# Offshoring, Sourcing Substitution Bias and the Measurement of US Import Prices, GDP and Productivity

Marshall Reinsdorf

Robert Yuskavage

# Offshoring, Sourcing Substitution Bias and the Measurement of US Import Prices, GDP and Productivity

by Marshall Reinsdorf and Robert Yuskavage*

April 2014

*The decade ending in 2007 was a period of rapid sourcing substitution for manufactured goods consumed in the US. Imports were substituted for local sourcing, and patterns of supply for imports changed to give a large role to new producers in emerging economies. The change in the price paid by the buyer of an item who substitutes an import for local sourcing is out of scope for the US import price index, and the price change for an imported item when a new supplier in a different country is substituted for an existing one is also likely to be excluded from the index calculation. Sourcing substitution bias can arise in measures of change in import prices, real GPD and productivity if these excluded price changes are systematically different from other price changes. To determine bounds for how large sourcing substitution bias could be, we analyze product-level data on changes in import sourcing patterns between 1997 and 2007. Next, we identify products in the US industry accounts that are used for household consumption and that are supplied by imports. We aggregate CPIs, and combinations of MPI and PPIs that cover these products up to the product group level using weights that reflect household consumption patterns. With some adjustments, the gap between the growth rate of the product group index containing MPIs and the growth rate of a corresponding product group index constructed from CPIs can be used to estimate sourcing substitution bias. For the nondurable goods, which were not subject to much sourcing substitution, the gap is near zero. Apparel and textile products, which were subject to considerable offshoring, have an adjusted growth rate gap of 0.6 percent per year. Durable goods have an adjusted gap of 1.2 percent per year, but the upper bound calculation suggests that some of this gap comes from effects other than sourcing substitution. During the period examined, sourcing substitution bias may have accounted for a tenth of the reported multifactor productivity growth of the US private business sector.*

_____

## 1. Introduction

Globalization has brought with it increased international engagement for many of the world's economies. In the case of the US economy, one of the more striking changes over the past few decades was the growing substitution of imports for products once sourced from local producers. As a share of US domestic absorption of nonpetroleum goods, imports of nonpetroleum goods grew from a starting point of just 8 percent in 1970-71 to 30 percent in 2008 (figure 1).[1] Imports of goods used for personal consumption expenditures (PCE) exhibited similar growth. Between 1969 and 2009, imports at f.o.b. prices grew from 6.1 to 21.4 percent of PCE for durable goods, from 5.1 to 31.9 percent of PCE for clothing and footwear, and from 2.4 percent to 18.6 percent of PCE for nondurables other than clothing, food and energy (McCully, 2011, p. 19).

Globalization has also changed sourcing patterns within imports. The rise in US imports of nonpetroleum goods as a share of domestic absorption of nonpetroleum goods from 1990 to 2008 is almost entirely accounted for by imports sourced from low wage countries (figure 1). Trade data from the US International Trade Commission show that the share of non-petroleum imports sourced from high wage countries (Western Europe, Canada, Australia, New Zealand and Japan) fell from 65 percent in 1990 to 42 percent in 2010, while at the same time China increased its share of US non-petroleum goods imports from 3.4 percent to 23 percent.[2] Lower prices made possible by lower production costs in emerging economies were thus an important driver of increases in imports.[3] For example, the cost of manufacturing labor in China during the period of

[1] Domestic absorption of nonpetroleum goods is calculated as personal consumption expenditures on goods excluding energy products, plus private and government gross investment. Imports of nonpetroleum goods (at fob prices) went from less than 4 percent of GDP in 1970-71 to nearly 12 percent in 2006-08.

[2] These country breakdowns for imports are based on final assembly points. The Chinese *content* of US imports as measured by value added in China is smaller than US gross imports from China. Low cost countries in the aggregate probably specialize in final assembly less than China does. For example, Germany, Japan and Canada are final assembly points for cars that contain parts sourced from low cost countries.

[3] Factors that helped to the lower import prices include falling communication costs, advances in managing the logistics of complex supply chains, China's entry into the WTO, trade liberalization agreements, and economic reforms in emerging economies. Also, reserve accumulation by Asian countries seeking to self-insure against sudden stops such as the Asian currency crisis of 1997 helped to make these countries' exports cheaper in dollar terms.

rapid import share gains was about 4 percent of the US level at market exchange rates using the estimates in Banister and Cook (2011) for China in 2008.

