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Effects of Terms of Trade Gains and Tariff Changes on the Measurement of U.S. Productivity Growth*

Robert C. Feenstra
University of California-Davis and NBER

Marshall B. Reinsdorf
U.S. Bureau of Economic Analysis

Matthew J. Slaughter
Tuck School of Business at Dartmouth and NBER

Michael Harper
U.S. Bureau of Labor Statistics

For additional information please contact:

Marshall B. Reinsdorf
U.S. Bureau of Economic Analysis
Marshall.Reinsdorf@bea.gov
202-606-5366
202-606-9665
This paper is posted on the following websites: http://www.iariw.org

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1. Introduction

Since 1995, growth in aggregate labor productivity in the United States appears to have accelerated markedly. The U.S. Bureau of Labor Statistics (BLS) reports that from 1973 to 1995, output per worker hour in the nonfarm business sector grew on average at just 1.4 percent per year. From 1995 through 2004 this rate accelerated to an average of 3.1 percent per year.[1]

It is widely acknowledged that the rate of productivity growth is the single most important determinant of a country's overall economic performance. In his famous work on the previous generation's productivity slowdown, Krugman (1990, pp. 9-13) put it this way.

> Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker … the essential arithmetic says that long-term growth in living standards … depends almost entirely on productivity growth … Compared with the problem of slow productivity growth, all our other long-term economic concerns—foreign competition, the industrial base, lagging technology, deteriorating infrastructure, and so on—are minor issues. Or more accurately, they matter only to the extent that they have an impact on our productivity growth.

This perspective on the centrality of productivity growth has also been endorsed by a number of policymakers, perhaps most prominently Federal Reserve Chairman Alan Greenspan.[2]

The sheer magnitude of the speed-up in U.S. productivity growth will, if sustained, carry dramatic implications for the U.S. economy. At the previous generation's average annual growth rate of 1.4 percent, average U.S. living standards were taking 50 years to double. Should the current average annual growth rate of 3.1 percent persist, then average U.S. living standards will take just 23 years to double—over a generation faster.

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[1] These calculations are based on BLS data series identification #PRS85006092, as reported on-line for historical data at www.bls.gov and, for recent years, in the June 2, 2005 Data Release, "Productivity and Costs: First Quarter 2005, Revised."

[2] In remarks before the Independent Community Bankers of America, Honolulu, Hawaii, March 13, 2002, Chairman Greenspan stated that, "the nation's fortunes, to a very great degree, depend on the evolution of the growth of productivity … It is structural productivity growth that determines how rapidly living standards rise over time. Productivity growth is an unmitigated good for the large majority of the American people.

This is one reason why studies of the sources of economic growth often focus on labor productivity. A common procedure is first to separate this productivity growth rate into contributions from increased capital intensity and from multifactor productivity growth (MFP), and then to study factors contributing to each of these, such as contributions of specific types of capital, contributions of changing work force composition, and contributions of MFP growth in specific industries. Many sources of growth may be identified, and although they may often seem small, a contribution of one or two tenths of a percent to the annual growth rate of labor productivity can be quite significant if sustained over a period of years.

In recent years a number of researchers have investigated the speed-up in US labor productivity growth, finding that has been accompanied by an acceleration of MFP.[3] Researchers also have been examining whether the acceleration has been broadly enjoyed across many industries or concentrated in certain sectors.[4] Much of this body of research has reached a common conclusion: the information-technology (IT) sector is at the core of the boom in aggregate productivity. The consensus from a range of academic studies is that about one-third of the acceleration in aggregate labor productivity has been accounted for by faster growth in MFP in the *production* of IT goods and services. About another third has accounted for by greater *use* of IT capital and services throughout the economy.

Quality-adjusted prices for many IT products have been falling for decades, but after 1995 many of these price declines accelerated. Faster IT price declines have been widely interpreted as evidence of faster MFP growth. Indeed, many studies use industry price changes as a proxy for industry MFP growth without fully considering the effects of price changes of inputs,

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[3] The BLS publishes measures of MFP for the private business sector. Using a new system to produce preliminary measures, the BLS found TFP grew 3.1 percent in 2003 and 3.3 percent in 2004, rates which were very high by historical standards and which account for much of the rapid labor productivity growth in those years. See Meyer and Harper (2005).

[4] Prominent studies include Baily and Lawrence (2001), Bosworth and Triplett (2000), Gordon (2000, 2003), Jorgenson (2001), Jorgenson and Stiroh (2000a,b), Nordhaus (2001, 2005), and Oliner and Sichel (2000, 2002).

particularly—as we shall see—of imported intermediate inputs.[5] These falling IT prices have also been identified as the link from IT-producing firms to IT-using firms. For example, Jorgenson (2001, p. 22) finds that, “In response to these [IT] price changes, firms, households, and governments have accumulated computers, software, and communications equipment much more rapidly than other forms of capital.”

An alternative explanation for these IT price movements, and by implication for the apparent acceleration in productivity that has been inferred from them is gains in the U.S. terms of trade, especially for IT products. Theoretical results due to Diewert and Morrison (1986) and Kohli (1990, 2004) state that a rise in price of a nation’s exports relative to its imports can affect its standard of living in a way that is observationally equivalent to faster MFP growth.

Furthermore, mismeasured gains in terms of trade can be mistaken for productivity growth, and this is our focus in the present paper. We are not the first to suggest that mismeasurement of the import or export price indexes would bias real GDP and therefore productivity growth. Hamada and Iwata (1984) noted that this may have occurred during the oil shocks of the 1970’s, for example. But we know of no study that systematically investigates whether the accelerated decline in IT prices—and thus accelerated increase in productivity—may be due in part to international trade, not technology.[6]

Our analysis starts from the largely overlooked fact that IT is one of the most globally

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[5] For example, Jorgenson (2001, p.22) argues that, “The Domar aggregation formula [for working with industry-level MFP growth] can be approximated by expressing the declines in prices of computers, communications equipment, and software relative to the price of gross domestic income, an aggregate of the prices of capital and labor services. The rates of relative IT price declines are weighted by ratios of the outputs of IT products to the GDP. Table 7 reports details of this MFP decomposition …” This line of analysis leads links directly to overall productivity growth: “The accelerated information technology price decline signals faster productivity growth in IT-producing industries. In fact, these industries have been the source of most of aggregate productivity growth throughout the 1990s” (p. 2). Similarly, Oliner and Sichel (2000, p. 17) state that, “In accord with the ‘dual’ framework described above, we have interpreted the sharp decline in semiconductor prices after 1995 as signaling a pickup in that sector’s MFP growth.”

[6] Slaughter (2002) is the first study we are aware of to conjecture a link among globalization, IT prices, and productivity. Mann (2003) subsequently addresses these ideas as well.

engaged sectors in the U.S. economy. IT firms have long been establishing global production networks via FDI and trade, such that now much of their output entails multiple production stages across multiple countries. Indeed, as will be documented below, in the 1990s, the key IT industries of computers, peripherals and semiconductors in the U.S. began to run large trade *deficits* with the rest of the world. When we include telecommunications equipment, then this deficit was $57 billion by 2000, or about 17 percent of the non-oil U.S. trade imbalance that year.

On many measures, the global engagement of U.S. IT firms deepened after 1995—precisely the period of accelerated price declines that have been interpreted as MFP. Two factors are especially notable. First, in the second half of the 1990s, IT was the only industry in the world that had a multilateral trade liberalization under the World Trade Organization. Ratified in 1997 by dozens of countries accounting for nearly 95 percent of world IT trade, the Information Technology Agreement (ITA) eliminated all world tariffs on hundreds of IT products in four stages from early 1997 through 2000. Second, what is now widely known as the Asian financial crisis started with the July 2, 1997 devaluation of the Thai baht. This crisis entailed large depreciations of the currencies of many countries that export IT products to the United States, and its effects were felt for several years.

This timing suggests that the ITA and the Asian financial crisis may have played an important role in the post-1995 trends in IT prices. It also suggests that previous estimates of productivity growth in IT-producing industries may have been overstated because of overlooked effects of price declines in imported intermediate inputs. In turn, such an overstatement would carry important implications for the understanding and sustainability of the recent acceleration in the growth of aggregate U.S. labor productivity and living standards.

The aim of this paper is to systematically explore this line of reasoning. We do so in several steps. First, in Section 2 we document the rising global engagement of the U.S. IT industry over the past decades. Section 3 describes movements during the 1990's in import and export prices indexes, and the impact of the ITA and currency depreciations. In section 4 we extends the theory in Diewert and Morrison (1986) to distinguish "true" productivity from (i) terms of trade effects, and (ii) the impact of tariff reductions. We argue that both terms of trade improvements and the gains from tariff reductions are conflated with standard measures of multifactor productivity. In sections 5 and 6 we attempt to determine what amount of the productivity improvements in the United States can actually be attributed to these trade-related causes.

The assumption that all imports are intermediate inputs is not satisfied in the construction of U.S. GDP statistics, so in section 7 we distinguish imports of intermediate goods, final consumer goods, and investment goods. Specifically, we argue that *investment* goods (including computers) should be omitted from the terms-of-trade for intermediate inputs. The import price index for computers will not affect the measurement of real output, but instead, will affect the measurement of real capital input, as we estimate. Section 8 concludes.

2. Globalization of the Information Technology Industry

To gauge the role of international trade in the production of IT goods and services, a sensible starting point is to present trade flows for some specific industries. Take, for example, computers, peripherals and semiconductors (Enduse category 213) and telecommunication equipment (Enduse 214).[7] These sectors include some of the most high-profile information and communication technology (ICT) industries.

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[7] The Enduse industry classification is used by the BEA for measuring GDP and productivity, so we also use it here. Trade data for Enduse industries comes from Bureau of the Census, 1992-2000.

Table 1 reports current-dollar trade flows in these two sectors for three years spanning most of the 1990s —1992, 1996, and 2000. The bottom of Table 1 also reports the share of economy-wide exports and imports flows accounted for by these industries. Over the 1990s exports in these sectors have been rising faster than the national total, such that their share of that total rose from 10.7 percent to 15.4 percent. But a more striking feature is the even higher level of imports in these sectors. Over the 1990s their national import share rose from 12 percent to 16 percent.

All this means that these two central ICT sectors are substantial net importers whose trade imbalance widened during the decade. Within these sectors, computers and semiconductors show that smallest trade deficits, while computer accessories and telecommunication equipment have the largest deficits. By 2000 the combined trade deficit in these ICT sectors was $57 billion, or fully 17 percent of the non-oil U.S. trade deficit that year.

Table 2 offers some additional evidence on the trade intensity of IT industries, defined as trade flows as a share of output. For 1997, Table 2 shows exports, imports, and net exports, all as a share of output for two IT industries – computers and peripheral equipment, and semiconductors and electronic components. (These two IT industries differ from the Enduse classifications used in Table 1.) The key message of Table 2 is that IT industries are much more trade intensive than the overall U.S. economy. In these industries both exports and imports as a share of output range between 19 and 38 percent. These measures of trade intensity are higher than manufacturing industries in general, for which exports and imports were just 14–21 percent of output. Taken together, Tables 1 and 2 indicate that many of the central IT industries in the United States are more trade-intensive than is the rest of the economy, and are substantial net importers.

There are many factors that contribute to the increasing globalization of the IT industry, including the creation and spread of global production networks (for an overview of such networks, see Feenstra, 1998). But in the second-half of the 1990's, two events in the global economy were of particular importance. First, under the auspices of the World Trade Organization (WTO), an Information Technology Agreement (ITA) committed signatory countries to eliminate all tariffs on a wide range of nearly 200 ICT products. These products covered both finished and intermediate goods such as computers and networking and peripheral equipment; circuit boards and other passive/active components; semiconductors and their manufacturing equipment; software products and media; and telecommunications equipment.

The original Ministerial Declaration on Trade in Information Technology Products was concluded in December 1996 at the first WTO Ministerial in Singapore. This declaration stipulated that for the ITA to take effect, signatory countries would have to collectively represent at least 90 percent of world trade in the covered products. The 29 original signatories accounted for only about 83 percent of covered trade. But by April 1997 many more countries had signed on to push the share over 90 percent, and the agreement entered into force in July 1997. Ultimately there were more than 50 ITA signatories that accounted for more than 95 percent of world trade in the covered ITA products. All ITA signatories agreed to reduce to zero their tariffs for all covered ITA products in four equal-rate reductions starting in 1997 and ending no later than the start of 2000.[8] Some developing countries were granted permission to extend rate cuts beyond 2000, but no later than 2005. Also, an ITA Review Committee was established to monitor compliance. The overarching goal of the ITA was to eliminate world tariffs in a wide range of IT products. Thanks to the number and commitment of signatory countries, it has virtually achieved that goal.

