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# **How Long Are Product Cycles?**

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# How Long Are Product Cycles?

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(Preliminary)

**Abstract:** In this paper I identify new goods in U.S. imports data at the product levels of 7-digit TSUSA or 10-digit HS codes. I show that consistent with product cycles, the North's new goods exports relative to old goods exports grow faster than the South's, and then the South catches up with the North. The catch-up takes 13 ~ 18 years and happens in the 1990s, an age of globalization and outsourcing. Since the double difference includes old goods exports within the same 4-digit mSIC industry as controls, the evidence is not tainted by the myriad forces that also affect the North's and the South's new goods exports. Importantly, I find these results only when new goods are properly identified. When I assign new goods and old goods randomly in the data the evidence for product cycles goes away.

**Keywords:** new goods; product cycles; double difference.

**JEL Classification:** F1, O3.

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## 1 Introduction

Four decades after Vernon (1966)'s seminal paper, it is hard to find an economist who does not know about product cycles, an intriguing pattern of trade for new goods: when new goods are created, they are first produced and exported by the North; later they get produced and exported by the South. Is there empirical evidence that product cycles are at work?

Product cycles are also an important channel for Northern innovations to move to the South, either through Southern imitation (Grossman and Helpman 1991), licensing (Yang and Maskus 2001), vertical integration (Antras 2005), or other channels. In today's age of globalization and outsourcing (e.g. Grossman and Helpman 2005), the North's ability to maintain a high standard of living is more dependent on its ability to continuously innovate and invent than ever before. If product cycles are long, the North enjoys a comfortable lead in technology and there is no imminent threat to its higher-than-average living standards; if the product cycles are short, however, the North's position is more precarious. How long are product cycles?

There is a large and well-established theoretical literature on product cycles following Vernon (1966),<sup>1</sup> and some product cycle models, such as Grossman and Helpman (1991), are now standard issue to the troop of economists. Although different models highlight different channels through which product cycles operate, they all predict that new goods are first produced and exported by the North, and then by the South. This suggests that the empirical work of product cycles should compare the trade patterns of the North with those of the South over time.

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<sup>1</sup> See Krugman (1980), Dollar (1986), Flam and Helpman (1987), Segerstrom et al. (1990), Stokey (1991), Glass (1997) and Theonig and Verdier (2004).

Yet the North-South comparison alone is insufficient for identifying product cycles, because many forces other than product cycles affect the North's and the South's trade patterns differently. The rate of economic growth, pace of trade liberalization, change in fixed trade costs and factor-based and technology-based comparative advantages may all differ between the North and the South. The unique feature of product cycles among these forces is that the dynamics in trade patterns predicted by product cycles is for new goods, and only for new goods. Thus product cycles have differential impacts on the trade patterns of new goods and old goods within finely dis-aggregated industries. If the other forces mentioned above affect new goods and old goods within the same industry symmetrically, they can be controlled for by the additional new-goods-old-goods comparison. This additional comparison is meaningless, of course, unless new goods are identified. Therefore, identifying new goods is vital to identifying product cycles.

An early line of empirical work on product cycles typically shows correlations between measures of export performance (e.g. net exports) and measures of innovation and new goods (e.g. R&D intensity) and is loosely related to theory (Deardorff 1984). More recently, Cantwell (1995) looks at the creation and citation of patents and Gagnon and Rose (1995) look at whether a U.S. industry switches from being a net importer to being a net exporter. Both studies report evidence against product cycles. Feenstra and Rose (2000), however, look at the order at which a good is exported to the U.S. and report evidence consistent with product cycles. While these studies all examine issues related to product cycles, they do not identify new goods and so do not control for such forces as economic growth, fixed trade costs and trade liberalization. To quote Feenstra

and Rose (2000), “we are not certain which model of the product cycle best characterizes the data---if indeed there is any evidence of a product cycle at all”.

In this paper I identify new goods in U.S. imports data at the product levels of 7-digit Tariff Schedule of the United States of America (TSUSA) or 10-digit Harmonized System (HS) codes. Using these data I construct the double (log) difference of the South’s new goods exports (to the U.S.) relative to old goods, relative to the North’s new-goods-old-goods relative exports within the finely dis-aggregated industries of 4-digit import Standard Industrial Classification (mSIC) codes. If, initially, the new goods spread faster to the North than to the South, the South’s new goods exports (relative to old goods exports) grow more slowly than the North’s, and the double difference declines; if, later, the South catches up with the North, the opposite happens and the double difference increases. Thus the U-shape of the double difference is evidence for product cycles. Furthermore, since the double difference includes old goods exports within the same industry as controls, the evidence is not tainted by the myriad forces that have differential impacts on the North’s and the South’s trade patterns but the same impact on the trade patterns of new goods and old goods within the same finely dis-aggregated industry (e.g. economic growth, fixed trade costs, trade liberalization, etc.). Finally, the distance between the bottom of the U-shape and the initial period provides a measure of the length of product cycles.

To preview the empirical results, presented in section 4, I find strong evidence that the double difference has the U-shape, and that the double difference reaches the bottom of the U-shape in 13 ~ 18 years. Relative to old goods exports within the same industry, the South’s new goods exports grow more slowly than the North’s new goods exports for

a period of 13 ~ 18 years, and then the South catches up with the North and the South's new goods exports grow faster. Importantly, I find these results only when new goods are properly identified. When I assign new goods and old goods randomly in the data the evidence for product cycles goes away.

The paper is organized as follows. Section 2 discusses the double differencing strategy. Section 3 explains the data construction. Section 4 presents the empirical results and Section 5 concludes.

## 2 The Double Differencing Framework

To motivate the empirical work, consider the monopolistic competition framework of Krugman (1979). The preferences have two tiers. The upper tier is Cobb-Douglas between industries  $k = 1 \dots K$ . For a given industry  $k$ , the lower tier preferences are constant elasticity of substitution (CES)  $[\sum_l (\alpha_l x_l)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$ , where  $l$  indexes varieties,  $\alpha_l$  and  $x_l$  are the taste parameter and quantity of consumption for variety  $l$ , and  $\sigma$  is the substitution elasticity.

There three two countries. The North and the South both export differentiated products (varieties) to the U.S. in many industries. All the variables with superscripts “\*” pertain to the South.