Changes in sourcing pose measurement challenges for national accounts and can result in bias in indexes of import prices and productivity. The price reductions that buyers realize when they substitute offshore sourcing for local sourcing are out of scope for the US import price index (MPI), which measures the change over time in the prices of things purchased from abroad by US residents. Failure to measure price declines associated with offshoring has been hypothesized to be an important source of upward bias in measures of US real output growth, particularly for manufacturing (Mandel, 2009, and Houseman et al., 2010a, 2010b and 2011). In addition, changes in prices when import buyers substitute to new source countries are likely to be missed by the MPI. Unmeasured price changes that occur when import buyers substitute to new suppliers in different countries affect the measurement of output growth similarly to the unmeasured price changes that occur when these new suppliers are substituted for local producers, but they also affect other uses of the MPI. For example, the MPIs for labor-intensive products did not show relative declines during the period of rapid growth of imports from low wage countries, implying that this import growth was not a cause of rising wage inequality (Lawrence and Slaughter, 1993, p. 198). Yet the inference of the lack of a link between growth of imports from low wage countries and growth of wage inequality may be mistaken if the MPIs for products with large sourcing changes were upward biased.

This paper examines the conceptual framework for measuring sourcing substitution bias. It also provides empirical evidence on the size of the biases in our measures of the growth rates of import prices, real GDP and productivity. Quantifying the size of sourcing substitution bias requires indirect inferences because the micro data on prices, characteristics and quantities needed for a direct estimate by a method such as hedonic regressions are unavailable. To determine bounds for how large sourcing substitution bias could be, we analyze product-level data on changes in import sourcing patterns. Next, we identify products in the US industry accounts that

are used for household consumption and that are supplied by imports. We aggregate CPIs, and combinations of MPIs and PPIs that cover these products using weights that reflect household consumption patterns and then compare the indexes that contain MPIs covering consumer products sourced from imports with indexes constructed from CPIs for those products. With some adjustments, the growth rate gaps from these comparisons can be used to estimate sourcing substitution bias in an extended imports index that includes price changes from offshoring.

## 2. The MPI's Treatment of Country Sourcing Changes

Items sourced from US producers are out of scope for the US MPI, so price reductions associated with shifts of production from the US to offshore locations are necessarily missed. When an item that has been offshored appears as a new import, it is left out of the calculation of the MPI until two months of data are available. Then the change in the import price for the item is included in the calculation of the change in the index for the good in question.

In the case of an item that was already imported before the shift in its production location, an import price from the old location might be available, but the version of the item from the new location is likely to be treated as a different item even if its physical characteristics are identical. The MPI is constructed as a matched model index, so this means that the price change that occurs when the source country changes is not reflected in the index. Matched model indexes are constructed by linking together short-run indexes that compare adjacent months based on subsamples of matched observations. In the short-run index, the current month is represented by subsample that excludes any model not present before, and the earlier month is represented by a subsample that excludes any model not subsequently present.[4]

---

[4] Besides relocation of production to a lower cost source country, other kinds of changes in imports can also have price effects that are missed because of linking. Nakamura and Steinsson (2012) find that desired price adjustments tend to be delayed until the time of introduction of a new model. This causes "product replacement bias" because the new models are linked into the MPI, causing their price change to be treated as a missing value. The sign of the bias depends on the sign of the desired adjustments.

Simple comparisons of MPIs and matched producer price indexes (PPIs) for the period of rapid growth in imports from low wage countries suggest that the MPI has, indeed, failed to capture price declines from sourcing substitution. Such comparisons are possible for seven detailed products. One of them, footwear, shows a downward trend in import prices relative to the PPI, but in the remaining six cases the MPI grows as fast as or faster than the PPI (figures 2-8).

## 3. Country Substitution and Offshoring as Sources of Bias

The problem of failure to measure the change in the average price paid by import buyers when new source countries replace traditional ones resembles the problem of "outlet substitution bias" in the consumer price index (CPI) (Reinsdorf, 1993, Hausman, 2003, Hausman and Leibtag, 2009, and Greenlees and McClelland, 2011). It can be termed "country substitution bias".

Another way that buyers have been able to pay lower prices is by substituting imports from emerging economies for locally sourced products. Substitution of cheaper imports for local sourcing is similar to substitution between different source countries for imports in its effects on measures of the growth of real GDP, productivity and the real value added of industries that import their intermediate inputs. Taken together, the biases from country substitution and offshoring can be termed *sourcing substitution bias*.[5]

Diewert and Nakamura (2010, 249) show that to avoid sourcing substitution bias in measuring the real value added of an industry that substitutes to an offshore supplier for intermediate inputs, the price change that accompanies the substitution must be included in price index used to deflate imports. In their model, the true index for the item is a unit value index because the quality does not vary between sources.[6] The version of the intermediate input that is produced locally in the initial period must be included in the unit value for that period. Because

---

[5] The term was introduced in Nakamura, et al. (2014).

