaggregated than the SITC subgroup level is not available.[3] While it is possible to obtain more finely disaggregated data for a few specific goods, a data set that has mutually exclusive and jointly exhaustive categories is critical to our study, since we seek to quantify the *overall* importance of product-cycle (or other) dynamics. We also attempt to provide evidence indicating that our data correspond to economically meaningful categories.

The subgroup level is a much finer classification than the three-digit "group" level, which includes e.g.: 'electric power machinery and switchgear' (SITC code 722); 'equipment for distributing electricity' (723); and 'telecommunications apparatus' (724). Examples of subgroups include: 'television receivers' (7241); 'radio receivers' (7242); and 'telecommunications equipment, not elsewhere specified' (7249). While the two former subgroups may be reasonable product definitions, the latter subgroup obviously is not a conceptually well-defined product. Nevertheless, category 7249 may behave as a well-defined product empirically if it is dominated by one specific good. On the other hand, if category 7249 is composed of roughly equal volumes of two or more different goods, it will be difficult for us to detect product-cycle dynamics in those goods. That is, *aggregates* of goods that *individually* undergo product cycles can have virtually any time-series pattern.

Even if the subgroup is an economically meaningful definition of a good, data for a given subgroup may mask product-cycle developments within the subgroup due to differences in quality across producing countries or time. We assume that the quality of a given subgroup remains constant over time. Thus, we are not able to assess the importance of effects such as those recently modelled by Grossman and Helpman (1991a,b). Grossman and Helpman are concerned with a world in which the quality of a given good improves stochastically through time. In their model, developed countries produce and export the higher quality versions of a good and import the lower quality versions. The product cycle then proceeds for specific versions of the good, which are produced first in the developed countries and later in the developing countries. It does not seem possible to test or account for phenomena of this sort, at least comprehensively. By assuming away quality improvements, we implicitly follow earlier work by Grossman and Helpman (1989), and view a product cycle as beginning with the discovery of a new good that is never again changed and is an imperfect consumption substitute for goods that already exist.

Table I provides some descriptive statistics on American and Japanese trade flows in 1988. The data have been grouped together to the one-digit "section" level; brief descriptions of the ten sections are also provided. In addition, the number of subgroups within each section is tabulated, as is the average size of each subgroup's 1988 contribution to the total sectional volume of trade (which is also tabulated). For instance, the seventy-six subgroups in the food and live animal section each accounted on average for .09% of aggregate American trade (exports plus imports) in 1988; the section as a whole accounted in 1988 for 6.8% of aggregate American trade.

**Table I**: Descriptive Statistics, 1988 Trade

| SITC Codes | USA | | | Japan | | |
|---|---|---|---|---|---|---|
| Section | Number | Trade | | Number | Trade | |
| Description | Subgroups | Avg | Total | Subgroups | Avg | Total |
| Food, Live Animals (0xxx) | 76 | .09 | 6.8 | 76 | .10 | 7.6 |
| Beverages, Tobacco (1xxx) | 9 | .14 | 1.3 | 9 | .07 | .6 |
| Inedible Crude Materials (2xxx) | 86 | .06 | 5.2 | 89 | .09 | 8.0 |
| Fuels, Lubricants (3xxx) | 14 | .44 | 6.2 | 14 | .76 | 10.6 |
| Animal/Vegetable Oils (4xxx) | 13 | .02 | .3 | 13 | .01 | .1 |
| Chemicals (5xxx) | 34 | .22 | 7.5 | 34 | .17 | 5.8 |
| Manufactures (6xxx) | 149 | .07 | 10.4 | 149 | .10 | 14.9 |
| Machinery, Transport (7xxx) | 63 | .71 | 44.7 | 62 | .62 | 38.4 |
| Misc Manufactures (8xxx) | 59 | .20 | 11.8 | 57 | .22 | 12.5 |
| Other (9xxx) | 4 | 1.22 | 4.9 | 4 | .31 | 1.2 |

Normalization

It is well known that the value of international trade (including American and Japanese trade) has grown substantially over the period in question. This development is partly a result of inflation, partly a result of real economic growth, and partly a result of the growing importance of international trade relative to total output. In assessing the relevance of various theories of international trade, we would like to abstract from such trend effects in our empirical analysis.

Another serious complication must be taken into account in using the data. While both countries began the sample with almost balanced trade accounts, increasingly large aggregate trade deficits (for the United States) and surpluses (for Japan) became apparent towards the middle of the 1980s, declining only slightly by the end of the sample. Any *microeconomic* analysis of international trade data should take into account the fact that the data also reflect such important *macroeconomic* factors as the American savings and investment imbalance of the 1980s.

In our empirical analysis, we normalize the data using a procedure that takes account of trends in inflation, growth, and the relative importance of international trade, as well as macroeconomic imbalances. In particular, as a measure of the normalized trade balance of subgroup i at time t, we analyze:

$$NB_{it} = \left( \frac{X_{it}}{\Sigma_i X_{it}} - \frac{M_{it}}{\Sigma_i M_{it}} \right) * 100.$$

This normalization works well in a number of different ways. The cross-sectional sum (and hence average) of this normalized measure across all subgroups is zero at any given point in time. Inflation that affects all exports and imports (at possibly different rates), does not affect the level of NB. By dividing both exports and imports by their respective aggregates, the normalization also takes into account macroeconomic trade balance effects. For instance, holding exports constant, a 1% growth in imports spread uniformly across all goods will not affect the level of NB. As business cycles are known to have a profound impact on trade balances, we would like to be able to control for such effects.[4] Time-series plots of the normalized data, aggregated to the one-digit SITC level, are provided in Figures A1-A20 at the end of the paper.