At time 0, there is no new good, and an equilibrium prevails in which the North and the South export old varieties (goods) to the U.S. All the old goods within an industry are symmetric. At time 1, a given set of new goods are created in some industries. The new goods within an industry are also symmetric. For one of these industries  $k$ , at time  $t \geq 1$ ,

the U.S. imports  $m_{ntk}$  and  $m_{ntk}^*$  new goods from the North and the South.  $m_{ntk}$  and  $m_{ntk}^*$  may be some or all of the new goods created.

Denote the U.S. expenditure on industry  $k$  by  $E_{tk}$  and the CES price index of  $k$  by  $P_{tk}$ .  $\alpha_{ntk}$  is the taste parameters for the new goods.  $p_{ntk}$  and  $p_{ntk}^*$  are the delivery prices (inclusive of variable trade costs) of new goods imported from the North and from the South. Then the North's and South's new goods exports to the U.S.,  $N_{ntk}$  and  $S_{ntk}$ , are

$$N_{ntk} = \alpha_{ntk} \frac{m_{ntk} p_{ntk}^{1-\sigma}}{P_{tk}} E_{tk}, \quad S_{ntk} = \alpha_{ntk} \frac{m_{ntk}^* (p_{ntk}^*)^{1-\sigma}}{P_{tk}} E_{tk}. \quad (1)$$

The delivery prices are

$$p_{ntk} = c_{tk} e_t b_{tk} d_{tk}, \quad p_{ntk}^* = c_{tk}^* e_t^* b_{tk}^* d_{tk}^*, \quad (2)$$

where  $c_{tk}$  and  $c_{tk}^*$  are the Northern and Southern marginal production costs of new goods,  $e_t$  and  $e_t^*$  are the North's and South's exchange rates,  $b_{tk}$  and  $b_{tk}^*$  are their markups, and  $d_{tk}$  and  $d_{tk}^*$  are their (variable) trade costs.

In addition to product cycles, many other forces affect the North's and South's new goods exports in the data. For example, as the South's size grows over time, the South will export a larger number of new goods, according to the monopolistic competition model (e.g. Krugman 1979). Alternatively, if technology reduces fixed trade costs, both the North and the South will also export larger numbers of new goods, according to a Melitz (2003) type framework. Another scenario is that more and more Southern countries liberalize their trade over time, either unilaterally or in multilateral agreements. As trade restrictions are removed, the South will export a larger number of new goods. Yet another plausible story is that over time, because of economic growth and technology progress, the composition of the South's factor endowments and the distribution of the South's productivities across industries may both change relative to the U.S. Then the

South will export a larger number of new goods in some industries and a smaller number of new goods in other industries, according to the Heckscher-Ohlin and Ricardian models. Thus it is difficult to find evidence for product cycles by looking at the North's and the South's new goods exports alone, or comparing the North's new goods exports with the South's new goods exports.

The search for the evidence of product cycles becomes feasible, however, if we compare the North's and the South's new goods exports with their old goods exports within narrowly defined industries. The South's new goods exports rise as the South grows in size or as the fixed trade costs fall, but so do the South's old goods exports. As long as the new goods exports and old goods exports grow at the same rate, change in country size and fixed trade costs do not affect the new goods exports relative to old goods exports. The South's new goods exports increase as the South liberalizes, but so do the South's old goods exports. As long as the liberalization does not bias in favor of or against the new goods within narrowly defined industries, trade liberalization does not affect the new-goods-old-goods relative exports within such industries. The South's new goods exports may increase in some industries and decrease in others following changes in factor-based or technology-based comparative advantage patterns, but so will the South's old goods exports of these very same industries. As long as the changes in (factor-based and technology-based) comparative advantage patterns are driven by between-industry shifts, they do not affect the new-goods-old-goods relative exports within narrowly defined industries. In contrast, while the North exports a larger number of new goods at the beginning of a product cycle, it does not export a larger number of old goods. Likewise, while the South's new goods exports pick up steam at a later stage

of a product cycle, its old goods exports do not do so. Therefore, comparing the new goods exports with the old goods exports within narrowly defined industries is vital for the identification of product cycles in the data.

The North's and South's old goods exports to the U.S. in industry k are analogous to equation (1)

$$N_{otk} = \alpha_{otk} \frac{m_{otk} p_{otk}^{1-\sigma}}{P_{tk}} E_{tk}, \quad S_{otk} = \alpha_{otk} \frac{m_{otk}^* (p_{otk}^*)^{1-\sigma}}{P_{tk}} E_{tk}, \quad (3)$$

and the expressions for the delivery prices,  $p_{otk}$  and  $p_{otk}^*$ , are analogous to equation (2).

Then the new goods exports relative to old goods exports for the North is

$$\ln \frac{N_{ntk}}{N_{otk}} = \ln \frac{\alpha_{ntk}}{\alpha_{otk}} + G_k(t), \quad G_k(t) = \ln \frac{m_{ntk}}{m_{otk}}. \quad (4)$$

The log difference between the North's new goods exports and old goods exports sweeps out the U.S. expenditure, the U.S. CES price index and the exchange rates, all of which could be changing over time and important determinants of U.S. imports. It also removes industry level variable trade costs ( $d_{tk}$ ), markups ( $b_{tk}$ ) and marginal costs ( $c_{tk}$ ).<sup>2</sup> Finally, it controls for the many forces (other than product cycles) that affect the North's new goods exports, such as changes in country size and fixed trade costs, trade liberalization and factor-based and technology-based comparative advantage patterns. As long as these forces affect the new goods and old goods within a given industry,  $m_{ntk}$  and  $m_{otk}$ , symmetrically, they are removed by the log differencing and does not affect the North's

*relative* new goods exports within industry k,  $\ln \frac{N_{ntk}}{N_{otk}}$ .

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<sup>2</sup> Product cycles might also work by reducing the marginal costs of new goods relative to old goods. This is indistinguishable from the other channels through which product cycles work, such as the diffusion process discussed later, and so can be collapsed into  $G_k(t)$  and does not affect the analysis. What are removed by the log differencing are the components of marginal costs that new goods and old goods of industry k have in common.