[6] The appendix demonstrates that the assumption of uniform quality implies a unit value price index. It uses the notation defined in the next section.

the import index constructed from this unit value includes a locally sourced version of the item (albeit in just one time period), it can be termed an *extended imports index*.

Measuring real GDP is similar to the problem considered by Diewert and Nakamura (2010). To avoid sourcing substitution bias in real GDP, an extended import price index that includes price changes from offshoring must be used to deflate imports. Under the final expenditure approach, GDP is calculated as domestic absorption (known as "gross domestic final expenditures" in the United Nations' System of National Accounts) plus exports minus imports. A change in import prices that is passed through to domestic absorption prices does not change nominal GDP, so it should not change the deflator for GDP. For this to occur the change in the import component of the price index for GDP must be such that it cancels out the change in the domestic absorption component of this price index. Price changes associated with shifts to offshore sourcing affect the domestic absorption price index the same way as changes in prices of continuously imported items do, so they must also be included in the price index used to deflate imports.

## 4. Using Unit Value Indexes to Bound the Country Substitution and Offshoring Bias

The detailed data on prices and characteristics needed for direct estimates of sourcing substitution bias is unavailable, so we use two indirect methods. The first indirect method finds plausible upper bounds for the bias based on data on changes in sourcing patterns and estimates from Houseman *et al.* (2011) on the typical size of the price gaps between US producers and producers in low cost emerging economies.

A simple formula for the bias under assumptions suitable for finding an upper bound can be derived from a model with two groups of countries. Let the item's price in period 0 be $p_0^H$ if it is sourced from a high cost country and $p_0^L$ if it is sourced from a low cost country. Offshoring is handled by including the period 0 local production in the US in the quantity sourced from country group H, which we denote by $q_0^H$.

The versions of the product from low cost and high cost countries are assumed to be of the same quality, so the true price index is the unit value index:

$$\frac{\bar{p}_1}{\bar{p}_0} = \frac{(p_1^H q_1^H + p_1^L q_1^L)/(q_1^H + q_1^L)}{(p_0^H q_0^H + p_0^L q_0^L)/(q_0^H + q_0^L)}. \tag{1}$$

Now suppose that for both country group L price and country group H the period 1 price equals $r$ times the period 0 price. The linked index therefore equals $r$ and has a bias of $r - \frac{\bar{p}_1}{\bar{p}_0}$.

Diewert and Nakamura (2010, p. 247) derive a formula for the bias of the linked index in which the growth in the *quantity* share of country group L is multiplied by the discount offered by group L expressed as a proportion of $p_0^H$ and by $r$. The required quantity shares can be calculated from value share data (Houseman *et al.*, 2010, p. 70), but the need to make these calculations makes a bias formula in terms of quantity shares inconvenient and not so transparent. If we are willing to accept an approximation, value shares can be used as proxies for the quantity shares in the Diewert-Nakamura formula. Write the change in the value share of the low cost countries as $s_1^L - s_0^L$. Then the approximation is:

$$\text{bias} \approx (s_1^L - s_0^L)(1 - p_1^L/p_1^H)r.$$

This formula may understate the bias significantly, however. To eliminate the error of approximation, let $\beta$ be the ratio of quantity shares to value shares for country group L. To calculate $\beta$, imports from country group L are revalued to the higher price, and a normalization factor is included to make the shares add up to 1:

$$\beta = \frac{p_1^H/p_1^L}{1 + s_1^L(\frac{p_1^H}{p_1^L} - 1)}. \tag{2}$$

Here it is worth pausing to note that the distinction between quantity shares and value shares can also matter when component indexes constructed from unit values are aggregated. In

the Paasche price index for GDP, for example, the weights used to aggregate the component

indexes are proportional to the *values* in the final period. Yet specifying the price indexes for the

imports of a product and for the final uses for domestic absorption of that product as unit value

indexes implies that the weights on these indexes should be proportional to the *quantities* imported

and used for domestic absorption. Nevertheless, the inconsistency that arises when unit value

indexes are aggregated using value weights is unlikely to be quantitatively important.