For a variety of reasons, we are also interested in measurements of total trade volume. We choose a corresponding normalization to measure the importance of trade in subgroup i at time t:

$$NV_{it} = \frac{1}{2}*\left(\frac{X_{it}}{\Sigma_i X_{it}} + \frac{M_{it}}{\Sigma_i M_{it}}\right)*100.$$

This measure sums to 100 across all subgroups.

Intra-Industry Trade

Conventional measures of intra-industry trade are plotted in Figures 1 and 2. In particular, Figure 1 contains time-series plots of the average value of $1-|NB_{it}|/(2NV_{it})$.[5] Figure 2 contains the analogous measure with the average weighted by trade volumes. Large values of these measures are associated with a high degree of intra-industry trade. The measures are typically quite low (especially for Japan), indicating relatively little intra-industry trade. The American sample average is approximately .4, indicating that trade in one direction is four times the level of trade in the other direction for the typical subgroup. The American data indicate a moderate trend toward greater intra-industry trade.

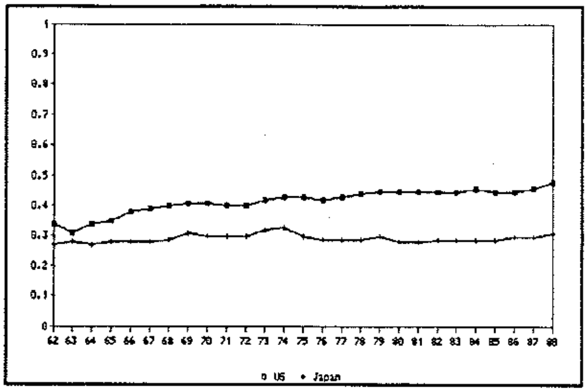


**Figure 1**: Intra-Industry Trade Measures

It is well-known that more finely disaggregated data show many fewer manifestations of intra-industry trade than more coarsely aggregated data (e.g., Deardorff (1984)). It is reassuring to us that our data are sufficiently disaggregated so as to eliminate a large portion of intra-industry trade. It is possible that the level of aggregation sufficient to eliminate most signs of intra-industry trade is also sufficient to expose product-cycle dynamics, if they exist. For instance, quality-ladder phenomena of the sort described by Grossman and Helpman (1991a,b) might be expected to be manifest in more widespread intra-industry trade.

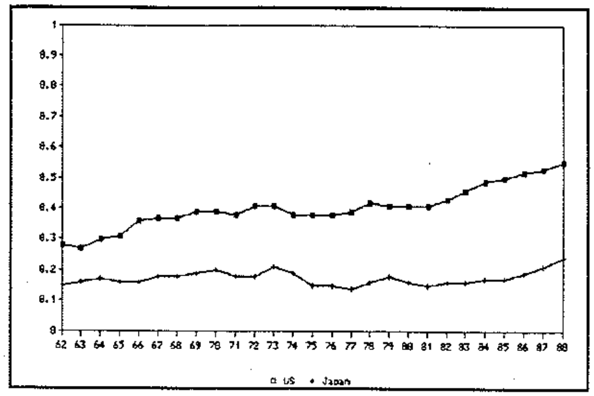


**Figure 2**: Weighted Intra-Industry Trade Measures

**IV: Results**

Some Theoretical Issues

This paper is an unabashedly empirical exercise; we do not pretend to make any theoretical contributions to the literature. Presentations of the factor-proportions theory are available in many sources, including Leamer (1984). The appendix to this paper presents a simple model of the product cycle taken from Krugman (1979); this model guides our empirical work. The reader is referred to Grossman and Helpman (1991a) for a lucid exposition of quality ladders and their relation to the product cycle.

Heuristically, we characterize a completed product cycle in a developed country as the following sequence of events affecting a single good: 1) the good begins its product cycle with a negligible trade balance; 2) it then enters a period of trade surplus; and 3) is followed by a period when the trade balance declines and goes into deficit. (In our analysis, we use a variety of different subsets of these restrictions.) We search for the presence of such cycles with a period greater than one year. We exclude as implausible and uninteresting the possibility that product cycles occur either within the span of a single year or over a span of more than thirty years. Our data may include a number of products whose cycles have been truncated at either the beginning or the end of our sample. Depending on the specific circumstances of the good whose product cycle is truncated, we may or may not identify the good as undergoing a product cycle.

In the case of a developing country, one would expect to find product cycles in mirror image to the above definition. In other words, the developing country would import the good first and export it only later. While the United States clearly is appropriately viewed as a developed country (over this period), it is more difficult to classify Japan. By many accounts, Japan began our sample as a developing country, although everyone would agree that it finished our sample as a developed country. If one accepts the description of Japan as a developing country in the 1960s and a developed country by the 1980s, then it is possible that Japan may have imported new goods in the 1960s and exported them in the 1980s.[6]

<u>Basic Results</u>

As a first approach to the data, we examine changes in the direction of trade between the beginning and end of our sample. Table II shows a breakdown of trade volume by initial (1962) and final (1988) levels of the trade balance.[7] In both 1962 and 1988, the SITC subgroups were classified into three categories: 1) those with a value of NB within one standard deviation of zero ("Balance"); 2) those with a value of NB greater than one standard deviation above zero ("Surplus"); and 3) those with a value of NB at least one standard deviation below zero ("Deficit"). The data tabulated are percentages of total 1988 trade volume; standard deviations are subgroup-specific.