Analogous to equation (4), the South's new goods exports relative to old goods exports are

$$\ln \frac{S_{ntk}}{S_{otk}} = \ln \frac{\alpha_{ntk}}{\alpha_{otk}} + G_k^*(t), \quad G_k^*(t) = \ln \frac{m_{ntk}^*}{m_{otk}^*}. \quad (5)$$

If the taste parameters for new and old goods are the same for the North and for the South, as is the case in equations (4) and (5), they will be removed by the second log differencing between the North's relative new goods exports and the South's relative new goods exports

$$\ln \frac{S_{ntk}}{S_{otk}} - \ln \frac{N_{ntk}}{N_{otk}} = G_k^*(t) - G_k(t). \quad (6)$$

This second differencing also helps formalize the implication by the product cycles theory. Consider first the following comparative static scenario. At time 1, a set of new goods are created (no more new goods are created after time 1). All the other goods produced at time 1 are old goods. The creation of these new goods sets in motion a diffusion process (e.g. Trajtenberg and Yitzhaki 1989) for the numbers of Northern and Southern new goods,  $m_{ntk}$  and  $m_{ntk}^*$ : at each subsequent time period  $t > 1$ , it is a probabilistic event that the North and the South acquire the ability to export a given new good. This implies that the Southern new goods exports could be positive from the very beginning of the product cycle, time 1, unlike in some stylized product cycle models (e.g. Krugman 1980). This also implies that the North might not export all of the new goods at time 1. Furthermore, the probability to acquire a new good is higher for the North initially, but becomes higher for the South eventually. That is to say, the new goods spread faster to the North initially and the North's new goods exports (relative to old goods exports) grow faster than the South's. Eventually, at, say, time T, the South catches

up with the North and the South's new goods exports (relative to old goods exports) grow faster than the North's. Let a ' denote the derivative with respect to time.

**The Product Cycle Hypothesis**  $G'_k(t) > G_k^{*'}(t)$  before T and  $G'_k(t) < G_k^{*'}(t)$  after T; i.e.

the double difference,  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$ , traces out a U-shape over time and reaches its bottom at T.

The Product Cycle Hypothesis can also be motivated by the following dynamic scenario. Suppose that in the data, we get to observe the introduction of new goods in the window of time  $[1, t_1]$ , during which new goods may be introduced at every time period  $t \geq 1$ . The new goods created at time  $t_0$  are acquired by the North (in most cases) or the South (in some cases) at  $t_0 \geq 1$ , and then during  $t > t_0$ , the South gradually acquires the North's vintage  $t_0$  new goods (due to Southern imitation, licensing, international knowledge spillover, etc). We cannot distinguish the vintages of new goods; i.e. at  $t = 2$ , we observe the vintages 1 and 2, and at  $t = 3$ , we observe the vintages 1 ~ 3, etc. However, we can distinguish the set of new goods created during  $[1, t_1]$  from the set of old goods, those already in production at time 1. Then for the double difference,  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$ , initially, the North's advantage in acquiring new goods dominates and the North's new goods exports (relative to old goods exports) grow faster. Later, after  $t = T$ , the spillover effect to the South dominates and the South's new goods exports (relative to old goods exports) grow faster.

In some stylized product cycle models (e.g. the quality ladder model of Grossman and Helpman 1991), all the old goods are replaced by new goods in a short period of time. What the Product Cycle Hypothesis needs is that all the old goods do not disappear so

that they can be used as controls in the double difference. When the Product Cycle Hypothesis is taken to the data, if the old goods are defined as those that are not new goods, they may include the new goods introduced after the window  $[1, t_1]$ . I discuss this issue in sections 3 and 4. In some other stylized product cycle models (e.g. Flam and Helpman 1987), new goods are produced only in the North. As the North acquires new goods and its new goods exports increase, some old goods that the North used to produce automatically move to the South so that the North's old goods exports decrease and the South's old goods exports increase. This makes the difference between new goods exports and old goods exports even more prominent. Finally, in Vernon's (1966) original formulation, the product cycles theory features three tiers of countries: new goods appear in the U.S. first, then in other Northern countries and then in the South. Most product cycle models, though, feature only two tiers of countries, the North and the South. The Product Cycle Hypothesis holds up in both scenarios. The exact way of modeling product cycles does not affect the analysis as long as different models and different channels through which product cycles work are all consistent with the Product Cycle Hypothesis.

A straightforward way to take the Product Cycles Hypothesis to the data is to pool across all the industries that have new goods and estimate

$$\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right) = \beta_k + \gamma_1 t + \gamma_2 t^2 + \varepsilon_{notk}, \quad (7)$$

where  $\beta_k$  represents industry fixed effects. If the double difference,  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$ ,

indeed has the U-shape, then  $\gamma_2 > 0$  and  $\gamma_1 < 0$ . The bottom of the U-shape  $T = -\frac{\gamma_1}{2\gamma_2}$ ,

and its standard error can be calculated by the delta method (Greene 1997) using the covariance matrix of  $\gamma_1$  and  $\gamma_2$ . I take up the issue of functional forms in section 4.

### **3 Data**

To implement regression (7) I employ product level data on new goods for U.S. manufacturing imports over the period 1972 ~ 2001. The construction of this data set took two years of intensive work. I start with the data on the identities of new goods put together by Xiang (2005). Briefly speaking, the new goods are identified by comparing the product listings of the manufacturing industries in the 1987 Standard Industrial Classification (SIC) manual with those in the 1972 SIC manual. Take the industry “drawing and insulating of nonferrous wire” as an example. The 1972 SIC manual defines this industry by a list of nine products (e.g. “coaxial cable, nonferrous” and “magnetic wire, insulated”). This list becomes longer in the 1987 SIC manual and consists of the original nine entries plus five new entries (e.g. “cord sets, flexible: made in wiredrawing plants” and “fiber optic cable”). Xiang (2005) collects such new entries for every manufacturing industry and then identifies the 825 new entries whose names do not resemble that of any 1972-SIC-manual entry.<sup>3</sup>

These new entries (SIC manual new goods henceforth) represent the manufacturing products newly produced in the U.S. sometime between 1972 and 1987. Since there is demand for them by the U.S., the U.S. will also import them from the countries that produce them, as long as the substitution elasticity between domestic goods and foreign goods is finite. As discussed in section 2, I can identify product cycles by tracing the U.S.