Returning to the problem of deriving an exact expression for the bias in the linked index,

write the unit value index as a ratio of harmonic means that have value shares as weights:

$$\frac{\bar{p}_1}{\bar{p}_0} = \frac{\dfrac{s_0^H}{p_0^H} + \dfrac{s_0^L}{p_0^L}}{\dfrac{s_1^H}{p_1^H} + \dfrac{s_1^L}{p_1^L}}$$

$$= r \frac{\dfrac{s_0^H}{p_0^H} + \dfrac{s_0^L}{p_0^L}}{\dfrac{s_1^H}{p_0^H} + \dfrac{s_1^L}{p_0^L}} \qquad (3)$$

If $s_0^L = 0$ equation (3) can be simplified to $r\left[1 + s_1^L\left(\frac{p_1^H}{p_1^L} - 1\right)\right]^{-1}$. Subtracting this expression

from $r$ shows that the bias in the linked index is $s_1^L(1 - p_1^L/p_1^H)r\beta$ in the case when $s_0^L = 0$.

If $s_0^L > 0$, some algebra shows that the bias in the linked index still equals the share gain of

the low wage countries times their price discount times $r\beta$. With $p_0^L/p_0^H$ substituted for $p_1^L/p_1^H$ in

the expression for $\beta$ given by equation (2), simplifying the general bias expression gives:

$$r - \frac{\bar{p}_1}{\bar{p}_0} = r - r \frac{s_0^H + s_0^L \dfrac{p_0^H}{p_0^L}}{s_1^H + s_1^L \dfrac{p_0^H}{p_0^L}}$$

$$= r \frac{\left(s_1^L - s_0^L\right)\left(\frac{p_0^H}{p_0^L} - 1\right)}{s_1^H + s_1^L \frac{p_0^H}{p_0^L}}$$

$$= \left(s_1^L - s_0^L\right)\left(1 - p_0^L / p_0^H\right) r \beta. \tag{4}$$

The first term in equation (4) is the change in the share of imports coming from low cost countries. In table 1 (which covers the period of 1996-2007) this group of countries is defined as Asia other than Japan, Latin American, Africa, Eastern Europe and former Soviet Republics, but in practice China accounts for most of the changes in this share. Large changes in the group's import share occurred between 1996 and 2007 for many product groups: the share change was 18.3 percentage points for computers and consumer durable goods other than motor vehicles, 10 percentage points for motor vehicles, and 5.1 percentage points for apparel and footwear.

The next term in equation (4) is the proportion by which the price differs between high cost and low cost countries. Based on estimates in the literature of typical price differentials between imports from high wage and developing countries, Houseman, *et al.* (2011, p. 125) argue that 0.5 is a plausible ratio of developing country prices to the high wage country price.[7] This figure can be used to calibrate the second term in equation (4) for purposes of finding plausible bounds for country substitution bias in the imports index and for sourcing substitution bias in the extended imports index. Letting *r* equal 1, the upper bound for country substitution bias in the annual growth rate of the MPI is about a quarter percentage point for apparel and footwear, about 0.7 percentage points for motor vehicles, and slightly under 1 percentage point for other consumer

---

[7] Houseman *et al.* also assume 0.7 for the ratio of their price from middle income countries to that from high wage countries. To keep the calculation of upper bounds simple, we treat the middle income countries like developing countries. China was not a middle income country and was the dominant source of the market share gains for consumer durable goods other than motor vehicles and for apparel and footwear.

durable goods including computers. These products are not necessarily representative of other kinds of products, however: for food and beverages, the bias is zero.[8]

The combined effects of offshoring and country substitution are measured in an extended import index that includes local production that was replaced by imports. Denote the period 0 share of domestic absorption that is supplied by imports by $\hat{s}_0^M$. (The internal transportation margins and wholesale and retail trade margins required to get imports to final consumers are not included in the measure of imports used to calculate $\hat{s}_0^M$.) To calculate an upper bound estimate of the effect of sourcing substitution on the extended imports index, the period 0 share of domestic absorption supplied by imports or local production for which offshore suppliers will be substituted is assumed to equal the period 1 share of domestic absorption supplied by imports, $\hat{s}_1^M$. Let $\tilde{s}_0^L$ be the share of extended imports in the period 0 coming from low cost countries. This equals:

$$\tilde{s}_0^L = s_0^L(\hat{s}_0^M/\hat{s}_1^M) \tag{5}$$

Then the bias in the extended import index is calculated as $(s_1^L - \tilde{s}_0^L)(1 - p_0^L/p_0^H)\beta$.