**Table II**: Breakdown of Total 1988 Trade Volume

**United States**

| | 1988 Surplus | 1988 Balance | 1988 Deficit | Total |
|---|---|---|---|---|
| 1962 Surplus | 28.6 | 17.5 | 1.6 | 47.7 |
| 1962 Balance | 14.4 | 6.6 | 12.9 | 33.9 |
| 1962 Deficit | 0.6 | 8.3 | 9.5 | 18.4 |
| Total | 43.6 | 32.4 | 24.0 | 100.0 |

**Japan**

| | 1988 Surplus | 1988 Balance | 1988 Deficit | Total |
|---|---|---|---|---|
| 1962 Surplus | 10.1 | 7.4 | 4.3 | 21.8 |
| 1962 Balance | 34.0 | 6.3 | 14.7 | 55.0 |
| 1962 Deficit | 5.0 | 4.4 | 13.9 | 23.3 |
| Total | 49.1 | 18.1 | 32.9 | 100.0 |

Table II provides clear evidence of the persistence of trade flows. For instance, the subgroups that were in surplus in 1962 accounted for 47.7% of normalized American trade volume in 1988. Of these goods, subgroups accounting for only 1.6% of (1988) trade moved to deficit by 1988. Deficit categories show a similar amount of persistence; using 1988 weights, only 0.6% of total trade occurred in categories that began the sample in deficit and moved to surplus. For Japan, the numbers are not quite as striking, but the pattern is still clear. Only 4.3% of 1988 trade occurred in categories that moved from surplus into deficit, and 5.0% in categories that moved from deficit into surplus.

More rigorous statistical techniques also deliver the economic message of persistence in commodity-specific trade balances. Standard chi-squared tests reject (at better than the .01% confidence level) the hypothesis that categories ending in surplus (deficit) are distributed independently of those beginning in surplus (deficit). Similarly, the correlations (traditional or Spearman's rank measure) between the normalized trade balances in 1962 and 1988 are positive and significant for both countries.[8]

The trade flows that change direction are presented in Table III, which lists subgroups that moved from surplus to deficit, and vice versa, between 1962 and 1988. We list only subgroups that accounted for at least 0.25% of total 1988 trade volume. For the United States, the list is small and not particularly informative. For Japan, however, there are a number of categories and a clear pattern among them. The goods that move from surplus to deficit are all lower technology, labor-intensive goods. The goods that move from deficit into surplus are higher technology, capital-intensive goods. While these changes in trade flows may be indicative of product cycles, an alternative explanation is that they simply represent the maturation of Japan as a developed economy.

These results can be shown even more starkly. Figures 3 and 4 are histograms (of American and Japanese data respectively) that classify subgroups into cells indicating how many years the subgroup was in surplus.[9] For instance, a subgroup that was in surplus for each of the twenty-seven years would be in the cell at the extreme right of the histogram. These histograms are weighted by the volume of 1988 trade. The bimodality of both histograms is striking, indicating that most trade is accounted for by

**Table III**: SITC Subgroups with Changing Direction of Trade

**United States**

| SITC Subgroup | % of 1988 Trade Vol. | Product Definition |
|---|---|---|
| | | 1962 Surplus and 1988 Deficit |
| 7250 | 0.5% | domestic electrical appliances |
| 8930 | 0.6 | articles of plastic, n.e.s. |
| | | 1962 Deficit and 1988 Surplus |
| 5140 | 0.3 | other inorganic chemicals |
| 8960 | 0.6 | antiques and works of art |

**Japan**

| SITC Subgroup | % of 1988 Trade Vol. | Product Definition |
|---|---|---|
| | | 1962 Surplus and 1988 Deficit |
| 311 | 1.2% | fresh fish |
| 8411 | 0.8 | clothing of textile fabric |
| 8414 | 0.8 | clothing, knitted or crocheted |
| 8944 | 0.3 | outdoor sporting goods, except firearms |
| | | 1962 Deficit and 1988 Surplus |
| 7142 | 2.9 | calculators and computers |
| 7151 | 0.7 | machine tools |
| 7195 | 0.3 | powered tools, n.e.s. |
| 8619 | 0.7 | measuring and scientific instruments, n.e.s. |

categories in consistent surplus or deficit. (As unweighted histograms are quite similar, most categories are also in consistent surplus or deficit.)