The tariff reductions over 1997-1999 experienced by a number of U.S. ICT industries are

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[8] Give sources for ITA tariff cuts. The four tariff cuts for the U.S. occurred in July 1997, January 1998, January 1999, and for a small number of commodities January 2000. Our data period for price data runs through December 1999, so we are omitting the small number of tariff cuts in January 2000. [CHECK THIS]

shown in Table 3. The ITA tariff cuts are defined at the 8-digit level of the Harmonized System (HS) system, used to track import commodities. In the second column of Table 3, we indicate the percentage of import value within each industry that are covered by ITA commodities. For computers, peripherals and semiconductors, 100% of imports were included in the ITA tariff cuts. In the smaller industry of blank tapes for audio and visual use, 90% of the imports were covered by the ITA, and in the large sector of telecommunication equipment, 80% of the import value was covered by the ITA. Table 3 also includes the information for several other industries where more than 50% of import value was covered by the ITA, and industries such as industries such as business machines and equipment, and measuring, testing, and control instruments, where less than 50% of the import value was impacted by the ITA agreement.[9]

In Table 3 we show the average tariffs at the beginning of 1997, before the ITA was implemented, and at the end of 1999, when it was concluded. It is apparent that U.S. tariffs in these industries even before the ITA agreement were low: average tariffs are between one and four percent in all industries, and zero or nearly so in computer accessories and semiconductors. This means that the ITA tariff cuts for the United States were correspondingly small. But remember that the ITA was a multilateral agreement, so that tariff cuts in the U.S. could be matched by equal or larger tariff cuts abroad. For firms sourcing their IT products from overseas locations, the tariffs cuts within the ITA could therefore have a multiplied impact on lowering their import prices and costs, as we will argue in a later section.

A second event leading to increased global sourcing during the 1990's was the devaluation of currencies following the Asian financial crisis, starting with the July 2, 1997 devaluation of the Thai baht. As the crisis spread, the currencies of other Asian countries were sharply devalued, including Indonesia, Malaysia, Korea, Taiwan, Singapore and the Philippines. Many of the

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[9] Omitted from Table 3 are industries where less than 10% of imports are covered by the ITA.

countries with large depreciations of their currencies supplied substantial amounts of IT products to the United States, thereby lowering their import prices.

In the final column of Table 3, we show the depreciation of an import-weighted real exchange rate for each of the industries. The depreciation is calculated between January 1997 and the lowest point of the real exchange rate, which was generally in August 1998. It was not unusual to see depreciations exceeding 10% and as large as 20% for the supplying countries in each IT industry. Note, however, that these depreciations reversed themselves after that time, so that by December 1999 the real exchange rates in most industries were similar to their level in January 1997. Thus, the depreciation of currencies from countries supplying IT products was a transitory phenomenon, which occurred during the same period at the ITA tariff cuts. In the next section we investigate the impact of the tariff cuts and depreciations on U.S. import prices.

3. U.S. International Prices

3.1 Import and Export Price Indexes

The International Price Program (IPP) of the Bureau BLS calculates monthly import and export price indexes with a Laspeyres formula, which uses base-period quantities as weights. Details of the construction of these indexes are provided in the Appendix, and we have attempted to reproduce them using detailed data provided by the IPP. In Figures 1 and 2 we show the published BLS non-petroleum import and export price indexes over our sample period, along with Laspeyres, Geometric and Törnqvist indexes that we have constructed using IPP data. Our Laspeyres indexes are nearly identical to the published BLS price indexes for September 1993 – December 1996, but differ slightly in the January 1997 – December 1999 period. The differences in the latter period reflect concordances used there that are not fully accurate, but the differences seem small enough to proceed.[10]

Also shown in Figures 1 and 2 are the Geometric indexes and the Törnqvist indexes. A true monthly Törnqvist price index would require the use of monthly trade weights for imports and exports. We have instead used annual trade weights, combined with monthly data on the import and export prices.[11] Then the Törnqvist price index from month t-1 to month t in the year Y(t), for import or export sector j is:

$$P_{Mj}^{t-1,t} = \exp\left[\sum_{i\in I_j} w_{mi}^t \ln\left(\frac{p_{mi}^t}{p_{mi}^{t-1}}\right)\right], \text{ where, } w_{mi}^t \equiv \left(\frac{\sum_{s\in Y(t)} p_{mi}^s q_{mi}^s}{\sum_{s\in Y(t)} p_m^s{}' q_m^s}\right) \qquad (1)$$

$$P_{Xj}^{t-1,t} = \exp\left[\sum_{i\in I_j} w_{xi}^t \ln\left(\frac{p_{xi}^t}{p_{xi}^{t-1}}\right)\right], \text{ where, } w_{xi}^t \equiv \left(\frac{\sum_{s\in Y(t)} p_{xi}^s q_{xi}^s}{\sum_{s\in Y(t)} p_x^s{}' q_x^s}\right) \qquad (2)$$

where p_{mi}^t (p_{xi}^t) denotes the price for disaggregate import (export) commodity i in month t; I_j is the set of commodities included in a particular import or export sector j (e.g. a 3-digit Enduse industry); $p_{mi}^t q_{mi}^t$ $(p_{xi}^t q_{xi}^t)$ is the monthly expenditure on that import (export) in month t, which is measured relative to total imports (exports) of $p_m^t{}' q_m^t$ $(p_x^t{}' q_x^t)$ within sector j; and $s\in Y(t)$ denotes all 12 months s within the year that includes month t. As noted above, the weights w_{mi}^t (w_{xi}^t) denote the *annual* import (export) shares for commodity i.

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[10] There are two reasons why we cannot duplicate BLS procedures after 1997. First, as noted in the Appendix, two datasets were provided by the IPP: September 1993 – December 1996 and January 1997 – December 1999. The prices in the second dataset had to be re-based to match the first dataset, and we could not duplicate the BLS procedures in this regard because the “classification group” numbers used to track commodities were themselves changed between the datasets. Fortunately, re-basing only affect the Laspeyres price indexes, and not the Törnqvist or Geometric indexes. Second, the concordance between the “classification group” and Harmonized system (HS) numbers, used to obtain the current trade weights for the Törnqvist indexes, were incomplete due to changing HS numbers after 1997. This led to some omitted commodities in the Törnqvist indexes. To mitigate this problem, we construct the Laspeyres, Geometric and Törnqvist indexes over exactly the same set of commodities in each sector. In that way, differences between the indexes are due to their weights and formulas, and not due to differing commodities used in the aggregation.

[11] In practice, the monthly trade weights are too volatile to be reliable.

The month-to-month indexes in (1)-(2) are cumulated in order to obtain the long-term Törnqvist price indexes for imports and exports. Note that the Törnqvist import price indexes defined in (1), constructed from IPP data, are *net of tariffs*. For imports, we expect the Törnqvist index to lie below the Laspeyres index for the same reason that an exact cost-of-living index for consumers lies below a Laspeyres index: the Laspeyres index is using historical quantity weights, which tend to be too high for commodities whose prices rise fastest. This ranking of the Laspeyres and Törnqvist price indexes is confirmed in Figure 1, where the Geometric price index lies in-between these two.

For exports, on the other hand, we might guess that the Törnqvist price indexes would lie above the Laspeyres index, because exporting firms would increase their quantity sold of commodities whose price has gone up (so the Laspeyres index would understate those price increases). As shown in Figure 2, however, this guess is incorrect: the Törnqvist price index lies below the Laspeyres index, and the Geometric index is again in-between these two. This ranking of export price indexes was also found in Alterman, Diewert and Feenstra (1999). As they explain, it can be understood as resulting from technological improvement in the supply of exports, leading to higher quantities and falling prices along the foreign demand curve. So the export price index reflects substitution along foreign demand curves, and therefore the Laspeyres index overstates the increase in prices, just as the import price index reflects substitution along U.S. demand curves.

We have also constructed the import and export price indexes for various ICT industries, and several examples are shown in Figures 3 – 6. For brevity, we focus on import prices and do not show the Geometric index, which is quite close to our calculated Törnqvist price index. In addition, the various import price indexes are very close in the early part of our sample, so we start these graphs at January 1996 or January 1997, so as to focus attention on the later part of the sample. For each industry we show the BLS, Laspeyres and Törnqvist indexes for imports, and also a simulated index that will be discussed in the next section.

3.2 Impact of the ITA and Exchange Rates

The tariff cuts under the ITA and the depreciation of the Asian currencies over 1997-98 can be expected to influence both the price and quantity of imports. We investigate the impact on import prices by constructing industry-level Törnqvist indexes inclusive of tariffs. The Törnqvist index of tariff-inclusive import prices is defined by:

$$P_{Tj}^{t-1,t} = \exp\left[\sum_{i \in I_j} w_{mi}^t \ln\left(\frac{p_{mi}^t(1+\tau_{mi}^t)}{p_{mi}^{t-1}(1+\tau_{mi}^{t-1})}\right)\right]. \tag{3}$$

We construct (3) by multiplying the price quotes collected by the IPP by the appropriate HS tariff rates τ_i^t, and then aggregating up – using the same weights as in (1) – to obtain the monthly Törnqvist price indexes. Notice that the ratio of (3) and (1) gives a Törnqvist index of month-to-month changes in tariff rates:

$$\text{Tar}_j^{t-1,t} = \exp\left[\sum_{i \in I_j} w_{mi}^t \ln\left(\frac{1+\tau_{mi}^t}{1+\tau_{mi}^{t-1}}\right)\right]. \tag{4}$$

Let us denote the cumulated indexes in (1), (2), (3) and (4) for Enduse industry j by P_{Mj}^t, P_{Xj}^t, P_{Tj}^t, and Tar_j^t, respectively. Then using these monthly indexes, we consider the following price regression:

$$\ln P_{Tj}^t = \alpha_{j0} + \sum_{k=1}^{3} \alpha_k \delta_k^t + \beta \ln \text{Tar}_j^t + \sum_{\ell=0}^{9} \beta_\ell \ln \text{Exch}_j^{t-\ell} + \gamma \ln P_{Xj}^t + \varepsilon_{jt}, \tag{5}$$

where: α_{j0} is a fixed-effect for each industry; δ_k^t are three indicator variables for the stages of the ITA (i.e. July 1997, January 1998 and January 1999); Exch_j^t is a Törnqvist index of real exchange rates in industry j, which is entered with the current and nine lagged values;[12] and P_{Xj}^t is the cumulated export price index from (2) in industry j. The export price index P_{jX}^t in included in (7) between price regressions of this type should always include prices in competing markets. As an alternative to using the export price, however, we also experiment with including the domestic price P_{Dj}^t in sector j, as measured by the producer price index.[13]

The results from this price regression are shown in Table 4, where in part A we include the export price and in part B the domestic price index. Regression (1) is run over those industries where 100% of the import commodities are covered by the ITA; from Table 3, these industries are computers, peripherals and semiconductors. Regression (2) is run over those industries where 50 – 99% of the import value covered by the ITA, and these industries are also shown in Table 3. Regression (3) is run over those industries where 1 – 49% of the import value is covered by the ITA.

As a check on the reliability of the estimates, we also include two regressions for control groups of import that include no ITA commodities. Regression (4) is run over a control group of manufactured industries. In addition, when using the domestic price index as a control, we can also include agricultural industries as another control group. This is done in regression (5).[14]

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[12] We constrain the exchange rate coefficient to follow a second-order polynomial lag. Imposing this lag structure has only a minimal impact on the sum of the exchange rate coefficients, however, which are reported in Table 4.

[13] Because the producer prices indexes (PPI) are available on 4-digit standard industrial classification (SIC), we aggregate these using trade weights to obtain a PPI on the import or export Enduse classification.

[14] The Enduse classifications differ for imports and exports across agricultural products and raw materials, so those industries cannot be included in the control group when using the export price index. The control group of industries used in regression (4) include chemicals (Enduse 125), capital goods (Enduse 2), automobiles and parts (Enduse 3), and consumer goods (Enduse 4).

Looking first at regression (1), for computers, peripherals and semiconductors, the indicator variables for the ITA tariff cuts (July 1997, January 1998 and January 1999) are all negative, indicating a drop in prices that is not accounted for by the tariff variable. The cumulative drop due to the indicator variables is 19% when the export price is included in the regression (part A), and 14% when the domestic price is included (part B). The tariff variable itself is highly insignificant when the export price is used (part A), but becomes significant with a large value of 8.88 when the domestic price is used (part B). This "pass-though" coefficient estimate is much larger than normally seen, and indicates that the tariff declines have a *highly magnified* effect on lowering the import prices. Admittedly, the tariffs themselves are very low in these industries (see Table 2), so even with the very large pass-though coefficient, the impact of the tariff cuts on import prices is still modest (as will be shown below).