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<sup>3</sup> This list is available at <http://www.krannert.purdue.edu/faculty/cxiang/ng-name-list.xls>. For more details, see Xiang (2005).

imports of these new goods from the North and the South over time and comparing them with the U.S. imports of old goods from the North and the South.

For the next step, I match the names of these SIC manual new goods to the descriptions of the product level codes in the U.S. import data of Feenstra et al. (2002). The U.S. import data have U.S. imports by product by source country for 1972 ~ 2001. For 1972 ~ 1988, the product level codes are 7-digit Tariff Schedule of the United States of America (TSUSA). For 1989 ~ 2001, the codes are 10-digit Harmonized System (HS). For example, the SIC-manual new good “rowing machines” is matched to “exercise rowing machines”, TSUSA 7352055 and HS 9506910020. The product level codes that are not matched to any SIC manual new goods are old goods.

I focus on the descriptions of the codes rather than the codes themselves because it is not unusual for the codes assigned to a given description to change from year to year. For example, “dolls nes up to 13 inches” is TSUSA 7372025 for 1978 but 7372225 for 1979 ~ 1982. Thus the only way to consistently track a product over time is by its description, not by its code (Feenstra 1996). On the other hand, the descriptions contain many abbreviations such as “pts o non-psto g t e e a/c” (parts of non-piston gas-turbine engines ...), TSUSA 6607165, and “chips, dice + wafers - semicon”, TSUSA 6878510. This forces me to examine the description of every product level TSUSA and HS code. For a small number of SIC-manual new goods I am able to find clues about their (10-digit) HS codes by searching the Customs Rulings Online Search System (CROSS) database of the U.S. Customs and Border Protection (USCBP). CROSS contains some of the product-classification rulings by the USCBP headquarter and New York office from 1989 to present.

Some SIC-manual new goods represent service or non-tradable activities whose counterparts I am unable to find in the trade data, such as “Research and development on aircraft engines and engine parts by the manufacture”. They are dropped from the data. Also dropped are the product level codes that correspond to too many new and old SIC manual goods for me to track, such as “parts and accessories for electro-diagnostic apparatus”, HS 9018199560. They account for 1.4% and 2.1% of the observations for the product-level TSUSA and HS data, respectively. The third category of observations that I drop consists of the product level codes specifically for the imports subject to quota or from a given source country, such as “computers (spc prclm, japan 100% dty,ts 676.1530,eff 4/17/87)”, TSUSA 9458330, and “elec furnacs, heatrs a ovens nes, a pts, canadian artcl apta”, TSUSA 6844100. They account for 0.18% and 0.13% of the observations for the product-level TSUSA and HS data, respectively. Finally, the product level codes are assigned to 4-digit 1987 import SIC (mSIC) industries.<sup>4</sup> Since the SIC manual new goods are all manufactured goods, I keep only the manufacturing mSIC industries, the industries whose 1987 mSIC codes start with 2 or 3. Among the 399 4-digit mSIC industries 243 have positive values of new goods trade for at least one year. See the Data Appendix for more details of this step.

The data on new goods may be subject to measurement errors due to misclassification: some product level codes that are old goods might be classified as new goods, and vice versa. However, the classification errors affect the product level codes themselves, whether the products these codes represent come from the North or from the

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<sup>4</sup> The mSIC classification system is a close cousin of the SIC classification system for domestic production. The main difference is that in the cases where the SIC system classifies activities by process, the mSIC system does not. See Feenstra (1996) and Feenstra et al. (2002) for more details.

South.<sup>5</sup> Thus the differencing between the North's relative new goods exports and the South's relative new goods exports helps control for this issue. To be specific, suppose the classification errors take the multiplicative form. Then the expressions for the North's and South's relative new goods exports become

$$\ln \frac{N_{ntk}}{N_{otk}} = \ln \frac{\alpha_{ntk}}{\alpha_{otk}} + G_k(t) + \ln u_{notk}, \quad \ln \frac{S_{ntk}}{S_{otk}} = \ln \frac{\alpha_{ntk}}{\alpha_{otk}} + G_k^*(t) + \ln u_{notk}. \quad (8)$$

If the classification errors,  $u_{notk}$ , are the same for the North and the South, as is the case in equation (8), they are removed from the expression for the double difference,  $\ln\left(\frac{S_{ntk}/N_{ntk}}{S_{otk}/N_{otk}}\right)$ , and do not affect regression (7). I also experiment with additional robustness exercises in section 4.

For the next step, I designate a non-U.S. country as a Northern country if its average real per capita GDP for the period 1972 ~ 1996 is more than \$7000. The per capita GDP data come from Penn World Tables 5.6. 31 countries fall into this category and their names are listed in the Data Appendix. The other countries are Southern countries. Then for a given 4-digit mSIC industry with positive new goods trade, I aggregate across product level codes and across Northern and Southern countries to calculate the Northern and Southern exports of new and old goods,  $N_{ntk}$ ,  $S_{ntk}$ ,  $N_{otk}$  and  $S_{otk}$ . The aggregation is necessary because product cycle models compare between tiers of countries. Theory predicts that new goods appear in the North first, but not in *which* Northern country. Likewise, theory predicts that new goods move to the South later, but not to *which* Southern country. Thus we may observe in the data that cell phones are first produced in Japan or Germany or Finland and later move to Indonesia or Malaysia or Poland. All are

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<sup>5</sup> Some codes are specifically for the imports from a given source country and they are dropped from the data, as discussed in the previous paragraph.

consistent with theory. In addition, product level trade data by country are notoriously noisy (e.g. GAO 1995, Schott 2004) and the aggregation helps alleviate this problem.

Then I calculate the double difference,  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$ . Because the double difference is

not defined when new goods are exported by the North only (i.e.  $N_{ntk} > 0$  but  $S_{ntk} = 0$ ) and such observations contain useful information, I also calculate the double difference

alternatively as  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}} + 1\right)$ .<sup>6</sup> Table 1 shows the summary statistics. Either way to

calculate the double difference produces similar results.

The last thing to do before estimating regression (7) is to decide on a starting year and Figure 1 illustrates the importance of doing so. At time -1, there is no new good; thus in theory the double difference is not defined, but due to white noise the data are likely to offer us a number for the double difference. Likewise, at time 0, there is no new good, and the double difference observed in the data is pure noise. Then new goods appear at time 1 and suppose from time 1 onwards, product cycles are at work and the double difference has the U-shape. If we start at time 1, we will have no problem picking up the U-shape. However, if we start at time -1, we will see the double difference increase first before it traces out the U-shape. The noises in the data at time -1 and 0 may lead us to incorrectly conclude that there is no evidence for product cycles.