The evidence marshalled thus far indicates a paucity of dynamics in the sense of trade balances of individual goods crossing zero. This constitutes strong prima facie evidence against pervasive product cycles. A closer examination of the data yields the same conclusion. For instance, 254 of the American categories (accounting for 48% of 1988 American trade) were in deficit in 1988. But only 139 categories (23% of 1988 trade) had been in surplus for at least one year in any of the preceding 26 years. Further, most of these trade imbalances were statistically insignificant. Only 21

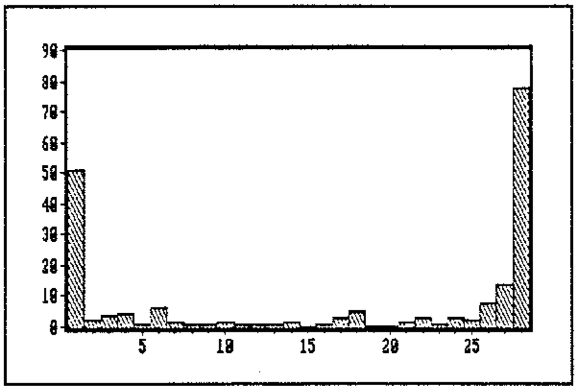


Figure 3: American data

categories accounting for 3% of 1988 trade had 1988 deficits that were at least one standard deviation from zero as well as at least one surplus in any preceding year that was also a standard deviation above zero. A comparable rule using two standard deviations in place of one does not yield any categories. The Japanese results are similar: 307 categories (45% of 1988 trade) were in deficit in 1988; 173 of these categories (18% of 1988 trade) also had an earlier surplus. Only 37 categories (5% of 1988 trade) had 1988 deficits/earlier surpluses that were at least one standard deviation from zero, and only a single category (with .02% of 1988 trade) satisfied the same criteria at the two standard deviation level.[10] These results seem robust; for instance, if the data are grouped into three-year non-overlapping averages instead of single years, the results are even stronger.

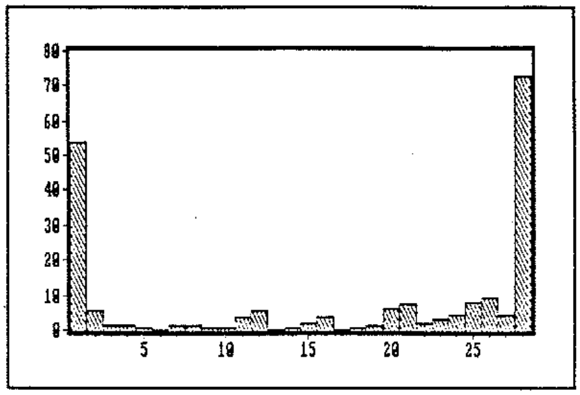


Figure 4: Japanese data

The trade balance of a good undergoing a product cycle can be expected: 1) to begin its life cycle insignificantly different from zero; 2) to be followed by a period of trade surpluses; 3) which are then succeeded by a persistent period of deficits. The evidence presented in this section indicates that even very loose subsets of these restrictions appear to be inconsistent with most trade flows, thereby seriously undermining the case for widespread product cycles.

Robustness

One of the attractive features of our study is that our data sets include all merchandise trade of the United States and Japan. We were also able to obtain a limited sample of data at the five-digit SITC level for the United States. This data set covered 47% of U.S. merchandise trade in 1988. The five-digit data contain a high degree of measurement error due to inconsistencies in the definition of product categories over time. Nevertheless, as one check on the robustness of our findings, we recomputed the breakdown of 1988 trade volume as in Table II using five-digit data. Less than 1% of total 1988 trade occurred in five-digit categories in which the direction of trade had changed significantly since 1962.

Many of the goods traded internationally are raw or intermediate inputs into the production process; this is especially true of the SITC codes in the 2000-4999 range. Over the sample, these goods typically account for 12% of American and 19% of Japanese trade. It seems unlikely that goods such as raw wool, iron ore, and crude petroleum would undergo a product cycle. However, these goods do experience very large relative price changes over the sample that cause their share of total trade to fluctuate dramatically. In the most extreme case, Japanese imports of crude petroleum moved from 5% of total trade in 1962 to 18% in 1980 and back to 5% in 1988. In order to focus on product cycles in manufactured goods and eliminate the effect of raw materials prices on total trade, we replicated the analysis of the previous section using SITC subgroups between 5000 and 8999. The trade balances in these subgroups were re-normalized using trade in manufactures only. None of our results were materially affected.

Although it is rare for subgroup trade balances to change sign, there are many subgroups whose trade balances moved significantly during the sample without crossing zero. Over 60% of total 1988 trade volume in both the United States and Japan was in subgroups whose 1988 NB measure was more than two standard deviations from the 1962 NB. In many instances, these subgroups represent goods that are popularly associated with product-cycle behavior.[11] For example, in both the United States and Japan, the semiconductor NB exhibits strong growth throughout the sample, while clothing NB's drop markedly. In other industries, such as passenger cars, a sustained decline in the American NB is matched by a sustained increase in the Japanese NB. We are not sure whether such behavior is evidence of product cycles or of more fundamental shifts in economic activity.[12] However, if one were to interpret this behavior as evidence of product cycles, then one would be forced to conclude that the lifetimes of these product cycles were in excess of 30 years.

We finish this section with one potentially important caveat. While average tariff levels in both the United States and Japan are relatively low, a number of goods are protected from international competition through either tariffs and quotas (e.g., in agriculture and textiles) or other non-tariff barriers (e.g., the Japanese Voluntary Export Restraint in automobiles). Protectionism may prevent or slow production migration of a product in the latter parts of its product cycle. As most trade in our sample is in categories that receive relatively little protection, we believe that our negative results on the product cycle are probably robust to such considerations. Nevertheless, this issue can be settled definitively only with the aid of disaggregated time-series data on effective rates of protection.