Turning to regression (2) and (3), these are run over industries with 50 – 99% of the import value covered by ITA products, or 1 – 49% so covered, respectively. Both regression indicate a pass-through coefficient substantially higher than 2, so again, there is a *magnified* impact of the ITA tariff cuts on the import prices. Our explanation for these results is that the ITA was a multilateral tariff reduction, with U.S. tariff reductions matched by those abroad, so with import processed in multiple countries their prices can easily fall more than the drop in U.S. tariffs. In these regressions, the ITA indicator variables are much smaller than found in regression (1): the ITA now has an additional downward effect on import prices of 2 or 3% by the end of 1999. The exchange rate coefficient reported is the sum of coefficients on the current and nine lagged values. These estimates show that a 10% permanent depreciation of foreign currencies results in 3.5 – 8% lowering of U.S. import prices.

Finally, we contrast these results with the control industries in regressions (4) and (5). For the manufactured products (regression 4), the estimate coefficient on tariffs is 0.33 or 0.44 depending on the specification of the competing price, indicating that 33 - 44% of the tariff reductions are passed through to import prices. This is a somewhat low but still reasonable estimate for manufacturing industries. For agricultural products (regression 5), we find that the pass-through coefficient is insignificantly different from unity, indicating the 100% tariff reductions are passed-through to import prices. Complete pass-through of this type can be expected for homogeneous products with competitive markets, whereas incomplete pass-through can be expected for markets characterized by imperfect competition (where exporting firms strategically absorb some of the tariffs). The fact that these two control groups provide the expected results for tariff pass-through gives us some confidence that the magnified tariff coefficients in regressions (2) and (3) really do reflect the multilateral nature of the ITA, with drops in import prices and exceed the tariff reductions.

To illustrate the impact of the ITA and exchange rates on import prices, we calculate what would have happened to import prices if both tariffs and exchange rates were constant at their January 1999 values. That is, we use the regressions in Table 4 to predict that path of import prices, holding constant tariffs and exchange rates.[15] The results of this simple counterfactual are shown by the index labeled “Simulated” in Figures 3 – 6.

For example, Figure 3 shows the BLS, Laspeyres, Törnqvist and simulated price indexes for computer imports. The Törnqvist price index is about 10 percent points below the BLS index

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[15] The regression coefficients in part (A) or part (B) of Table 4 give nearly identical ending values (for December 1999) for the simulated index, which is computed by treating tariffs and exchange rates as constant at their January 1997 levels. Since the ending values are the same, we choose to use the regressions in part (A) or part (B) depending on which choice gives the smoothest predicted values between January 1997 and December 1999. For computer, peripherals and semiconductors we use part (B), while for telecommunications we use part (A).

by December 1999, and 5 percent point below our calculated Laspeyres index. The simulated price index ignores the (temporary) depreciations of foreign currency over 1997-98, and the (permanent) tariff cuts under the ITA. For both reasons, the simulated index is above the Törnqvist index. Interestingly, we see that by December 1999, the simulated price is nearly equal to our calculated Laspeyres price index. In other words, *the quantitative impact of the ITA on import prices is nearly equal to the formula bias in the Laspeyres index as compared to the Törnqvist.* There is nothing in our calculation that would guarantee this outcome, but it is a neat empirical relationship that also holds for the other ICT products: computer accessories (Figure 4), semiconductors (Figure 5) and telecommunication equipment (Figure 6). In every case, we see that the simulated index, which is above the Törnqvist price index, is nearly equal to our calculated Laspeyres index at the end of the sample period.

4. Measurement of Productivity Growth with International Trade

4.1 Effect of Tariff Changes

In this section we extend results from Diewert and Morrison (1986) to incorporate changes in tariffs. We shall follow their approach to modeling imports and exports, whereby all traded goods are intermediate inputs. To this end, let us identify three groups of commodities:

- those for final demand (quantities $q_i^t \geq 0$ and prices $p_i^t > 0$, for i = 1,…,M);
- exported intermediate inputs (quantities $x_i^t \geq 0$ and international prices $p_{xi}^t > 0$, i=M+1,…,M+N). For simplicity we ignore taxes or subsidies on exports;
- imported intermediate inputs (quantities $m_i^t \geq 0$ and international prices $p_{mi}^t > 0$, with domestic prices $p_{mi}^t + \tau_i^t$ i=M+1,…,M+N).

The final goods and free trade prices are the (M+2N)-dimensional vector $P^t = (p^t, p_x^t, p_m^t)$, and the quantities of these goods by $y^t = (q^t, x^t, m^t) \geq 0$. Further denote the (M+2N)-dimensional vector of tariffs by $T^t = (0^{M+N}, \tau^t)$. Then the revenue function for the economy is:

$$R^t(P^t+T^t, v^t) \equiv \max_{y^t \geq 0} \left\{ \sum_{i=1}^{M} p_i^t q_i^t + \sum_{i=M+1}^{M+N} p_{xi}^t x_i^t - \sum_{i=M+1}^{M+N} (p_{mi}^t + \tau_i^t) m_i^t \mid y^t \in S^t(v^t) \right\} \qquad (6)$$

where $S^t(v^t)$ is a convex technology set in each country, which depends on the parameters v^t representing *primary factor endowments*. We assume that $S^t(v^t)$ is strictly convex with respect to m^t, meaning that imports need not be combined with each other or with primary inputs in fixed proportions to produce q^t and x^t. The superscript t on the revenue function indicates that the *technology* in country j can change over time. As usual, we subtract imported intermediate inputs from industry outputs to compute economy value-added.

Because tariff revenue is retained within the importing country, the international guidelines for national income accounting known as System of National Accounts use import prices that are *net of tariffs* to measure GDP and the trade balance. Let $X^t = \sum_{i=M+1}^{M+N} p_{xi}^t x_i^t$ and $M^t = \sum_{i=M+1}^{M+N} p_{mi}^t m_i^t$ denote the value of exports and imports at tariff-free prices, so that nominal GDP measured by the expenditure on final goods is:

$$GDP^t \equiv \sum_{i=1}^{M} p_i^t q_i^t + (X^t - M^t) . \qquad (7)$$

Then substituting for X^t and M^t, we can re-write nominal GDP as:

$$GDP^t = \sum_{i=1}^{M} p_i^t q_i^t + \sum_{i=M+1}^{M+N} (p_{xi}^t x_i^t - p_{mi}^t m_i^t) = R^t(P^t+T^t, v^t) + \sum_{i=M+1}^{M+N} \tau_i^t m_i^t , \qquad (8)$$

where the second equality is obtained using the definition of the revenue function $R^t(P^t+T^t, v^t)$. Nominal GDP equals revenue $R^t(P^t+T^t, v^t)$ plus tariffs on imports. We can think of $R^t(P^t+T^t, v^t)$ as the economy-wide value of output measured by summing the value added of all industries with tariffs included in intermediate input costs but excluded from all industries' gross output. In practice, BEA avoids a violation of the textbook identity between the total value added of all industries and GDP as measured by the expenditure approach by including tariffs in the margin used to payments in the in the wholesale trade industry. Tariffs are included in the margins used to measure the gross output of this industry, thereby making the textbook equality between total value added of all industry and GDP as measured by final expenditures hold in practice.

To analyze the effect of tariff changes on measured nominal GDP, based on equation (8) we define the GDP function as:

$$G^t(P^t, \tau^t, v^t) \equiv R^t(P^t+T^t, v^t) + \sum_{i=M+1}^{M+N} \tau_i^t m_i^t \ . \tag{8'}$$

Eliminating tariffs, while keeping international prices fixed, raises the GDP function, as can be seen from the following result:

Proposition 1

Holding fixed P^t and v^t, the value of GDP $G^t(P^t, \tau^t, v^t)$ in (8') is maximized at $\tau^t = 0$.

Proof: Because the derivative of the revenue function with respect to τ^t is $-m^t$, it follows that the first derivative of the GDP function is zero evaluated at $\tau^t = 0$. The second derivative at $\tau_t = 0$ is the matrix $\partial m^t / \partial p_m^t = \partial^2 R^t / \partial (p_m^t)^2$, which is negative semi-definite because the revenue function is concave in the import prices. It follows that $\tau^t = 0$ is a maximum. QED

Diewert (2006, 301), citing Jorgenson and Griliches (1972), observes that tariffs and similar taxes on intermediate inputs (which consist primarily of excise taxes) should be included in input prices when measuring productivity change. The revenue function R^t it allows us to develop models for this purpose because it depends on tariff-inclusive prices. (Although we omit excise taxes, which are not of interest for our purposes, they have analogous effects.) To model productivity change, let us assume that:

$$R^t(P^t+T^t, v^t) = A^t R(P^t+T^t, v^t) . \tag{9}$$

In other words, we are restricting attention to Hicks-neutral technological change. Some of our results below will hold more generally, but (9) allows for particularly simple proofs. Assuming that the function R is either translog or quadratic, we can solve for the “true” change in technology as the change in $R^t(P^t+T^t, v^t)$ not accounted for changes in P^t+T^t or in v^t:

$$\left(\frac{A^t}{A^{t-1}}\right) = \left(\frac{R^t}{R^{t-1}}\right) / [P_E(P^{t-1}+T^{t-1},P^t+T^t,y^{t-1},y^t)\ Q_E(w^{t-1},w^t,v^{t-1},v^t)] , \tag{10}$$

where: $R^t \equiv R^t(P^t+T^t, v^t)$ is the economy-wide revenue; $P_E(P^{t-1}+T^{t-1},P^t+T^t,y^{t-1},y^t)$ is an exact price index of the final demand, export, and tariff-inclusive import prices; $Q_E(w^{t-1},w^t,v^{t-1},v^t)$ is an exact quantity index of the factor endowments. For the translog revenue function P_E and Q_E are Törnqvist indexes, while for the quadratic P_E and Q_E are Fisher Ideal indexes.

Notice that a change in tariffs has *no impact* on the left-hand side of (10), and therefore no impact on the right-hand side either. In other words, the change in tariffs within the value-added function $R^t \equiv R^t(P^t+T^t, v^t)$ will just cancel with the change in tariffs within the exact index $P_E(P^{t-1}+T^{t-1},P^t+T^t,y^{t-1},y^t)$ leading to *no change* in correctly measured productivity. This is a reasonable result because in a static model tariffs lead to inefficient choices of inputs in production, not an inward shift in the position of the production possibility frontier.

The “true” measure of technology change in equation (10) can be contrasted with aggregate MFP as conventionally computed:

$$\text{MFP}^* \equiv \left(\frac{G^t}{G^{t-1}}\right) / \, [P_E(P^{t-1},P^t,y^{t-1},y^t)\; Q_E(w^{t-1},w^t,v^{t-1},v^t)], \tag{11}$$

where: $G^t \equiv G^t(P^t, \tau^t, v^t)$ is nominal GDP; $P_E(P^{t-1},P^t,y^{t-1},y^t)$ is an exact GDP deflator of the final demand, export, and tariff-free import prices; and $Q_E(w^{t-1},w^t,v^{t-1},v^t)$ is again the exact quantity index of the factor endowments. In (11) we are deflating the growth in nominal GDP by a GDP deflator that uses tariff-free rather than tariff-inclusive prices. Now, in contrast to (10), a change in tariffs *will affect* the measure of MFP*. This is demonstrated for the case of a tariff elimination in the next proposition.

Proposition 2

Assume that $A^{t-1} = A^t$, $P^{t-1} = P^t$, $v^{t-1} = v^t$ and $\tau^{t-1} \neq 0$. Then reducing tariffs to zero, $\tau^t = 0$, will lead to MFP* > 1 in (11), so multifactor productivity is measured as positive.

Proof: The assumptions that $P^{t-1} = P^t$ and $v^{t-1} = v^t$ lead to $P_E(P^{t-1},P^t,y^{t-1},y^t) = 1$ along with $Q_E(w^{t-1},w^t,v^{t-1},v^t) = 1$. Since $A^{t-1} = A^t$, the GDP function $G^t(P^t, \tau^t, v^t)$ is identical in the two periods, except that $\tau^t \neq 0$, so in period 0 GDP not being maximized. Reducing tariffs to zero will raise GDP, so $G^t > G^{t-1}$, so that MFP* > 1 in (11). QED

The effect of a tariff elimination on the measure of real output used to calculate MFP* is illustrated in Figure 7. Initially production takes place at point y_0, where a tangency occurs between the production possibilities frontier (PPF) and the budget line A_0 that includes the tariff in the price of good 1. Nominal GDP is not measured using this budget line, however, but rather with the budget line through point y_0 that *omits* tariffs, B_0. Gains from trade realized by exporting good 2 and importing good 1 yield an initial welfare level of Q_0.