The new goods I have identified are newly produced in the U.S. sometime between 1972 and 1987 and it is unclear when they start to be exported by the Northern countries to the U.S. To help pick the starting year I tabulate the year-of-first-use of the 7-digit

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<sup>6</sup> Both ways to calculate the double difference drop the observations for which  $N_{ntk} = S_{ntk} = 0$ . Since new goods have not yet emerged in these cases, such observations should be dropped (see also Figure 1 and the discussions about the starting year).

TSUSA codes in Table 2. The year-of-first-use is the first year in which a 7-digit TSUSA code shows up in the data. The TSUSA data start in 1972 and so not surprisingly, there is a spike in 1972: many TSUSA codes have 1972 as their year of first use. The next spike comes in 1978, followed by 1980, 1982, 1985 and 1986. While new TSUSA codes may get introduced for a variety of reasons, the series of spikes starting in 1978 is consistent with the wave of new goods exports to the U.S. arriving in 1978. In addition, the trade data for 1972 ~ 1977 might be more noisy than those for the other years for two reasons (Feenstra 1996). One, extensive changes were made to the 1977 data because the raw data stored on tapes contained many mistakes. Two, the descriptions of the codes were not included in the raw 1972 ~ 1977 data and had to be added manually. Therefore 1978 is likely to be a better starting year than 1972. I also experiment with using 1972 as the starting year and obtain similar results.

A related question is, what is the ending year? Since I define the old goods in the trade data as those that do not correspond to any SIC manual new good, the farther away are the data from 1987, the more likely do the “old goods” in the trade data include the new products introduced after 1987. I tabulate the year-of-first use of the 10-digit HS codes in Table 3. Since the HS data start in 1989, not surprisingly there is a big spike in 1989 and a small spike in 1990. The next spike shows up in 1994, followed by 1995 and 1996. While this series of spikes may represent the new products introduced after 1987, it may also be the continuation of the wave of new goods exports that started in 1978. It is also interesting that while 30% of TSUSA codes are used in the first available year of 1972, 61% of HS codes are used in the first available year of 1989. This might suggest

that new goods are more important for U.S. imports in 1978 ~ 1988 than in 1989 ~ 2001. Thus it is unclear whether 1993 is a better ending year than 2001 and so I use both.

#### 4 Results

Table 4 reports the results of regression (7). Since time and time square do not vary across industries I use robust standard errors that accommodate cross-industry correlations in the error term within a given year (the “cluster” option in STATA). To make a cleaner presentation Table 4 reports 100 times the coefficient of time square and 100 times its standard deviation. The industry fixed effects are included in all columns.

Column 1 uses industry trade values as weights and is for the period 1978 ~ 2001. The weighting is used because the observations with low trade values are more likely to be prone to measurement errors. One concern with the weighting is that trade values also vary over time, but an analysis of variance shows that 97% of the variation in trade

values is cross-section. The dependent variable is  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}} + 1\right)$ . The coefficients of

time and time square are -0.20 and 0.0056, respectively, and both are statistically significant. This shows that the double difference has a U-shape, consistent with the Product Cycle Hypothesis. This also implies that the bottom of the U-shape, T, is reached about 17.69 years after 1978, or in 1994-1995. The standard error of T is calculated using the delta method (Greene 1997) as 0.81 and so T is statistically significant. It is intuitive that in 1994-1995, a time of globalization and outsourcing (e.g. Feenstra and Hanson 1996, Grossman and Helpman 2002, 2005), the South catches up with the North in terms of the growth of new goods exports (relative to old goods exports) to the U.S.

Columns 2 ~ 5 are variations of the specification of column 1. Column 2 reports the

un-weighted regression results and they are very similar to Column 1. The bottom of the U-shape, T, is a significant 15.76. Column 3 uses  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$  as the dependent variable and again, the results are very similar to Column 1, with T being a significant 16.78. I also experimented with using  $\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}$  as the dependent variable and obtained similar results. Column 4 uses 1978 ~ 1993 as the sample period. The coefficients of time and time square have the expected signs and are both significant, and T is shorter at 12.97 (significant) due to a shorter sample period. This puts T in the year 1990. Column 5 uses 1972 ~ 2001 as the sample period. Again, the results are qualitatively similar with T being longer at 24.27 (significant) due to a longer sample period. This puts T in the year 1995.

So far the evidence has been consistent with the Product Cycle Hypothesis. Because such evidence hinges on the proper identification of new goods, it follows that if new goods had *not* been properly identified there would have been *no* evidence for the Product Cycle Hypothesis. To verify this I perform the following exercise. First, I randomize the designations of new goods and old goods within each industry. Second, I estimate regression (7) for the sample with randomly designated new goods and old goods, using industry trade values as weights and 1978 ~ 2001 as the sample period. Finally, I repeat steps one and two 1000 times and obtain 1000 estimates of the coefficients of time and time square as well as the bottom of the U-shape, T. Column 6 reports the average time and time square coefficients and T, as well as their standard errors, for these 1000 regressions. The time and time square coefficients are essentially zero (-0.000079 and 0.0000064, respectively) with standard errors 4.3 and 1.9 times their

sizes while T stands at 12.27 with the enormous standard error of 7724. As expected, there is no evidence for product cycles when new goods are randomly designated.

Columns 7 ~ 11 are robustness exercises that use the specification of column 1. Columns 7 and 8 address the possible measurement errors in the identities of new goods. About 20% of 7-digit TSUSA codes identified as new goods have 1972 as their year-of-first-use (the corresponding percentage is 31% for old goods), and some of them might be old goods. To address this concern I calculate the ratio of the number of TSUSA codes that are identified as new goods and have 1972 as their year-of-first-use to the total number of TSUSA codes by industry and examine the distribution of this ratio across industries. The 80<sup>th</sup> and 90<sup>th</sup> percentiles of the distribution are 0.04 and 0.14, respectively. I then drop all the industries above the 90<sup>th</sup> percentile and re-run regression (7). Column 7 reports the results and they are very similar to column 1. I also experimented with dropping all the industries above the 80<sup>th</sup> percentile and obtained qualitatively similar results.