**V: Summary and Conclusion**

In this paper, we have analyzed data on international trade flows disaggregated to the four-digit SITC level for the United States and Japan. Our data reveal a striking absence of quantitatively important dynamics in trade balances of individual goods. In particular, almost all goods that were net exports (imports) of the United States in the early 1960s were still American net exports (imports) in the late 1980s; this sluggish behavior also characterizes the Japanese data. Indeed, it is rare to find any good whose trade balance changed significantly from net export to net import or vice versa at any time over the entire 27 years of our sample. This feature of the data is consistent with essentially static theories of international trade such as the standard factor-proportions theory. However, the pervasive sluggishness of trade flows seems to be inconsistent with technological theories of international trade that model goods as undergoing a product cycle. We conclude that product-cycle phenomena are essentially unimportant in aggregate trade flows.

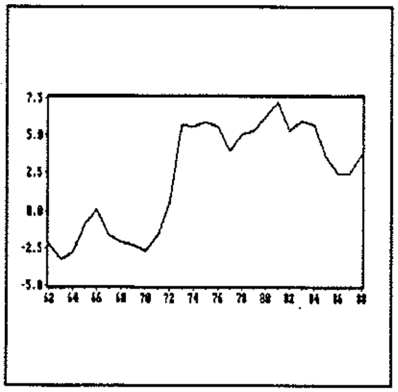

Figure A1: American 0xxx

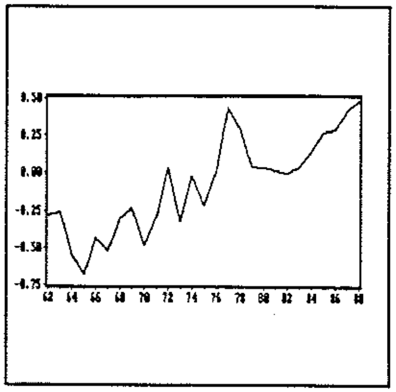

Figure A2: American 1xxx

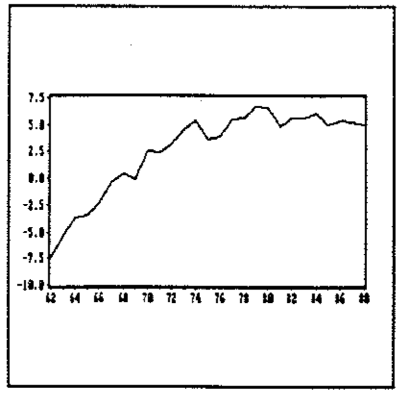

Figure A3: American 2xxx

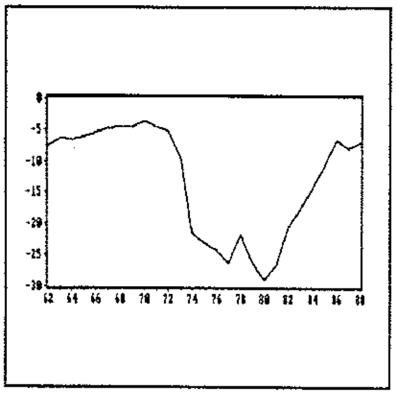

Figure A4: American 3xxx

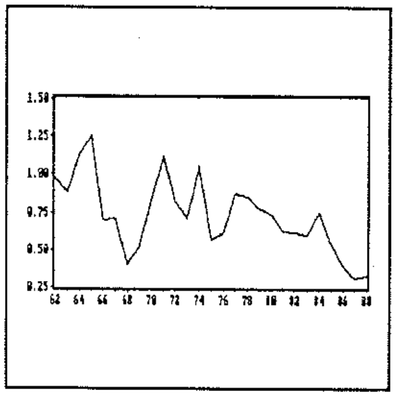

Figure A5: American 4xxx

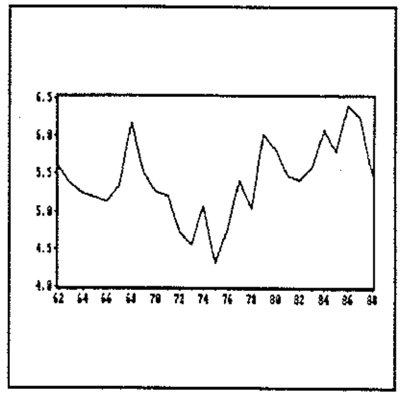

Figure A6: American 5xxx

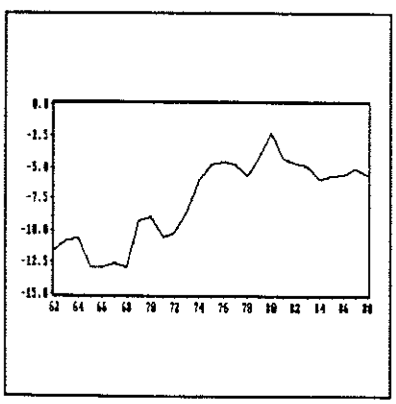

Figure A7: American 6xxx

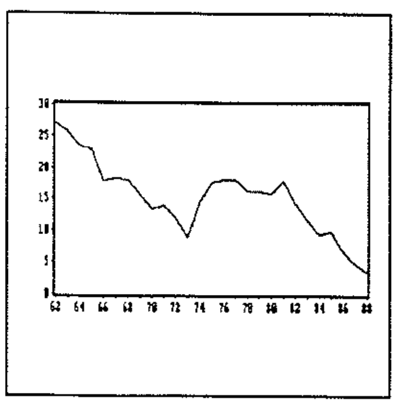

Figure A8: American 7xxx

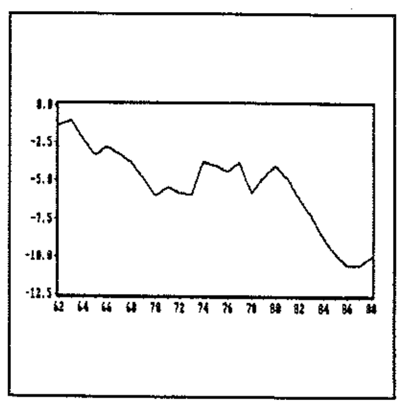

Figure A9: American 8xxx

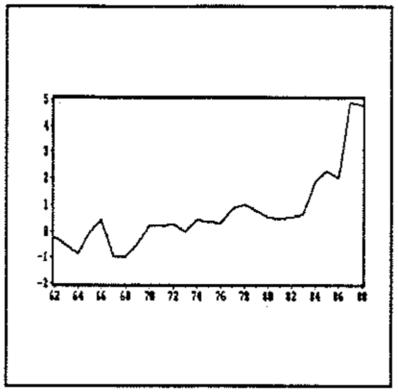

**Figure A10**: American 9xxx

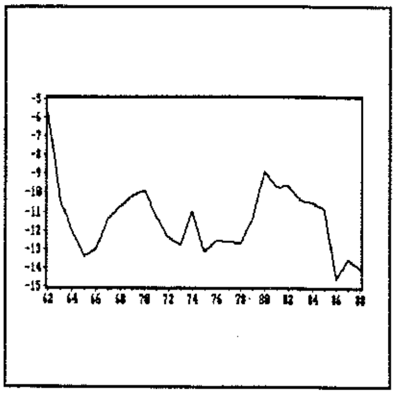

**Figure A11**: Japanese 0xxx

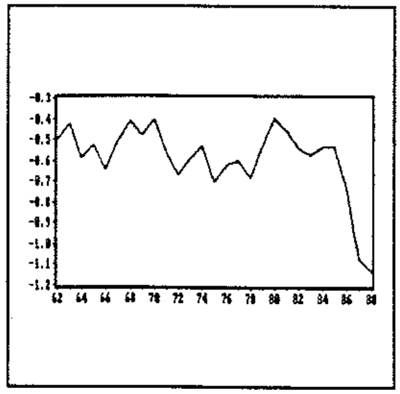

**Figure A12**: Japanese 1xxx

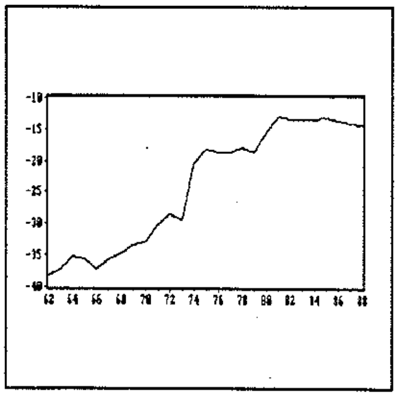