After the tariff elimination producers' budget line A_1 has the same slope as B_0, so production moves to point y_1. Welfare rises, as society is now able to consume at point Q_1. Measured GDP rises by an amount that accurately reflects the rise in welfare. None of the rise in nominal GDP can be attributed to the unchanged prices used for GDP measurement, so measured real GDP and MFP* rise by amounts commensurate with the rise in nominal GDP. Nonetheless, the position of the PPF—which MFP is supposed to measure—is unchanged. *The prices used in the measurement of GDP reflect the slope of the indifference curve, not the slope of the production possibility frontier, so conventional measures of productivity mistake changes in allocative efficiency caused by movements along the PPF for changes in the position of the PPF itself.*

More generally, a reduction in tariffs will lead to positive MFP growth as conventionally measured, even though "true" productivity, as measured by equation(10), is unchanged. Our interpretation of this result is that the growth in MFP reflects the rise in GDP due to tariff reduction, rather than "true" productivity change. In other words, the gains due to tariff reduction are being conflated with the measurement of productivity growth. This result is our *first* reason why MFP* is conflating "true" productivity changes with effects due to international trade. The *second* reason will be that the existing international price indexes are biased, leading to biased estimates of MFP, as discussed in the next section.

4.2 Terms of Trade and Productivity

Following Diewert and Morrison (1986) and Kohli (1990, 2004, 2005, 2006), let us now break up the GDP deflator $P_E(P^{t-1},P^t,y^{t-1},y^t)$ into portions reflecting domestic prices and international prices. To be concrete, suppose that $P_E(P^{t-1},P^t,y^{t-1},y^t)$ is a Törnqvist index. Then it can be decomposed as:

$$P_E(P^{t-1},P^t,y^{t-1},y^t) = P_{Dom}^{t-1,t} \times P_{ToT}^{t-1,t} \ . \tag{12}$$

In this expression, $P_{Dom}^{t-1,t}$ is a Törnqvist index of domestic prices, defined by:

$$P_{Dom}^{t-1,t} \equiv \exp\left[\sum_{i=1}^{M}\left(\frac{1}{2}\right)\left(\frac{p_i^{t-1}q_i^{t-1}}{G^{t-1}}+\frac{p_i^t q_i^t}{G^t}\right)\ln\left(\frac{p_i^t}{p_i^{t-1}}\right)\right] , \tag{13}$$

while $P_{ToT}^{t-1,t}$ is a terms of trade index incorporating export and import prices:

$$P_{ToT}^{t-1,t} \equiv \exp\left[\sum_{i=M+1}^{M+N}\left(\frac{1}{2}\right)\left(\frac{p_{xi}^{t-1}x_i^{t-1}}{G^{t-1}}+\frac{p_{xi}^t x_i^t}{G^t}\right)\ln\left(\frac{p_{xi}^t}{p_{xi}^{t-1}}\right)-\left(\frac{1}{2}\right)\left(\frac{p_{mi}^{t-1}m_i^{t-1}}{G^{t-1}}+\frac{p_{mi}^t m_i^t}{G^t}\right)\ln\left(\frac{p_{mi}^t}{p_{mi}^{t-1}}\right)\right]. \tag{14}$$

Combining (11) and (12), measured MFP is then:

$$MFP^* \equiv \left(\frac{G^t}{G^{t-1}}\right) / \, [\, P_{Dom}^{t-1,t} \times P_{ToT}^{t-1,t} \times Q_E(w^{t-1},w^t,v^{t-1},v^t)]. \tag{15}$$

Equation (15) states that productivity growth for the economy is measured by the ratio of nominal GDP deflated by three terms: a gross domestic purchases price index, a terms-of-trade index, and a quantity index of factor endowment growth. Applications of this technique include Cas, Diewert and Ostensoe (1989) for Canada, Kohli (2004) for Switzerland, and Kohli (2005) for Hong Kong.

Above we saw that reductions in tariffs can lead to overestimation of the growth of MFP. In addition, if measurement errors in import and export price indexes affect the terms-of-trade component of equation (15), productivity growth will be mismeasured. Errors in the terms-of-trade index could arise from the use of Laspeyres formulas to measure import and export price indexes. In particular, if the terms of trade measured with Laspeyres formulas is downward biased (i.e. rises more slowly) as compared to the Törnqvist terms of trade index, productivity growth will be *overstated*. The reason for this overstatement is that some gains in nominal GDP from improvements in terms of trade are mistaken for gains from productivity growth.

5. Terms of Trade for the United States

5.1 U.S. Terms of Trade as Measured by the BLS Import and Export Price Indexes

In Figure 8 we show five measures of the U.S. terms of trade. The first four indexes are conventional terms of trade index measured as the ratio of export to import prices, and the fifth is the theoretically correct index based on (14).

The first index in Figure 8 is the ratio of published BLS export and import prices indexes for goods excluding petroleum. The second measure, which is the ratio of our constructed Laspeyres indexes, rises slightly faster than the ratio of the published BLS indexes, but again, this difference is not too large. The third measure is the ratio of the Geometric export and import prices indexes. The fourth measure is the ratio of the Törnqvist export and import prices indexes in (1) and (2), and is labeled as "Törnqvist1" in Figure 8:

$$\text{Törnqvist1 index} \equiv \left(\frac{P_X^{t-1,t}}{P_M^{t-1,t}} \right), \tag{16}$$

where the export and import indexes used in (16) are defined as in (1) and (2), but now summed over *all* the export and import commodities i=M+1,…,M+N:

$$\ln P_X^{t-1,t} \equiv \sum_{i=M+1}^{M+N} w_{xi}^t \ln\left(\frac{p_{xi}^t}{p_{xi}^{t-1}} \right), \quad \ln P_M^{t-1,t} \equiv \sum_{i=M+1}^{M+N} w_{mi}^t \ln\left(\frac{p_{mi}^t}{p_{mi}^{t-1}} \right). \tag{17}$$

The weights w^t_{xi} (w^t_{mi}) denote the annual export (import) shares for commodity i, as defined in (1) and (2), and these weights each sum to unity.

Both the Geometric and Törnqvist1 indexes rise substantially faster than the Laspeyres index during 1997-1999. Comparing December 1996 to December 1999, the Geometric index rises 7.1 percent and the Törnqvist1 index rises 6.1 percent as compared to the Laspeyres terms of trade, which rises 4.4 percent (Table 5). So the difference between the Geometric or Törnqvist1 indexes and the Laspeyres terms of trade is 1.7-2.7 percentage points over the three years. These amounts are shown in the final column of Table 3, where we report the values of the indexes re-normalized to 199612 = 100, and also their differences. Comparing the Geometric and Törnqvist1 indexes with the BLS-based terms of trade over 199612-19912, the Geometric index rises 5.0 percentage points more over the three years, implying a growth rate difference of 1.6 percent per year, and the Törnqvist1 index rises 4.0 points more, implying a growth rate difference of 1.3 percent per year.

In addition to the Törnqvist1 ratio, we also report a second Törnqvist index in Figure 8 based on the theory from the previous section. To develop this index we first rewrite (14) using monthly prices but with *annual* weights (as used in the IPP indexes). Then the terms of trade index in (14) is rewritten in logs as:

$$\ln P^{t-1,t}_{ToT} = \sum_{i=M+1}^{M+N} \chi^t w^t_{xi} \ln\left(\frac{p^t_{xi}}{p^{t-1}_{xi}}\right) - \sum_{i=M+1}^{M+N} \mu^t w^t_{mi} \ln\left(\frac{p^t_{mi}}{p^{t-1}_{mi}}\right). \qquad (18)$$

There are two weights appearing on exports and import in (18). The first weights w^t_{xi} (w^t_{mi}) again denote the annual export (import) shares for commodity i. The second weights χ^t (μ^t) denote the annual shares of exports (imports) in GDP, and are defined by:

$$\chi^t \equiv \left(\frac{\sum_{s\in Y(t)} p_x^{s\,\prime} q_x^s}{\sum_{s\in Y(t)} G^s}\right), \text{ and, } \mu^t \equiv \left(\frac{\sum_{s\in Y(t)} p_m^{s\,\prime} q_m^s}{\sum_{s\in Y(t)} G^s}\right), \tag{19}$$

where $s \in Y(t)$ denotes all 12 months s within the year that includes month t.

When trade is not balanced, the aggregate shares for exports and imports in (19) will differ, and so will the combined shares used on exports and imports in (19). In contrast, the conventional terms of trade in (16), which we will refer to as the “pure terms of trade”, is a ratio of export to import price indexes with weights that each sum to unity. To relate (18) to the pure terms of trade index in (16), we can re-write (18) as:

$$\begin{aligned}\ln P_{ToT}^{s-1,s,t} &= \chi^t \sum_{i=M+1}^{M+N} w_{xi}^t \ln\left(\frac{p_{xi}^t}{p_{xi}^{t-1}}\right) - \mu^t \sum_{i=M+1}^{M+N} w_{mi}^t \ln\left(\frac{p_{mi}^t}{p_{mi}^{t-1}}\right) \\ &= \frac{(\chi^t + \mu^t)}{2} \ln\left(\frac{P_X^{t-1,t}}{P_M^{t-1,t}}\right) + \frac{(\chi^t - \mu^t)}{2} \ln(P_X^{t-1,t} \times P_M^{t-1,t}),\end{aligned} \tag{20}$$

where the second line follows by algebra using the export and import price indexes in (17).

Equation (20) shows that pure terms-of-trade index, the first term on the right side of equation (20), must be adjusted by a trade balance term, the last term in (20), to equal $P_{ToT}^{t-1,t}$ which is the terms of trade index defined by Diewert and Morrison (1986) and Kohli (1990, 2004, 2005), as in (14). Let us re-write (20) slightly as:

$$\ln P_{ToT}^{t-1,t} = \frac{(\chi^t + \mu^t)}{2} \left[\ln\left(\frac{P_X^{s-1,s,t}}{P_M^{s-1,s,t}}\right) + \frac{(\chi^t - \mu^t)}{(\chi^t + \mu^t)} \ln(P_X^{s-1,s,t} \times P_M^{s-1,s,t}) \right]. \tag{20'}$$

The first term on the right of (20') is the average share of trade in GDP. We can express $\ln P_{ToT}^{t-1,t}$ as the product of this average trade share and an index that depends only on import and export prices and quantities, which we call the Törnqvist2 index. That index is:

$$\text{Törnqvist2 index} \equiv \exp\left[\ln\left(\frac{P_X^{s-1,s,t}}{P_M^{s-1,s,t}}\right) + \frac{(\chi^t - \mu^t)}{(\chi^t + \mu^t)}\ln(P_X^{s-1,s,t} \times P_M^{s-1,s,t})\right]$$

$$= \text{Törnqvist1 index} \times \exp\left[\frac{(\chi^t - \mu^t)}{(\chi^t + \mu^t)}\ln(P_X^{s-1,s,t} \times P_M^{s-1,s,t})\right]. \qquad (21)$$

Törnqvist2 index differs from the Törnqvist1 index by an adjustment for the trade imbalance. When imports exceed exports and import prices are falling faster than export prices, this will pull up the adjusted (Törnqvist2) terms-of-trade index relative to a conventional (Törnqvist1) terms-of-trade index. This is the case for IT products, where we reported in Tables 1 and 2 that imports grew during the 1990s to exceed exports.

The adjusted terms-of-trade index shown by the Törnqvist2 line in Figure 8 also rises faster than the conventional terms-of-trade index shown by the Törnqvist1 line. From Table 3, we see that the Törnqvist2 index rises 9.6 percent over 199612-199912, implying a growth rate of 3.1 percent per year. The growth rate of the Törnqvist2 index exceeds that of the Laspeyres terms-of-trade index by 1.7 percent per year, and it exceeds the growth rate of the ratio of BLS indexes by 2.4 percent per year. The difference between the Törnqvist2 index and the ratio of BLS indexes is nearly twice as large as the difference between the Törnqvist1 index and the ratio of BLS indexes. In other words, adjusting for the trade imbalance has roughly the same impact as correcting index number formula to use a geometric rather than an arithmetic formula. .

5.2 Implications for Output Growth of Terms of Trade as Measured by the BLS Import and Export Price Indexes

As is shown in (18'), to estimate the difference between “true” and measured productivity, we need to multiply the adjusted terms-of-trade by the average share of trade in GDP, i.e. by $(\chi^t + \mu^t)/2$. Over 1997-1999, the average GDP share of merchandise trade excluding imports of petroleum and capital goods was 7.5 percent. The Törnqvist1 estimate of the terms-of-trade effect of 1.3 percent per year therefore implies an upward bias in measured real GDP growth of 0.1 percent per year. This is our first calculation of the upward bias in total factor productivity for the U.S. economy due to the output effects of mismeasurement of export and import prices.

Our second calculation of the output side effect focuses more narrowly on the value added of the business sector, which excludes the contributions households, non-profit institutions and government (including government enterprises) to GDP. The broadest measures of US multifactor and labor productivity growth available from BLS use business sector real value added as their measure of output.[16] We make the approximately correct assumption that all imported goods are used by or distributed by the business sector, so that the entire terms-of-trade effect operates on this sector of the economy. The average share of merchandise trade excluding petroleum and capital goods imports relative to business sector value added was 9.5 percent in 1997-1999. Multiplying this by the bias of 1.3 percent per year in the terms-of-trade index, we obtain an upward bias in measured productivity of 0.12 percentage points per year.