Some product level codes represent military products and so their trade is likely to be heavily regulated, such as “self-propelled guns, howitzers, and mortars...”, HS 9301009408. Some product level codes identified as old goods may in fact be new goods introduced after 1987, such as “videophones”, HS 8517194000. Some product level codes are designated as new goods based on their unit values or whether they are new or used and such designations may be more prone to measurement errors. Examples include “drilling machines, metal removing, multiple spindle ... valued \$3025 and over, new”, HS 8459290040 and “drill mac mtlwork new single spin ex nc upright, \$2500 & ov”, TSUSA 6743236. I drop all these product level codes and re-run regression (7). Column

8 reports the results and they are very similar to column 1.

I also experiment with different designations of Northern and Southern countries. First, I drop the six oil producing countries (see the Data Appendix for their names) from the set of Northern countries and re-estimate regression (7). Column 9 reports the results and they are very similar to column 1. Then, I use the average per capita GDP of \$10000 instead of \$7000 as the cutoff for Northern countries. This reduces the number of Northern countries to 24 (see the Data Appendix for their names). Column 10 reports the results and they are very similar to column 1. Finally, one may be concerned that the results are driven by the free-trade agreement with Mexico in 1994. Column 11 reports the results of dropping Mexico, and they are very similar to column 1.

The results reported in Table 4 are all based on the regression specification (7). However, the Product Cycle Hypothesis implies only that the double difference has the U-shape, not that it has the specific functional form prescribed in (7). To address this concern I perform non-parametric regressions for the average double difference<sup>7</sup> on time using the “lowess” command in STATA (Deaton 1997). As compared with the parametric estimation (7), the non-parametric estimation does not impose a specific functional form on the data, nor does it produce point estimates of the parameters of interest (e.g. the bottom of the U-shape, T) with standard errors. Thus the parametric and non-parametric estimations are complementary.

Figure 2 plots the average double difference,  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}} + 1\right)$ , across industries, weighted by industry trade values, against time for 1978 ~ 2001. Also shown are the predicted values of the double difference by the parametric and non-parametric

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<sup>7</sup> It is hard to perform non-parametric regressions in a panel setting with industry fixed effects.

estimations. The solid curve is generated by the parametric estimation used in column 1 of Table 4. The dashed curve is generated by the non-parametric estimation with the bandwidth of 0.6.<sup>8</sup> The average double difference declines initially, reaches the bottom around 1990, and then rises afterwards, clearly showing a U-shape. The non-parametric curve follows the data more closely than the parametric curve and reaches the bottom around the year 1990, whereas the parametric curve bottoms out around 1995. However, the shape of the non-parametric curve is still consistent with the Product Cycle Hypothesis. Figure 3 shows the scatter plot, the solid parametric curve and the dashed non-parametric curve for 1978 ~ 1993. The parametric curve is generated by the results of column 4 in Table 4 and the non-parametric curve also has the bandwidth of 0.6.<sup>9</sup> The non-parametric and parametric curves are now very close to one another and both bottom out around 1990.

Summarizing the results of this section, there is strong evidence for product cycles. The North's new goods exports relative to old goods exports grow faster than the South's new goods exports relative to old goods exports for 13 ~ 18 years starting in 1978, and then the South catches up with the North. The results are robust to alternative starting and ending years, different definitions of new and old goods, alternative designations of Northern countries and different functional forms of the regression specification. On the other hand, the results hold up only when new goods are properly identified; when new goods and old goods are randomly designated there is no evidence for product cycles.

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<sup>8</sup> The non-parametric estimation performs a weighted local polynomial regression at every data point using all the other data points in the neighborhood, and the bandwidth specifies the size of the neighborhood. Larger bandwidths produce smoother estimates (and so follow the data less closely) and the choice of bandwidth is trial-and-error in applied work. See Deaton (1997) for more discussions. I also experimented with the bandwidths of 0.4 and 0.8 and the results are qualitatively similar.

<sup>9</sup> Again, using the bandwidths of 0.4 and 0.8 produces qualitatively similar results.

## **5 Conclusion**

In this paper I construct product-level U.S. import data for new goods and show that consistent with product cycles, the North's new goods exports relative to old goods exports grow faster than the South's new goods exports relative to old goods exports, and then the South catches up with the North. The catch-up takes 13 ~ 18 years and happens in the 1990s, an age of globalization and outsourcing.

## Data Appendix

When the description of a product level code, B, matches both SIC manual new goods and SIC manual old goods (those entries in the 1987 SIC manual that are not new goods), I first search for all the SIC manual goods, new and old, that match the description of code B. I then assign a fraction of code B to new goods and the rest to old goods, the fraction being equal to the number of SIC manual new goods matched to B divided by the total number of SIC manual goods matched to B. For example, “electrical carbon and graphite articles...”, HS 8545904000, matches both “fibers, carbon and graphite”, a SIC manual new good, and “carbon specialties for electrical use”, a SIC manual old good. Half of HS 8545904000 is assigned to new goods.

Before running regression (7) I drop the following categories of observations. One, I drop the observations that show up in the data before their year-of-first-use and those that show up after their year-of-last-use. The year-of-first(last)-use is the first (last) year that a product level code appears in the data. They account for 1.1% and 1.2% of the observations in the product-level TSUSA and HS data, respectively. Two, I drop the product level codes that are not assigned to any 4-digit 1987 mSIC industry. They account for 6.1% and 0.67% of the observations in the product-level TSUSA and HS data, respectively. Three, I drop the 19 4-digit 1987 mSIC industry codes that end in “ZZ” (e.g. 20ZZ, 22ZZ). These are not real industries but catch-all categories for the product level codes that cannot be assigned to a real mSIC industry (Feenstra 1996). Four, I drop the nine 4-digit mSIC industries that have less than 5 years of data. I have experimented with keeping the observations in categories 2 ~ 4 above and obtained similar results.

The average real per capita GDP between 1972 and 1996 is over \$7000 but below \$10000 for Venezuela, Ireland, Germany East, Spain, Israel, Singapore and Trinidad & Tobago, and over \$10000 for Saudi Arabia, Italy, The Bahamas, Bahrain, New Zealand, Austria, Hong Kong, United Kingdom, Finland, Iceland, Belgium, Japan, Netherlands, France, Denmark, Germany (West), Norway, Sweden, Australia, Kuwait, Switzerland, Canada, Qatar and United Arab Emirates. The oil-producing countries are Venezuela, Saudi Arabia, Bahrain, Kuwait, Qatar and United Arab Emirates.