**Figure A13**: Japanese 2xxx

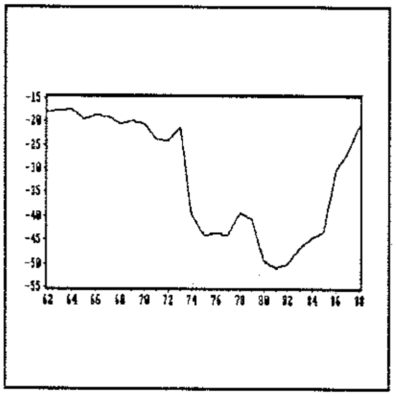

**Figure A14**: Japanese 3xxx

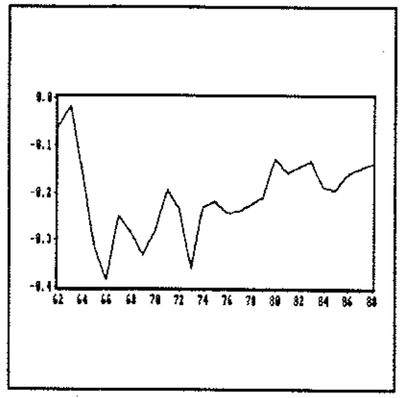

**Figure A15**: Japanese 4xxx

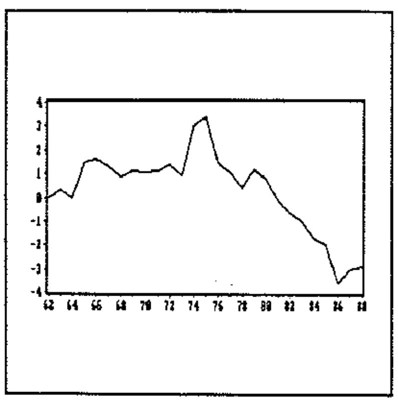

**Figure A16**: Japanese 5xxx

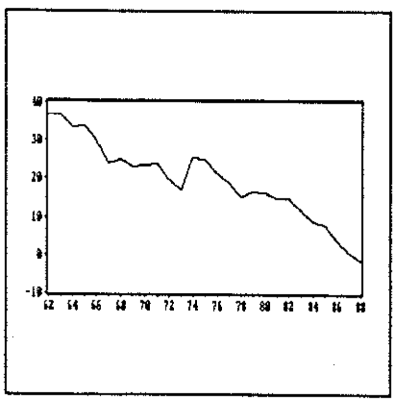

**Figure A17**: Japanese 6xxx

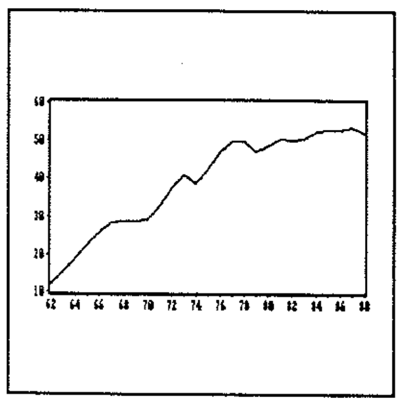

**Figure A18**: Japanese 7xxx

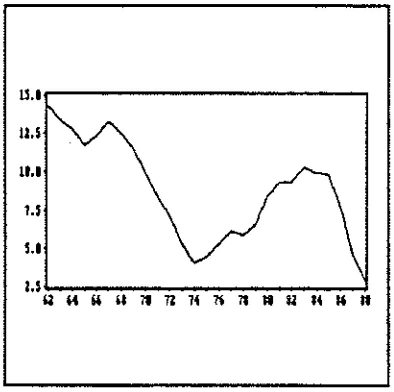


Figure A19: Japanese 8xxx

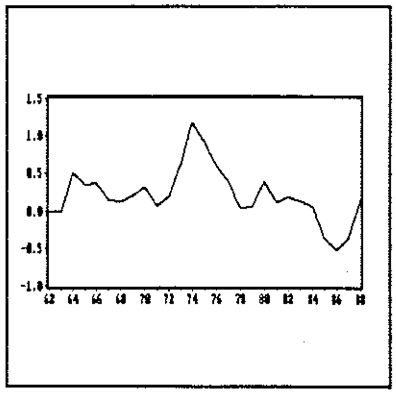


**Figure A20**: Japanese 9xxx

**Appendix**

This appendix explores the implications of Krugman's (1979) model of the product cycle for the time-series behavior of trade in individual goods. The fundamental assumptions of the model are: 1) consumers value variety in the goods they consume; 2) producers are continually inventing new varieties of goods; 3) the ability to invent new goods is restricted to a subset of all countries (the "developed" countries); and 4) the remaining countries learn how to produce new goods only after a substantial time lag. For simplicity, Krugman further assumes that all goods enter symmetrically in the utility function and that consumers always consume at least a small amount of every good that is available. He also assumes that only one factor is used in production and that all goods require the same amount of this factor. Finally, Krugman takes the rates of innovation and technology transfer as exogenous.

We define $U_t$ as the utility function of the representative agent for period t, and $c_t(i)$ as the period t consumption of good i. Then the essence of the model is given by equations (A1) through (A4).

$$(A1)\quad U_t = \left\{\sum_{i=1}^{n_t} c_t(i)^{\theta}\right\}^{\frac{1}{\theta}}, \qquad 0 < \theta < 1$$

$$(A2)\quad n_t = n_t^N + n_t^O$$

$$(A3)\quad \dot{n}_t = \phi n_t$$

$$(A4)\quad \dot{n}_t^O = \tau n_t^N$$