If we also exclude the farming sector from both business value added, and agricultural exports from U.S. merchandise exports, then we obtain an average trade share of 9.3 percent over 1996-1999. In that case, the upward bias in productivity for the non-farm business sector is again 0.12 percentage points per year.

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[16] In analyzing multi-factor productivity for any sector, the conceptually correct measure of the sectors' output is its gross sales outside the sector, which should equal the sector's value added plus its purchases of intermediate inputs from outside the sector. The output concept for the business sector therefore ought to equal its value added plus its use of imported intermediate inputs. However, inclusion of these imported intermediate inputs in both output and inputs was found to have a very small effect on the MFP estimates for this sector, so in calculating business sector MFP, BLS measures its output by its real value added. See Gullikson and Harper (1999, p. 50 and fn 29).

5.3 U.S. Terms of Trade and Output Effects as Measured by the NIPA Import and Export Price Indexes

An alternative to the BLS price indexes for imports and exports are the deflators for imports and exports in the National Income and Product Accounts (NIPAs). Although the BLS indexes use a Laspeyres formula at all levels of aggregation and hence have older weights than the NIPAs use, the BLS and NIPA price indexes measure similar concepts. They have behaved fairly similarly since 1998, when the NIPAs international trade indexes first incorporated BLS's price indexes for computers and semiconductors. For exports, the growth rates of the BLS and NIPA index have been about the same on average, though with differences of as much as 0.5 percentage points in some years. For imports, the growth rates have tracked more closely, but the BLS index has tended to be about 0.1 percent per year higher.

Although the either the BLS or the NIPA indexes can be used to measure terms of trade effects on nominal output growth, the NIPA indexes are more appropriate for an analysis of the effect of substitution bias on official measures of productivity. The NIPA indexes directly enter the calculations of the real output measures that are used to measure productivity change by the BLS Office of Productivity and Technology (OPT). In particular, setting aside the components of GDP whose productivity cannot be measured reliably (which account for just over a fifth of GDP based on their value added and which do not engage in foreign trade), leaves the highest-level aggregate in the official productivity statistics, the business sector. Therefore, the effect of our alternative indexes on the official estimates of business sector labor productivity is the same as the effect on the growth rate of real value added of business published in NIPA Table 1.3.1. The effects on measured MFP are more complicated, however, so we defer discussion of this question to the next section of the paper.

Substitution bias is likely to be greater in the aggregate import and export indexes from BLS than in the deflators for imports and exports in the NIPAs because the NIPAs use a Fisher index formula for higher level aggregation of Laspeyres component indexes obtained from BLS, whereas the BLS indexes use a Laspeyres formula at all stages of aggregation. In estimates of real GDP, the bias is further reduced because imports that are not intermediate inputs enter the calculations of GDP both as a subtraction and as an additions to final demand. If the same deflator is used in both places, any measurement error in real imports would be canceled out by a corresponding measurement error in real final demand, leaving the estimate of real GDP unaffected. In practice, identical deflators are rarely used, but for imported capital equipment the deflators used in the calculation of real fixed investment are so similar to those used in the calculation of real imports that a cancellation of biases may be presumed. Therefore, we assume that a bias in import indexes for capital goods would affect the capital stock used to calculate MFP, but have no effect on the measures of inputs or outputs in the calculation of business sector labor productivity.

To estimate the effects of substitution bias on goods import and goods export indexes used to calculate real GDP, we compared an aggregate of commodity-level Laspeyres indexes with an aggregate of the corresponding Törnqvist indexes. In constructing these aggregates, we used the same Fisher formula and the same detailed weights as the NIPAs. Our Fisher indexes of Laspeyres components therefore replicate the procedures used to construct the NIPA deflators. For exports the match between these indexes and the actual NIPA index is quite close—see Table 6. *[Note to readers: the numbers in Table 6 are preliminary and subject to revision.]* For imports, our match with the NIPA price index for is not less precise, but still reasonable. Note that we excluded from our experiments those commodities whose NIPA price index is not based on the kind BLS indexes that we are able to simulate. Importantly, BLS indexes for computers, computer accessories and semiconductors were not used in the NIPAs until 1998, so these items account for the large drop in the percent of expenditures excluded shown for 1998 in Table 6.

Subtracting the growth rates of Fisher index of Törnqvist components from the growth rates of Fisher index of Laspeyres components gives an average estimate of lower-level substitution bias of 0.29 percent per year for imports in the NIPAs and an average estimate of lower-level substitution bias of 0.24 percent per year for exports in the NIPAs. To gauge the amount of upper-level substitution bias that the NIPAs avoid by their use of a Fisher formula, we also subtracted growth rates of Fisher-of-Laspeyres indexes from growth rates of corresponding pure Laspeyres indexes. Those results implied an average 0.36 percent per year for imports and 0.27 percent per year for exports. Thus, the comparisons of pure Laspeyres aggregate import and export indexes to pure Törnqvist counterparts will tend to overestimate the effect of substitution bias on aggregate productivity estimates by a significant amount.

Based on a comparison of the index that uses Törnqvist components with the index that uses Laspeyres components, correcting for lower-level substitution bias in the NIPA indexes adds about 0.4 percentage points to the terms of trade index over three years (Table 7). Adjusting for the trade balance effect raises this to 0.8 percent over three years.

To calculate the effects of these biases on the growth rate of real GDP, we again use equation (20') and multiply the Törnqvist2 type index by the average shares of trade in GDP. The result implies a downward correction of 0.06 percentage points to cumulative real GDP growth from 1996 to 1999. For the growth rate of business sector real value added the correction is about 0.08. However, almost all of these effects come after computers and semiconductors enter our comparisons. As a result, rather than converting these figures to an annual basis by dividing by 3, these figures might be regarded as estimates for the cumulative effects from the two years ending in 1999. Of course, in either event, they indicate the substitution bias in international trade indexes added a fairly small amount to official estimates of productivity growth.

6. Effects of Measuring Imports on a Tariff-Inclusive Basis

Average tariffs fell in the period 1995-1999, and have continued to do so. Proposition 2 suggests that the effect of such a fall in tariffs will be to raise measured productivity growth.

To account correctly for tariffs in the measurement of productivity, we recalculate the imports price index with the tariffs included in the price of imported intermediate inputs. This raises their share of GDP, albeit by a modest 0.2 percentage points. Because imported intermediate inputs represent a larger share of GDP with tariffs included in their cost, more output growth is now attributed to growth in the use of these intermediate inputs, leaving less to be attributed to productivity. We measure this effect via a larger trade balance adjustment than was calculated with tariffs omitted. In addition, falling tariffs directly affect the price index for imports, raising the pure terms-of-trade index. These two effects together raise the terms of trade effect for 1996-1999 calculated for the Fisher-of-Törnqvist-components to almost 1.4 percentage points above the trade-balance adjusted Fisher-of-Laspeyres-components terms-of-trade index; see the last row of Table 7.

The effects of tariffs on GDP growth are approximately the same as the terms-of-trade effects that we calculated without tariffs, so consideration of tariffs doubles our estimates of the overstatement of productivity growth due to trade developments. Tariff-inclusive terms of trade changes added 0.12 percentage points to the revenue function $R^t(P^t+T^t, v^t)$ between 1996 and 1999. These price effects also added 0.18 percentage points to the measured growth of real value added of the business sector and to its measured productivity growth.

7. Correcting for Capital Inputs

The calculation we have made in the previous section for impact of terms-of-trade changes on productivity growth treated *all* exports and imports as intermediate inputs to the economy's GDP function; this is the starting point for the theory developed in Diewert and Morrison (1986). However, less than one-third of imports of goods are for intermediate uses in the National Income and Product Accounts (see NIPA Table 4.2.5.) Although this suggests that most imports should be excluded from estimates of the GDP function, this conclusion is too superficial. Imported commodities in personal consumption expenditures pass through the domestic distribution industries (wholesale and retail trade) and are generally deflated by an appropriate CPI, not by an import price index from the IPP program. Therefore, for an imported commodity for personal consumption, a revision to an import price index will affect only the amount of constant-dollar imports subtracted in the calculation of constant-dollar GDP, just as if this commodities were an imported intermediate commodity. The deflation of consumption expenditures will be unaffected. Therefore, for purposes of investigating the effects of revisions to import price indexes on the estimate of real GDP, about three-quarters of imports must be treated as intermediate inputs.

In contrast, in measuring constant-dollar investment, imported investment goods are generally deflated by the same import price index used in measuring constant-dollar imports. Consequently, after combining the effects on real investment and the effects on real imports, revisions to import price indexes for capital equipment, including computers purchased by business, have virtually no effect on the estimate of real GDP change. For our purposes, the conceptual limitation of imports in the GDP function to imported intermediate inputs means that imports used for fixed investment should be excluded from estimates of effects on real GDP or real value added. Nevertheless, these import price indexes do affect the estimation of MFP because they affect real investment and hence inputs of capital services. Below, we compare the effect of adjusting capital inputs on the MFP estimate to the effect of simply treating imported capital goods as if they were intermediate inputs.

7.1 Output side effects

Our improved price indexes for imports and exports affect estimates of MFP though two channels. First, they affect the output growth component of the MFP and labor productivity calculations by changing the growth rate of aggregate real value added. Second, they affect the inputs growth component of the MFP calculations by changing the capital input.

The Törnqvist terms-of-trade indexes probably differ more from the Laspeyres or BLS-based indexes of the terms of trade than the terms-of-trade indexes implicit in BEA's output measures would because BEA uses a Fisher index number formula. In general, Fisher indexes match Törnqvist indexes quite closely. However, BEA's aggregation process starts with indexes for mid-level aggregates calculated by BLS using a Laspeyres formula. Most of the difference between our Törnqvist terms-of-trade indexes and their Laspeyres or BLS-based counterparts appears to arise at detailed and intermediate levels of aggregation, so our estimates of bias in the terms-of-trade indexes are useful upper bounds for effects on BEA's output measures and on the productivity measures that depend on them.

7.2 Input side effects

Any bias in the growth rate of output (i.e. real value added) of the business sector or of the nonfarm business sector would imply an identical bias in the BLS estimates of these sectors' labor productivity growth. However, for BLS's MFP estimates, import price mismeasurement also matters on the input side. The log-change in the MFP measures for the two higher-level aggregates (Business and nonfarm business) is calculated as the difference between the log-change in an output index and the log-change in an index of inputs of capital and labor. Mismeasurement of import prices will affect MFP through the capital input measure, in addition to its effect on the output side through imported intermediate inputs.

We did a rough calculation of the possible magnitude of the capital input effect. The Törnqvist price index for imported capital equipment drops faster than the corresponding BLS price index by more than 1.5 percent per year in 1995-1999, but by less than 0.1 percent per year before 1995 (see Figure 4). Imported capital items account for about 30 percent of total business sector equipment investment in National Accounts data. Assuming that 30 percent of the indexes used to deflate equipment investment were subject to a upward bias of 1.5 percent per year starting in 1995 and no bias before then, the measurement error in the price of new equipment would be about 0.45 percent per year, beginning with 1995. Because capital stock is estimated by adding new investment to existing capital, which is about seven times greater, this assumption will have only small effects on the stock of equipment in 1995. However, equipment depreciates rapidly (about 13 percent per year during the late 1990s) and the effects would increase each year that the error persisted, eventually approaching the assumed 0.45 percent investment error. For example, by 2002 the capital stock growth rate would be 0.39 percent higher.

We estimate that the capital stock trend, for the entire 1995-2002 period, would increase by about 0.25 percent. In the BLS capital model, the growth rate for capital services inputs is the same as the growth rate for the productive capital stock, and equipment accounts for 15.3 percent of the value of output during the period. Therefore, the input side effect of correcting the import deflators would be to *lower* the MFP trend by 0.038 percent during the period. This small capital effect is in addition to the estimated 0.12 percent per year output-side effect on MFP.

Rather than explicitly modeled the effect of prices of imported capital goods on capital inputs, a simple shortcut might be to treat capital goods as if they were intermediate inputs and adjust for their prices on the output side rather than on the input side. Although the timing of any affects will obviously be distorted forward by this shortcut, in the case of a constant and persistent bias, the timing effect may not matter. This accuracy of this shortcut method is also of interest because researchers studying terms of trade effects have generally failed to exclude capital goods from intermediate inputs.

We can approximate the performance of the shortcut method by the difference between the Törnqvist2 and the Törnqvist1 measures of output effects (although this approximation will be slightly understated, our input effect estimate that we want to compare it to is also conservative.) The growth rate of the Törnqvist2 terms-of-trade index is 2.4 percent per year, 1.1 percent per year faster than the growth rate of the Törnqvist1 terms-of-trade index. Including imports in our average merchandise share calculation raises this share from 9.5 percent to 11.5 percent, so the shortcut method would lead to a bias estimate of 0.28 percent per year. This is 0.16 percent per year higher than our estimate with capital goods excluded from imports. For comparison purposes, in the long run, a constant bias of 0.45 percent per year in equipment investment would lead to a bias of about 0.07 percent per year in the growth of capital services inputs in the MFP calculation. Even in the long run, therefore, treating imported capital equipment as intermediate inputs overstates their effect on business sector MFP growth by a substantial margin.