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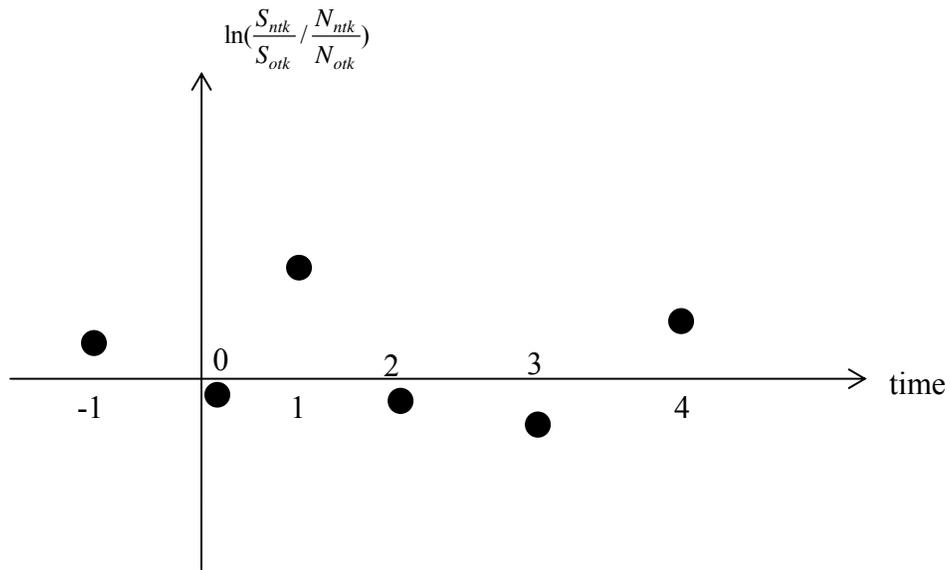