Equation (A1) presents a simple "Dixit-Stiglitz" utility function incorporating a taste for variety in a symmetric fashion. Because $\theta$ is strictly less than 1, consumers always consume some of each good; utility increases with the number of goods, $n_t$. Equation (A2) defines the number of goods available as the sum of the number of new goods, $n^N$, and the number of old goods, $n^O$. New goods can be produced only in the developed countries; old goods can be produced either in the developed countries or in the developing countries. Equation (A3) states that the total number of goods increases at a constant geometric rate. Equation (A4) states that technology transfer from the developed to the developing countries is proportional to the technology gap between the two groups of countries, as quantified by the number of new goods.

Since the number of available goods is continually increasing, the steady state of the model is expressed in terms of the ratio of $n^N$ to n. Defining $\sigma \equiv n^N/n$, equations (A2-A4) may be rearranged into a differential equation for $\sigma$, which is presented in equation (A5). This differential equation is stable, and its steady-state solution is given by equation (A6).

$$(A5) \quad \dot{\sigma}_t = \phi - (\phi + \tau)\sigma_t$$

$$(A6) \quad \sigma = \frac{n^N}{n} = \frac{\phi}{(\phi + \tau)}$$

Figure A21 presents the typical time-series pattern of the trade balance of the developed country for an individual good. The moments when the good is introduced is random, as is the moment when the good's technology is transferred. Immediately after invention, the good is produced only in the developed country, which exports some of its production. When the technology is transferred to the developing country, production ceases in the developed country, which then begins to import the good. The trade balance approaches 0 asymptotically because the growing number of goods available means that less is consumed of each particular good.[13]