8. Conclusions

Although the roles of import and export price indexes in productivity measurement are inconspicuous, they are important. For the measurement of labor productivity, two effects of foreign trade prices may be identified, and for the measurement of multifactor productivity a third effect is present. First, an improvement in pure terms of trade, defined as the ratio of the exports price index to the imports price index, can raise nominal GDP in much the same way as a gain in productivity. Second, even if export and import prices move together, unless net exports equal zero, these prices also affect nominal GDP through a trade imbalance affect.

The import prices that generate these effects are for intermediate goods, and for final goods that are distributed via the retail sector. Prices of imported capital investment goods have virtually no effect on the measurement of real output growth. However, in measuring MFP, these prices affect the measure of capital services inputs.

Using a Törnqvist formula to calculate alternative price indexes for imports and exports, we find that both indexes grow more slowly, but the effect on the imports index is considerably larger. We therefore obtain an effect on the pure terms-of-trade index in 1997-1999 of about 1.3 percent per year, compared to virtually no effect for 199309 to 199512. This alternative index of the terms of trade implies a reduction in the estimate of real GDP growth by 0.1 percent per year in 1997-1999. Finally, combined with the input effect from the revision of the capital good import price index, it implies a reduction in its growth rate of about 0.16 percent per year in the estimate of MFP for the business sector.

As a second approach to estimating the effect of using Törnqvist price indexes for imports and exports on the official estimates of business sector productivity, we replicated as nearly as possible the procedures actually used to compile the deflators that underlie the official estimates of business sector productivity. To this end, we used the weights and Fisher formula from the NIPAs to aggregate detailed Törnqvist component indexes for import and export items. The use of the Fisher formula for higher-level aggregation can be expected to avoid a significant proportion of the substitution bias seen in the BLS aggregate import and export price indexes, which use a Laspeyres formula. This expectation is borne out, as the estimates from our first approach of the understatement of the terms-of-trade index are cut in half.

Finally, we show that the omission of tariffs from the definition of prices for imported intermediate inputs in the NIPAs can be expected to result in overstatements of the growth rate of real output and productivity when tariffs fall. The use of tariff-inclusive prices raises the estimates of the terms of term and of the real growth rate of imported intermediate inputs. Even though the tariffs were low even initially, accounting for tariffs properly would lower the official estimate of business sector productivity growth by as much as the use of Törnqvist component indexes for the NIPA price indexes for imports and exports. This indicates that productivity estimates that omit tariffs (as they usually do) can be quite sensitive to broad changes in tariffs. We estimate that the combined effects of the lower-level substitution bias not avoided by the use of the Fisher aggregation in the NIPAs and the omission of tariffs resulted in a bias of 0.1 percent per year in the official estimate of US business sector labor productivity.

Appendix: International Price Indexes

The International Price Program (IPP) of the Bureau BLS calculates monthly import and export price indexes with a Laspeyres formula, which uses base-period expenditures as weights. Letting p_i^t denote the price for disaggregate commodity i in month t, and p_i^0 denote a base-period price for the same commodity. The ratio (p_{zi}^t / p_{zi}^0) is defined as the *long-term price relative* for import (z = m) or export (z = x) commodity i. The IPP used the base period 1990 up until December 1996, and base period 1995 thereafter, and obtains base-period exports and imports $p_{zi}^0 q_{zi}^0$ from Census. Let $w_{zi}^0 \equiv p_{zi}^0 q_{zi}^0 / \sum_{i \in I_j} p_{zi}^0 q_{zi}^0$ denote the trade weights of import or export commodity i within industry j, i.e. for $i \in I_j$. Then the Laspeyres index from the base period to month t is,

$$P_{Lzj}^t \equiv \frac{\sum_{i \in I_j} q_{zi}^0 p_{zi}^t}{\sum_{i \in I_j} q_{zi}^0 p_{zi}^0} = \sum_{i \in I_j} w_{zi}^0 \left(\frac{p_{zi}^t}{p_{zi}^0} \right), \quad \text{for } z = m, x. \tag{A1}$$

We can think of (A1) as a *long-term Laspeyre*s index from the base period to month t, for the import (z = m) or export (z = x) industry j.

The *month-to-month Laspeyres-ratio* index is then computed by taking the ratio of (1) in months t and t-1, obtaining,

$$P_{Rzj}^{t\text{-}1,t} = \frac{\sum_{i \in I_j} w_{zi}^0 (p_{zi}^t / p_{zi}^0)}{\sum_{i \in I_j} w_{zi}^0 (p_{zi}^{t-1} / p_{zi}^0)}, \quad \text{for } z = m, x. \tag{A2}$$

We call the month-to-month index in (A2) a *Laspeyres ratio* since this formula differs from the usual Laspeyres formula computed from prices between months t-1 and t. This monthly index is then cumulated to obtain the Laspeyres indexes reported by the IPP.

The reason that the IPP uses long-term relatives in the Laspeyres formula (A1) is because this guarantees that the index number formula will satisfy the "time-reversal" test. That is, suppose that prices change from p_{zi}^{t-1} to p_{zi}^{t} and then back to p_{zi}^{t-1} in month t+1. Then the long-term Laspeyres index in (A1) will change from $P_{Lzj}^{t\text{-}1}$ to P_{Lzj}^{t} and then return to $P_{Lzj}^{t\text{-}1}$ in month t+1. If we cumulate the month-to-month indexes in (A2), we then obtain:

$$P_{Rzj}^{t\text{-}1,t} \times P_{Rzj}^{t,t+1} = \frac{P_{Lzj}^{t}}{P_{Lzj}^{t\text{-}1}} \times \frac{P_{Lzj}^{t\text{-}1}}{P_{Lzj}^{t}} = 1, \quad \text{for } z = \text{m, x.} \qquad \text{(A3)}$$

In other words, the price changes will cancel out when cumulated in the month-to-month indexes. This is a highly desirable property that the IPP indexes satisfy by construction. This property would not be satisfied by a Laspeyres-type index that used *short-term* price relatives and fixed weights. Chaining that type of index would result in an upward bias, as demonstrated for the CPI by Reinsdorf (1998). So the Laspeyres index used by IPP avoids the upward bias when prices "bounce up and down," but it is still subject to the usual upward bias from using base-period rather than currents weights.

An alternative index that would not suffer from this upward bias is the Törnqvist index, defined in (1) and (2) of the main text. An third index we consider, which might be expected to lie in-between the Laspeyres and Törnqvist indexes, is the Geometric price index, defined by:

$$P_{Gzj}^{t-1,t} = \exp\left[\sum_{i \in I_j} w_{zi}^{0} \ln\left(\frac{p_{zi}^{t}}{p_{zi}^{t-1}}\right)\right], \quad \text{for } \; z = \text{m, x,} \qquad \text{(A4)}$$

which uses the same base-period weight $w_{zi}^{0} \equiv p_{zi}^{0} q_{zi}^{0} / \sum_{i \in I_j} p_{zi}^{0} q_{zi}^{0}$ as IPP, rather than current annual weights as in (1)-(2). Again, the month-to-month index is chained in order to obtain a long-term Geometric index, for each import or export sector.

To calculate all the price indexes, we use two datasets provided by the IPP program. The first dataset spans September 1993 to December 1996 and was used extensively in Alterman, Diewert and Feenstra (1999). That dataset contains long-term price relatives (that is, p_{zi}^{t} / p_{zi}^{0}) at the "classification group" level, which is similar to the 10-digit Harmonized System (HS) level. The classification groups have been carefully concorded to the HS system, so that the base-period weights (for 1990) used by the IPP program can be replaced by current annual import and export expenditures in order to calculate the Törnqvist indexes in (1)-(2). That is, current annual weights are used in the Törnqvist index when aggregating from the classification group level to the Enduse industries. Alternatively, the base-period weights (for 1990) can be used to construct the Geometric index in (A4).

A second dataset spans January 1997 to December 1999. The classification groups used in that dataset differ somewhat from those used in the earlier period, so we have developed an (incomplete) concordance between them. The price data available for this latter period are actually more detailed than the classification group level, and go down to the "item" level at which individual companies provide price quotes. So for this latter period, we first need to aggregate from the item level to the classification group level, and then aggregate from the classification groups to the Enduse industries. The lower-level aggregation (from the item level to the classification group) can be done using the base-period (1995) weights and the Laspeyres formula, as in (A1)-(A2), which follows the BLS procedure. Alternatively, the lower-level aggregation can be done using the base-period weights and a Geometric formula in (A4), where I_j then denotes the item-level quotes within a classification group.

After constructing Geometric indexes at the lower-level, we can proceed in two methods: (i) again apply the Geometric index formula at the upper-level of aggregation, from the classification group to the Enduse industries; or (ii) apply the Törnqvist index to aggregate the indexes for the classification groups to the Enduse industries. We shall refer to the first method as a Geometric index, and the second method as a Törnqvist index, though it should be understood that the Törnqvist index in the latter time period is actually using a Geometric formula at the lower-level of aggregation. In contrast, for the earlier time period the long-term price relatives for the classification groups are Laspeyres aggregates of the item-level price quotes calculated by BLS. So the Geometric and Törnqvist indexes for the earlier time period both use Laspeyres aggregates at the lower level of aggregation.

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Table 1: International Trade in ICT Industries over the 1990s ($million)

Industry		1992	1996	2000
Computers (Enduse 21300)	Exports	8,277	10,422	10,263
	Imports	5,042	6,927	14,284
	Trade Balance	3,235	3,495	-4,022
Computer accessories (Enduse 21301)	Exports	16,730	27,550	34,686
	Imports	26,659	54,590	75,514
	Trade Balance	-9,929	-27,040	-40,828
Semiconductors (Enduse 21320)	Exports	11,527	24,135	45,118
	Imports	15,477	36,713	48,341
	Trade Balance	-3,950	-12,579	-3,223
Telecommunications Equipment (Enduse 214)	Exports	10,520	19,137	28,987
	Imports	10,773	14,505	38,203
	Trade Balance	-253	4,633	-9,216
Total (Enduse 213+214)	Exports	47,054	81,244	119,054
	Imports	57,952	112,735	176,343
	Trade Balance	-10,898	-31,491	-57,289
Share in Overall Trade (percent)	Exports	10.7	13.3	15.4
	Imports	12.0	15.4	16.0
	Trade Balance	24.1	26.6	17.2

Notes: Trade exports and imports are in millions of current dollars, and trade balance equals exports minus imports. *Source*: Trade data for Enduse industries comes from Bureau of the Census, 1992-2000. The export, import and trade balance shares are computed by dividing trade in Enduse 213+214 by total U.S. exports, non-petroleum imports, and the non-petroleum trade deficit, from *Economic Report of the President*, 2004, Table B-104.

Table 2: Trade Intensity of IT Commodities in the 1997 Benchmark I-O Tables (percent)

Commodity	**% of Commodity Output Exported**	**% of Commodity Output Imported**	**Trade Balance**
Computer & peripheral equipment	19.2	37.8	–18.7
Semiconductors & Electronic components	36.1	36.6	–0.5
Manufacturing Products	13.8	20.5	–6.7

Source: Calculated from the “Use of Commodities” tables in the U.S. BEA’s Input-Output Accounts.

Table 3: Tariffs and Exchange Rates in ICT Industries, 1997-99 (percent)

Industry	% Imports covered by ITA	1997 Tariff (percent)	1999 Tariff (percent)	Depreciation, 1997-1998 (percent)
Computers (Enduse 21300)	100	1.4	0.3	9.4
Computer accessories (21301)	100	0.3	0.0	20.6
Semiconductors (21320)	100	0.0	0.0	23.2
Blank Tapes (16110)[a]	91	1.5	0.0	17.4
Telecomm Equipment (21400)	79	2.6	0.9	13.5
Lab Instruments (21600)	64	3.7	2.5	12.2
Records, Tapes & Disks (41220)	63	1.0	0.3	12.1
Electrical Apparatus (2005)	54	2.3	1.5	10.6
Business machines (21500)	39	2.0	0.9	14.0
Generators & access (20000)	38	1.6	1.5	7.9
Measuring, Testing, Control Instruments (21160)	30	1.8	1.0	9.8
Marine Engines and Parts (22220)[b]	29	1.6	0.3	10.7
Photo, Service Industry (21190)	22	2.1	1.5	11.4
Materials Handling Equip (21170)	21	0.4	0.1	13.0
Industrial Supplies, Other (16120)	20	2.1	1.7	14.8
Industrial Machines, Other (21180)	16	2.2	1.7	10.7

Notes:

a. Blank tapes (Enduse 16110) is not used in the regressions reported in Table 4, because this import industry does not have a corresponding export Enduse industry.

b. Within marine engines and parts (22220), the product receiving ITA tariff cuts was radar equipment.