Figure 1 Picking the Starting Time

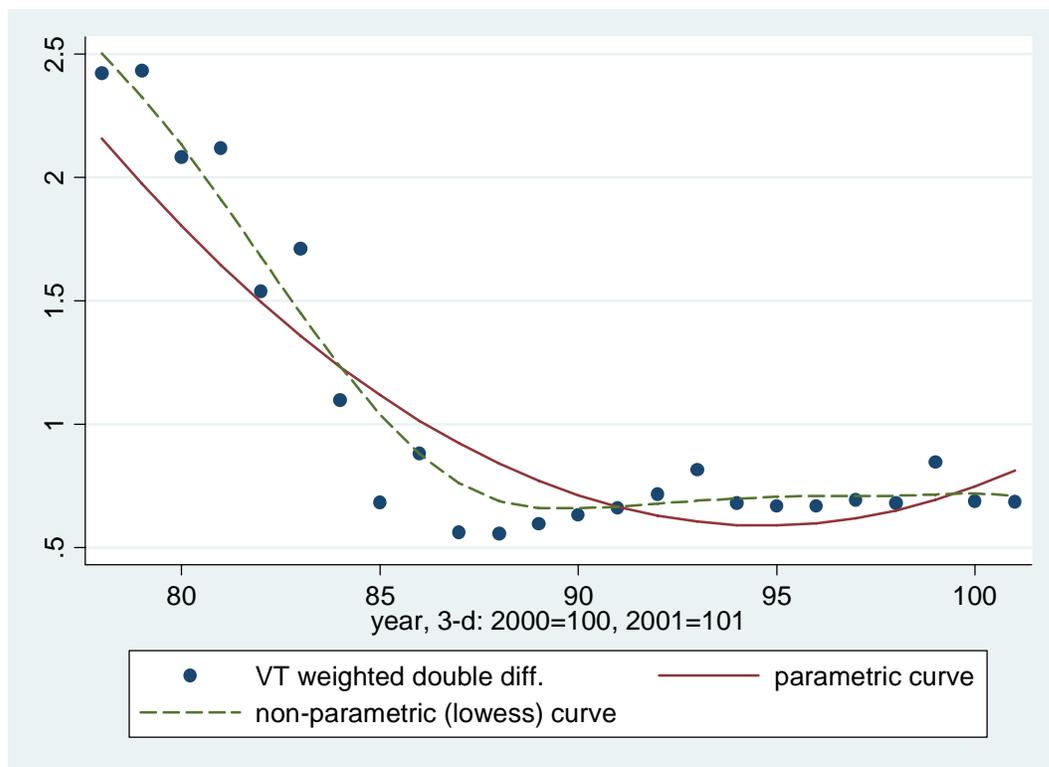


Figure 2 Non-parametric and Parametric Estimations, 1978 ~ 2001

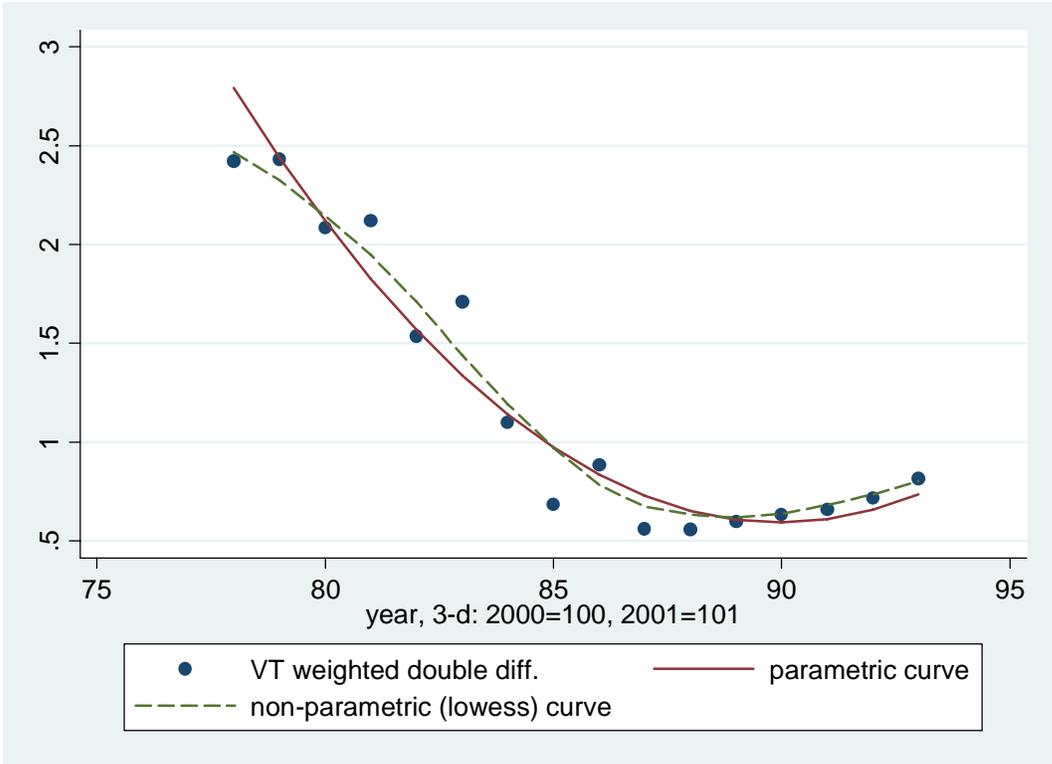


Figure 3 Non-parametric and Parametric Estimations, 1978 ~ 1993

Table 1 Summary Statistics

Variable	Obs	Mean	Std.	Min	Max
ln(Southern New Goods Exports)	4484	14.765	3.241	3.491	23.910
ln(Southern Old Goods Exports)	5224	17.672	2.692	5.889	24.091
ln(Northern New Goods Exports)	4608	16.228	2.693	3.768	23.407
ln(Northern Old Goods Exports)	5275	18.814	2.080	5.737	25.360
$\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}} + 1\right)$	4546	0.737	0.809	0.000	8.997
$\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$	4438	-0.390	1.685	-10.627	8.997

Notes:  $S_{ntk}$  represents Southern exports of new goods to the U.S.,  $S_{otk}$  represents Southern exports of old goods to the U.S.,  $N_{ntk}$  represents Northern exports of new goods to the U.S and  $N_{otk}$  represents Northern exports of old goods to the U.S.

Table 2 Tabulation of Year-of-first-use for TSUSA Codes

Year-of-first-use	Frequency	Percentage	Cumulative Percentage
72	6897	29.95	29.95
73	481	2.09	32.04
74	399	1.73	33.77
75	485	2.11	35.88
76	517	2.25	38.12
77	548	2.38	40.5
78	2459	10.68	51.18
79	272	1.18	52.36
80	1601	6.95	59.32
81	287	1.25	60.56
82	1110	4.82	65.38
83	229	0.99	66.38
84	566	2.46	68.84
85	5713	24.81	93.65
86	972	4.22	97.87
87	305	1.32	99.19
88	186	0.81	100
Total	23027	100	

Notes: The TSUSA codes are at the 7-digit level and used in the U.S. imports data for 1972 ~ 1988. Year-of-first-use is the year in which a TSUSA code first appears in the data.

Table 3 Tabulation of Year-of-first-use for HS Codes

Year-of-first-use	Frequency	Percentage	Cumulative Percentage
89	12809	60.96	60.96
90	1124	5.35	66.31
91	630	3	69.3
92	386	1.84	71.14
93	390	1.86	73
94	1138	5.42	78.41
95	2010	9.57	87.98
96	1423	6.77	94.75
97	619	2.95	97.7
98	121	0.58	98.27
99	87	0.41	98.69
100	128	0.61	99.3
101	148	0.7	100
Total	21013	100	

Notes: The HS codes are at the 10-digit level and used in the U.S. imports data for 1989 ~ 2001. Year-of-first-use is the year in which a HS code first appears in the data.

Table 4 Results of Regression (7)

	1	2	3	4	5	6	7	8	9	10	11
Time	-0.199	-0.017	-0.305	-0.398	-0.183	-0.000079	-0.246	-0.200	-0.201	-0.194	-0.208
	<i>0.032</i>	<i>0.006</i>	<i>0.048</i>	<i>0.036</i>	<i>0.046</i>	<i>0.000339</i>	<i>0.042</i>	<i>0.032</i>	<i>0.032</i>	<i>0.028</i>	<i>0.033</i>
Time <sup>2</sup> × 100	0.562	0.055	0.908	1.534	0.376	0.000642	0.691	0.565	0.573	0.537	0.599
	<i>0.102</i>	<i>0.021</i>	<i>0.163</i>	<i>0.163</i>	<i>0.101</i>	<i>0.001197</i>	<i>0.132</i>	<i>0.103</i>	<i>0.103</i>	<i>0.085</i>	<i>0.112</i>
Constant	2.350	0.846	1.829	3.173	2.854		2.778	2.357	2.357	2.329	2.482
	<i>0.252</i>	<i>0.041</i>	<i>0.326</i>	<i>0.209</i>	<i>0.516</i>		<i>0.334</i>	<i>0.253</i>	<i>0.247</i>	<i>0.228</i>	<i>0.231</i>
Length T	17.69	15.76	16.78	12.97	24.27	12.27	17.80	17.70	17.52	18.11	17.39
	<i>0.81</i>	<i>1.41</i>	<i>0.75</i>	<i>0.44</i>	<i>1.04</i>	<i>7724.11</i>	<i>0.82</i>	<i>0.81</i>	<i>0.78</i>	<i>0.65</i>	<i>0.88</i>
Adj. R <sup>2</sup>	0.514	0.524	0.537	0.486	0.494		0.519	0.515	0.537	0.571	0.546
No. Observation	4546	4546	4438	2800	5093		3027	4517	4547	4554	4543

Notes: Column 3 uses  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}}\right)$  as the dependent variable and all the other columns use  $\ln\left(\frac{S_{ntk}}{S_{otk}} / \frac{N_{ntk}}{N_{otk}} + 1\right)$ . Column 2 is not

weighted and all the other columns are weighted by industry trade values. Column 4 is for 1978 ~ 1993, column 5 is for 1972 ~ 2001 and all the other columns are for 1978 ~ 2001. The standard errors are in italics and robust to cross-industry correlations within a given year (the “cluster” option in STATA). See the text for the explanations of the results in each column.