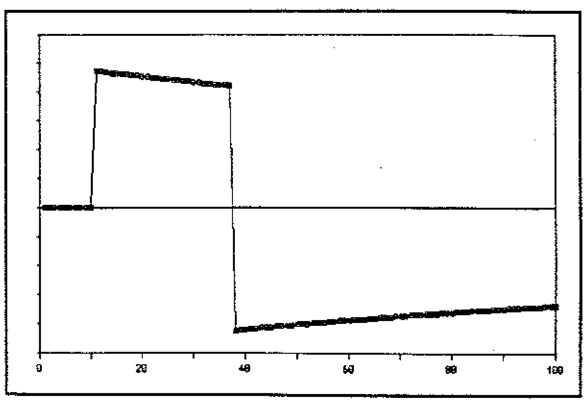

**Figure A21**: Trade Balance of a Product-Cycle Good in Krugman's Model

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## Endnotes

1. More recent theories stress the importance of economies of scale and product differentiation in trade; e.g., Grubel and Lloyd (1975) and Helpman and Krugman (1985). When such characteristics are important, countries tend to export and import different varieties of the same good, a phenomenon referred to as "intra-industry trade." As is the case with the factor-proportions theory, the theory behind intra-industry trade is static in nature and has few implications for dynamic patterns in trade flows. More importantly, intra-industry trade theory generates predictions of high volume, balanced trade at the level of individual goods. The focus of this study is on trade balances of individual goods; non-zero trade balances cannot be the result of pure intra-industry trade.

2. The original data included 625 categories of American trade flows. However, in a number of these categories the data were not defined consistently throughout the sample. For example, four-digit SITC categories distinguish five different thicknesses of steel plate. American customs forms did not conform to the SITC criteria until 1978. To obtain a consistent time series we were forced to add the five categories into one category. This problem was much less severe for the Japanese data, but we combined the corresponding Japanese categories in order to maintain comparability across the two countries.

3. Strictly speaking this is not true; data are available at the ten-digit "HS" (tariff) level, but only from 1989. Prior to 1989 the most finely disaggregated data available are seven-digit "TSUSA" (tariff) data. However, the definitions of the TSUSA categories are not consistent over time and change frequently. Further, the data are available only for imports; exports are reported on an incompatible basis that is more aggregated. Five-digit "end-use" data exist only from 1978. Moreover, the end-use data are less finely disaggregated than our SITC data; there are only 290 five-digit end-use categories. We thank: Kathryn Morisse and Charles Gilbert of the Federal Reserve Board; Howard Murad of the Bureau of Economic Analysis; and Hayden Merkle of the Census Bureau for sharing their knowledge of the data with us.

4. In practice, our results are not sensitive to macroeconomic imbalances. For example, we experimented with another normalization, $(X_{it}-M_{it})/\Sigma_i(X_{it}+M_{it})$, that does not control for macroeconomic trade balance effects, and none of our substantive conclusions were affected.

5. That is, $1-(1/N)\Sigma_i(|NB_{it}|/2NV_{it})$, where $N = 507$.

6. For this reason, we do not analyze bilateral Japanese-American data.

7. Similar results are obtained if one uses averages of the first three and last three years in place of 1962 and 1988 data. The results are also similar if one compares the first nine years to the last nine years.

8. Also, Kolmogorov-Smirnov tests for both the American and Japanese data decisively reject the hypothesis of identical 1988 distributions of trade balances independent of whether the 1962 balance was in surplus or deficit.

9. Unlike Tables II and III, Figures 3 and 4 do not require the trade balance to be more than one standard deviation from zero. Observations with a trade balance of exactly zero are counted as .5, which tends to shift categories toward the center of the histogram, thereby reducing signs of bi-modality and persistence.

10. This discussion treats both Japan and the United States as developed countries and searches for goods transferred to developing countries. It may also be interesting to treat Japanese trade flows as mirror images to those for the United States. 179 Japanese categories (55% of 1988 Japanese trade) were in surplus in 1988; 77 (19% of 1988 trade) also had an earlier deficit. Using a "one standard deviation rule" (as in the text), yields 12 categories (7% of 1988 trade) with significant surpluses preceding final deficits; a two standard deviation rule excludes all categories.

11. Positively trending American subgroups with at least a 1% share of total 1988 trade volume include: organic chemicals; semiconductors; and special transactions not classified according to kind. The associated American subgroups with negative trends are: pharmaceuticals; internal combustion engines; electrical switchgear; telecommunications apparatus n.e.s.; passenger cars; trucks and buses; and clothing of textile fabric. Japanese subgroups with positive trends include: internal combustion engines; calculators and computers; copiers and printers; electrical switchgear; telecommunications apparatus n.e.s.; semiconductors; passenger cars; trucks and buses; and record and tape players. Finally, the Japanese subgroups with downward trends are: fresh fish; fresh shellfish; refined petroleum products; and unwrought aluminum.

12. In many goods the trends in NB are matched by corresponding trends in NV, representing a change in the importance of that good in total trade. For example, American coffee imports were 6% of total imports in 1962 and declined steadily to 0.5% by 1988. This shift represents a decline in the value of coffee consumption relative to total consumption, rather than a product-cycle phenomenon.

13. This analysis assumes that the developed countries specialize in the production of new goods. If the productive capacity of the developed countries relative to the developing countries is greater than $\phi/\tau$, then the developed countries will produce some of the old goods as well as all of the new goods. In this case some new goods will not move into a trade deficit even after their technology is acquired by the developing countries. However, since new goods are continually being invented by the developed countries and exported to the developing countries, it must be the case that the production and export of some goods are transferred to the developing countries. In any event, most researchers have found the regime in which developed countries specialize in new goods to be more plausible since it implies that returns to productive factors are higher in the developed countries.

December 9, 1991

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