Sources:

Table 4: Dependent Variable – Import Price Index

	(1)	(2)	(3)	(4)	(5)
A. Using Competing Export Price					
July 1997	-0.044 (0.023)	0.011 (0.009)	-0.009* (0.004)	0.004 (0.003)	
January 1998	-0.015 (0.025)	0.016 (0.009)	0.003 (0.005)	0.003 (0.004)	
January 1999	-0.128* (0.019)	-0.004 (0.009)	-0.017* (0.004)	-0.010* (0.003)	
Sum of above	-0.189* (0.035)	0.023 (0.012)	-0.024* (0.005)	-0.004 (0.003)	
Tariff index	-0.188 (2.350)	2.870* (0.416)	2.944* (0.257)	0.325* (0.126)	
Exchange rate (9 lags)	0.127* (0.035)	0.383* (0.012)	0.433* (0.005)	0.357* (0.003)	
Export Price	1.163* (0.058)	0.602* (0.073)	0.730* (0.035)	0.191* (0.024)	
Observations	228	304	1064	2523	
R^2	0.97	0.81	0.83	0.69	
B. Using Competing Domestic Price					
July 1997	-0.057* (0.021)	0.016 (0.011)	-0.014* (0.004)	0.000 (0.000)	0.010 (0.009)
January 1998	-0.031 (0.023)	-0.004 (0.012)	0.001 (0.006)	-0.001 (0.002)	0.003 (0.009)
January 1999	-0.049* (0.019)	0.001 (0.009)	-0.018* (0.004)	-0.009* (0.002)	-0.007 (0.009)
Sum of above	-0.136* (0.034)	0.013 (0.013)	-0.031* (0.005)	-0.011* (0.002)	0.007 (0.008)
Tariff index	8.883* (1.832)	4.012* (0.544)	2.937* (0.244)	0.443* (0.094)	1.196 (0.664)
Exchange rate (9 lags)	0.184 (0.129)	0.794* (0.077)	0.358* (0.030)	0.292* (0.017)	0.202* (0.064)
Domestic Price	1.219* (0.056)	1.311* (0.122)	0.884* (0.037)	0.285* (0.028)	0.850* (0.056)
Observations	228	380	1140	3078	1139
R^2	0.98	0.89	0.83	0.81	0.70

Notes:

* significant at 5%; T-statistics are in parentheses.

Regression (1) is run over those industries where 100% of the imports are covered by the ITA. Regression (2) is run over those industries where 50 – 99% of the import value covered by the ITA. Regression (3) is run over those industries where 1 – 49% of the import value is covered by the ITA. Regression (4) is run over a control group of manufacturing industries that do not include any ITA commodities as imports, and regression (5) is run over a control group of agricultural industries that also do not include any ITA commodities.

Table 5: Terms-of-trade indexes (1996=100)

Terms-of-trade index	**Value in 199912 (199612 = 100)** (1)	**Difference from Ratio of BLS Indexes** (2)	**Difference from Laspeyres index** (3)
Ratio of BLS Indexes	102.1		
Laspeyres	104.4	2.3	
Geometric	107.1	5.0	2.7
Törnqvist1	106.1	4.0	1.7
Törnqvist2	109.6	7.5	5.2

Source: Column (1) reports the 199912 values of the indexes shown in Figure 8, relative to 199612 = 100. Column (2) is the difference between each index and a terms-of-trade index for 199912 calculated as the ratio of the export and import price indexes published by BLS. Column (3) is the difference between each index and the 199912 value of the Laspeyres terms-of-trade index.

Table 6: Rates of Change of Alternative Price Indexes of Goods Imports and Exports
(Percent per year; Preliminary)

	1995	**1996**	**1997**	**1998**	**1999**
Imports:					
NIPAs	2.7	–2.5	–4.2	–6.0	0.1
Laspeyres of Laspeyres components	2.9	–2.2	–3.9	–6.3	0.4
Fisher of Laspeyres components	2.5	–2.9	–4.3	–6.3	0.2
Fisher of Törnqvist components	2.3	–2.9	–4.4	–6.8	–0.5
Tariff-inclusive Fisher of Törnqvists	2.0	–3.0	–4.3	–6.8	–0.7
Upper level substitution bias*	0.45	0.74	0.41	0.00	0.18
Lower level substitution bias	**0.18**	**0.05**	**0.04**	**0.47**	**0.74**
Effect of NIPA exclusion of tariffs, non-matched items excluded	0.33	0.10	-0.07	0.03	0.16
Effect of all NIPA exclusions of tariffs**	0.34	0.18	-0.04	0.03	0.16
Pct. of goods imports excluded due to non-match, or non-use of a BLS import index	32.1	34.5	35.2	16.9	16.2
Exports:					
NIPAs	2.4	–2.6	–2.7	–3.2	–1.4
Laspeyres of Laspeyres components	2.9	–1.9	–2.6	–3.2	–1.2
Fisher of Laspeyres components	2.4	–2.5	–2.8	–3.2	–1.3
Fisher of Törnqvist components	2.1	–2.5	–3.0	–3.6	–1.6
Upper level substitution bias	0.55	0.56	0.18	-0.01	0.09
Lower level substitution bias	**0.30**	**-0.01**	**0.16**	**0.44**	**0.31**
Pct. of goods exports excluded due to non-match, or non-use of a BLS export index	27.1	27.8	28.5	19.1	19.3

* Shown for purposes of comparison; because the US NIPAs use Fisher indexes for aggregation, they avoid this bias.

** Calculated using all items whose price index comes directly from BLS. Percent of goods imports excluded is 17.3 in 1995 and 12.7 in 1999.

Table 7: Terms-of-trade indexes for Goods using Fisher Formula and NIPA Weights (1996=100)

Terms-of-trade index	**Value in 199912** (199612 = 100)	**Difference from Ratio of NIPA Indexes**	**Difference from NIPA Index with Trade Balance Effect**	**Difference from Ratio of Fisher-Laspeyres Indexes**	**Difference from Fisher-Laspeyres Index with Trade Balance Effect**
	(1)	(2)		(3)	
NIPA Indexes	103.0				
NIPA Indexes with Trade Balance Effect	105.9	2.9			
Fisher Combination of Laspeyres components	103.4	0.4			
Fisher Combination of Laspeyres components with Trade Bal. Effect	106.3	NA	0.4	2.9	
Fisher Combination of Törnqvist components	103.7	0.7	NA	0.4*	
Fisher of Törnqvist components with Trade Balance Effect	107.1	NA	3.4	NA	0.8
Tariff-Inclusive Fisher of Törnqvist components with Trade Bal. Effect	107.6	NA	3.9	NA	1.4

* Discrepancy from differences of values in column (1) is due to rounding.

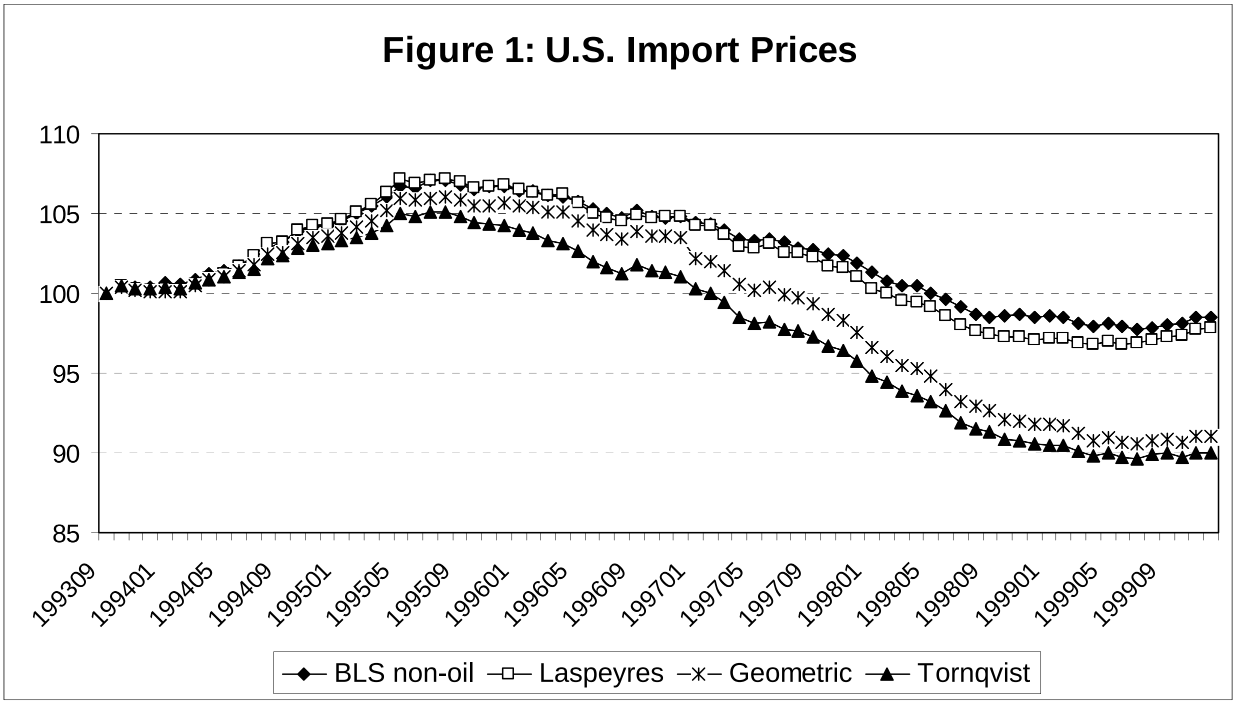

Figure 1: U.S. Import Prices

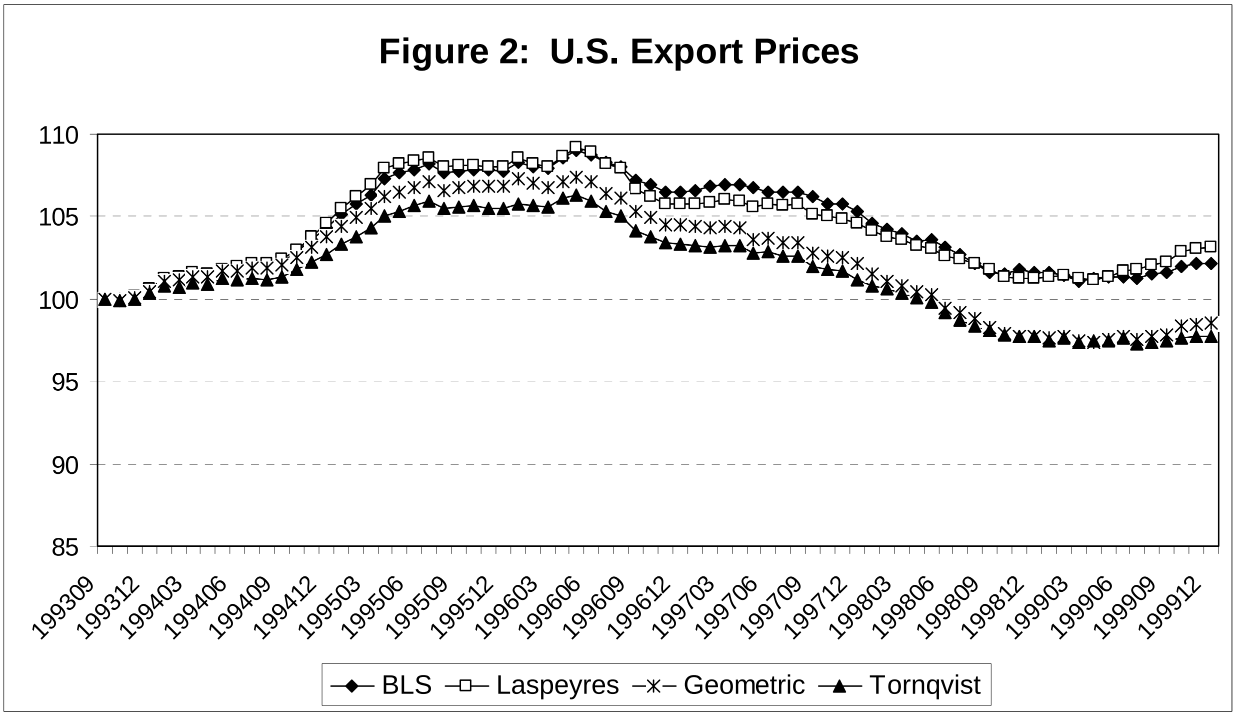

Figure 2: U.S. Export Prices

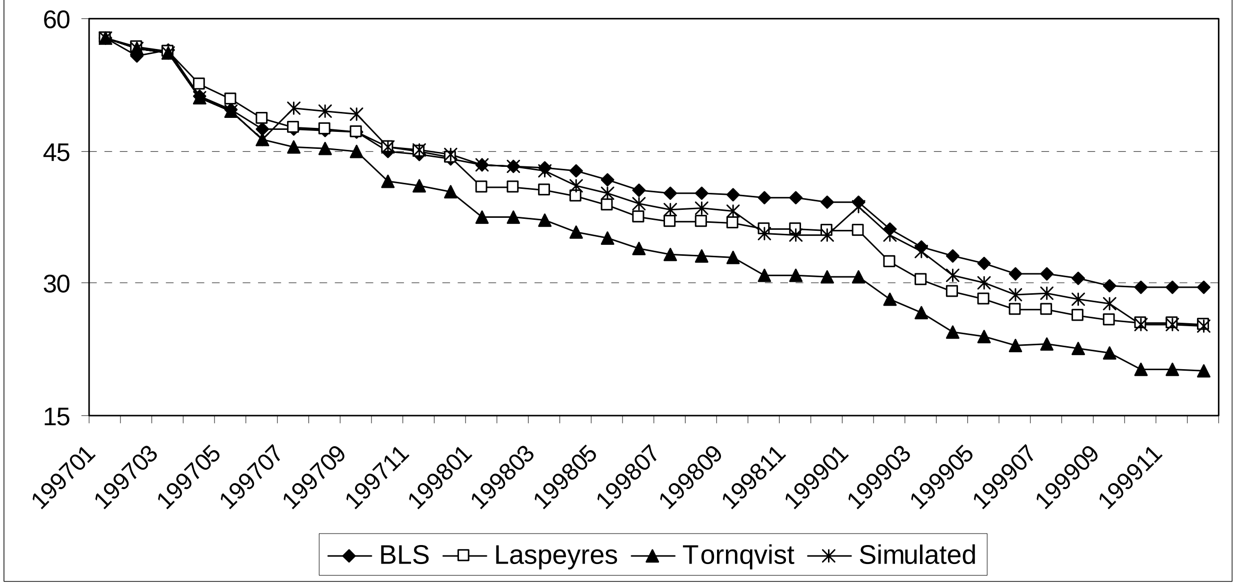

Figure 3: Import Prices, Computers (21300)

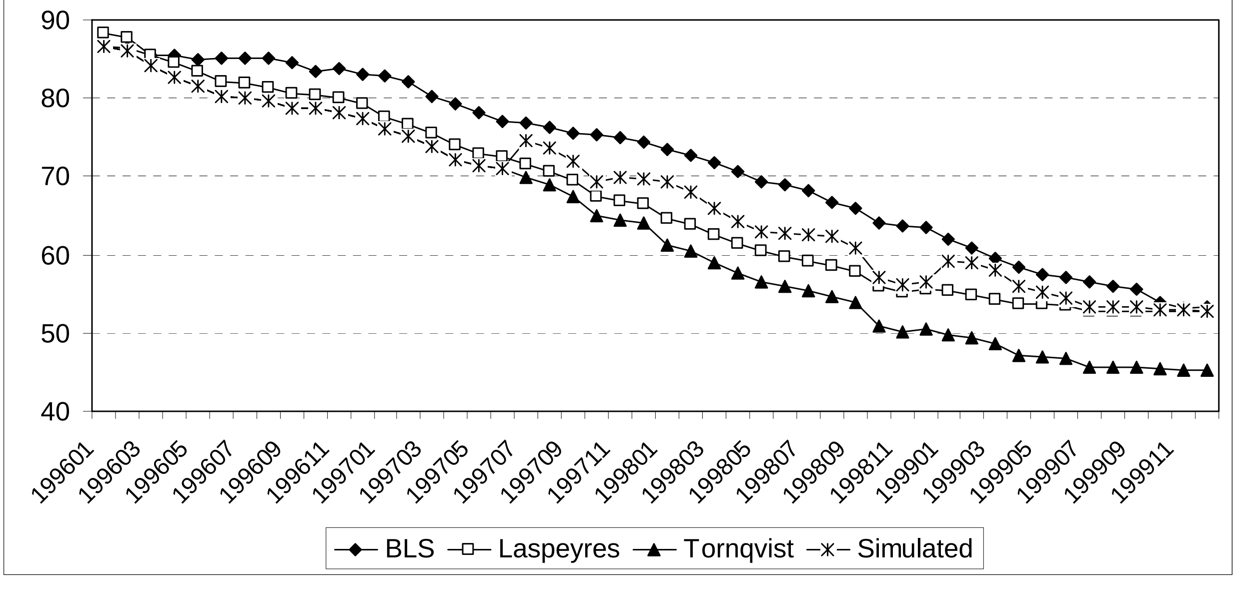

Figure 4: Import Prices, Computer Accessories (21301)

Figure 5: Import Price, Semiconductors (21320)

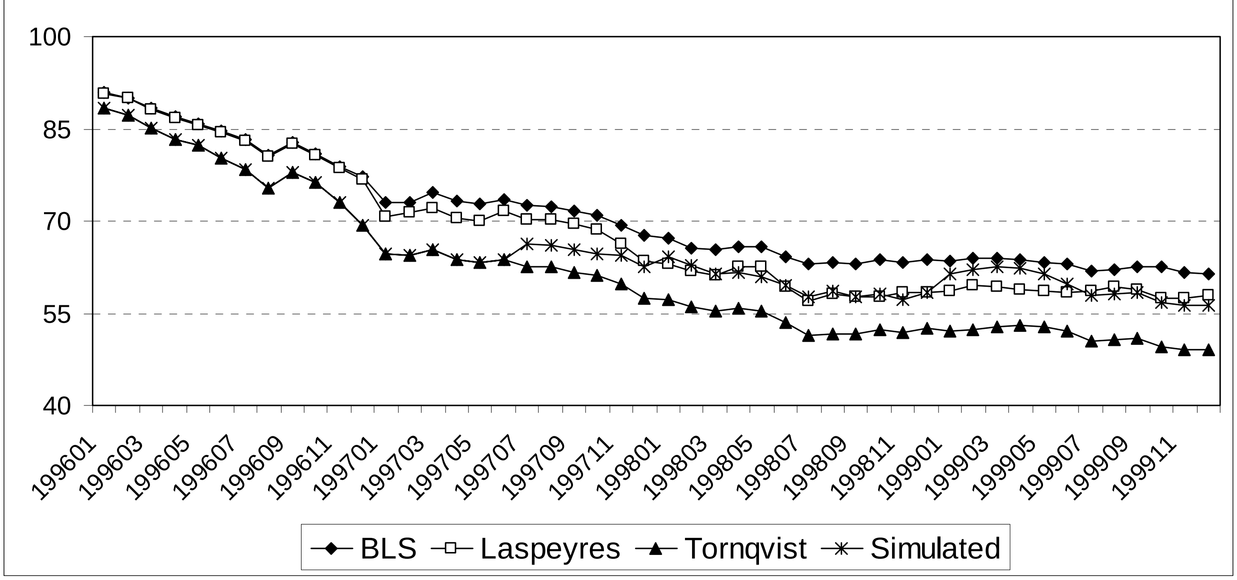

Figure 6: Import Prices, Telecommunications (21400)

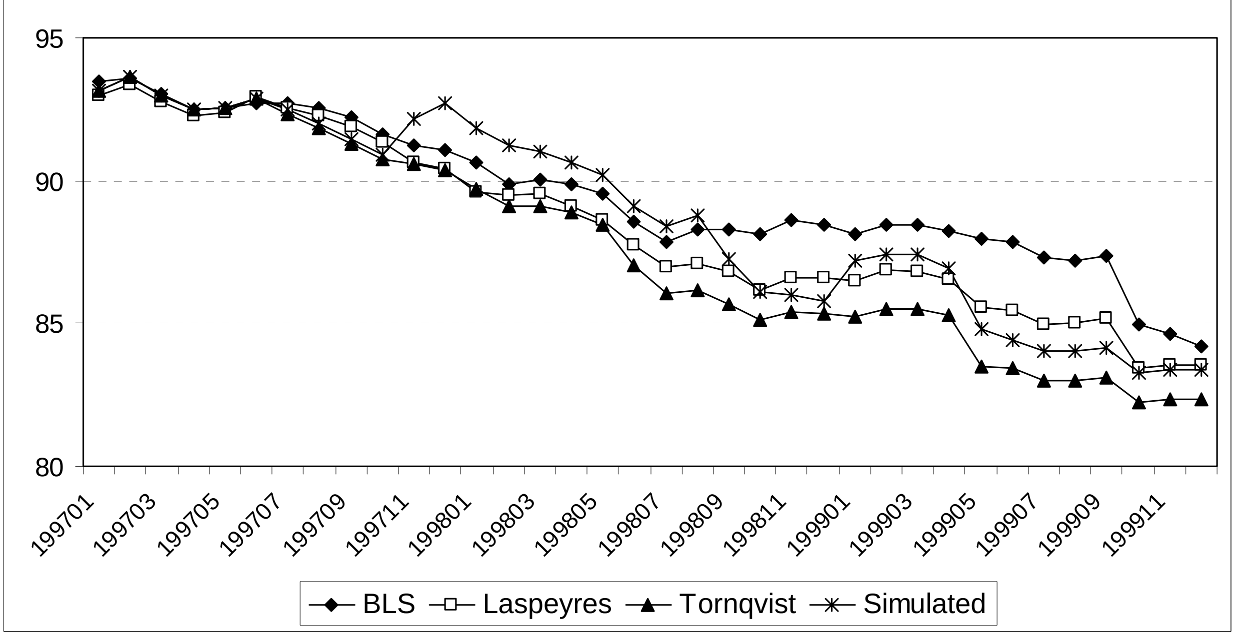

Figure 7: Rise in GDP and Rise in Welfare from a Tariff Elimination

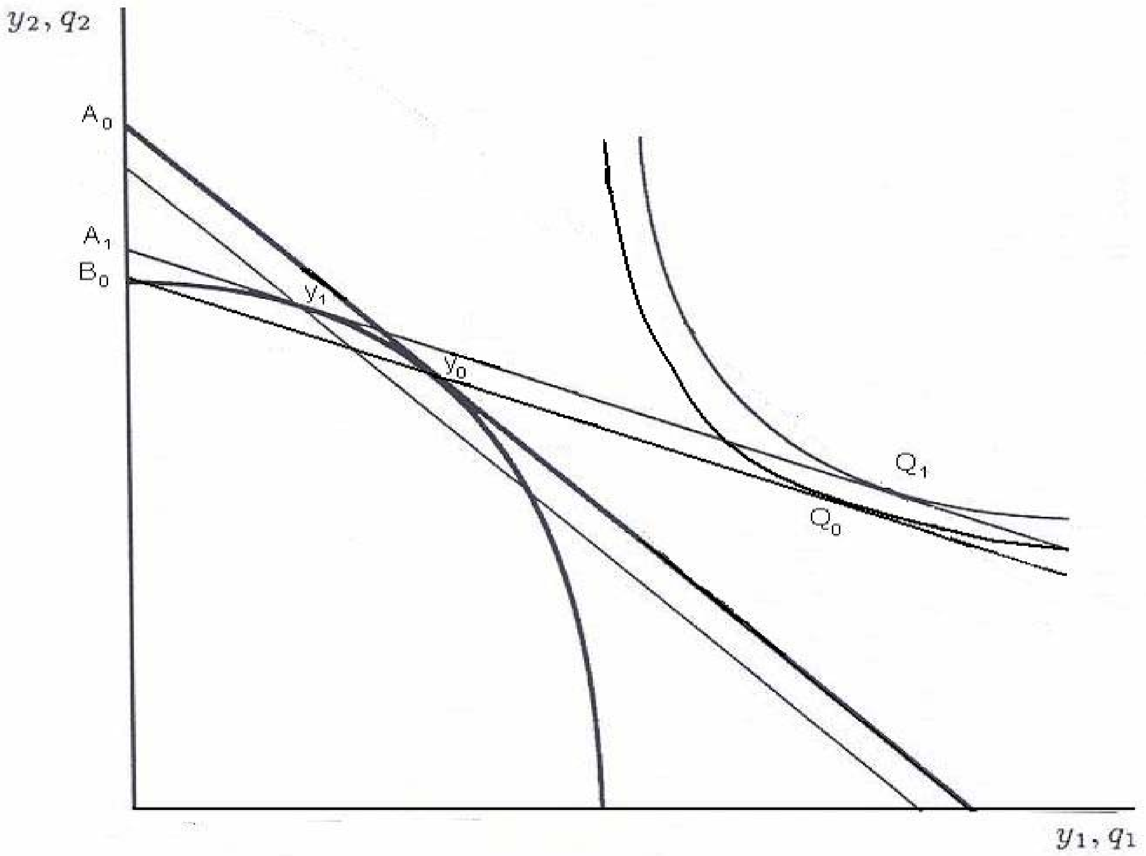

Figure 8: U.S. Terms of Trade