Comparing the middle column of numbers in table 1 to the first column shows that offshoring has a large impact on the extended index for apparel and footwear. Imports of apparel and footwear grew rapidly, so the bound for the effect on the growth rate of their index is over 1.5 percentage points when offshoring is included. The upper bound estimate of the effect of sourcing substitution on the extended import index for computers and other consumer durables is also high, at 1.8 percentage points. Yet for food and beverages, bringing in offshoring barely changes the bound for the effect, raising it to just 0.3 percentage points.

The extended imports index is designed to offset the effects of sourcing substitution on domestic absorption prices when it is used to deflate imports as part of measuring real GDP. The

---

[8] The two products found to have the largest potential bias in table 1 (computers plus consumer durables excluding motor vehicles and apparel) accounted for 7.8 percent of domestic absorption in 2007.

effect on the domestic absorption index itself may be a more useful measure. For imported goods used for household consumption it shows the effect of sourcing substitution on the CPIs for those goods assuming that pass through is complete. To estimate of the share of domestic absorption sourced from low cost countries we multiply the share domestic absorption sourced from imports by the share of imports sourced from low cost countries. This share increased over 1996-2007 by 14.3 percentage points for computers and consumer durable goods other than motor vehicles, by 5.4 percentage points for motor vehicles, and by 10.8 percentage points for apparel and footwear.

Because offshoring strongly affected apparel and footwear, the upper bound of the effect on the domestic absorption index, at 0.77 percent per year, is significantly higher than the upper bound for country substitution bias in the import index. The combined effects of offshoring and country substitution on the domestic absorption price indexes for consumer durables excluding vehicles also seem to be larger than the effect of country substitution bias on the import price index. On the other hand, motor vehicles and food and beverages were not so affected by offshoring, so for them the upper bounds for the bias in the domestic absorption indexes are just 0.45 percent per year and 0.03 percent per year, respectively.

### 5. Other Approaches that assume Imperfectly Substitutable Varieties

The appendix shows that unit value indexes that cover varieties from the different suppliers of a product assume that the varieties all have the same level of quality. Because lower prices may correspond to lower quality, the unit value indexes of table 1 may overstate the bias. Even if the physical characteristics match, an allowance for a quality decline when production moves offshore may be needed to account for higher transportation and warehousing costs, communication inefficiencies, and longer delays in receiving shipments.

One way to handle quality differences is to model varieties from different locations as imperfect substitutes. Models of imperfect substitutability have an implication that the availability of a wider range of varieties is itself something that increases buyers' welfare. This taste for

variety on the part of buyers can enable a product version that would not be identified as having a lower quality-adjusted price in a hedonic regression to capture at least a small market share simply by being distinctive. Of course, if the entry of new varieties creates gains for buyers, it must also be the case that the exit of a variety reduces buyers' welfare.

To develop a formula for measuring the bias in a matched model index from new and disappearing varieties and quality changes in existing varieties Feenstra (1994) models import buyers' tastes for variety as described by a CES function whose elasticity of substitution $\sigma$ is greater than 1. Higher expenditure shares correspond to lower quality-adjusted prices, so if an entering variety garners a higher expenditure share than the exiting variety that it replaces, that implies that the quality-adjusted price of the entering variety is lower, making the bias in the matched model index positive.[9]

Feenstra, Mandel, Reinsdorf and Slaughter (2011; hereafter FMRS) use the Feenstra (1994) formula to estimate the effect of variety entry and exit on the MPI treating countries as suppliers of different varieties. The average bias for the nonpetroleum imports is estimated to be about +0.6 percent per year in 1995-2006. This bias estimate reflects a combination of lower quality-adjusted prices from new source countries and an expansion in the range of varieties available to import buyers implied by increased diversity of import sources. With some assumptions, it can be interpreted as suggesting smaller estimates for country substitution bias than the bounds shown in the import index column of table 1 for durable goods. This is not surprising: letting $\sigma = 4.8$ (the average excluding crude commodities of the estimates for 1990 to 2001 in table VI of Broda and Weinstein, 2006) and letting 80 percent of imports in the final period come from country group L, for a given change in the share of country group L, the

---

[9] Let $\lambda_t$ be 1 minus the expenditure share of the varieties that are present in period t but not in period t–1, and let $\lambda_{t-1}$ be 1 minus the expenditure share of the varieties that are present in t–1 but not in t. Then multiplying by $(\lambda_t/\lambda_{t-1})^{1/(1-\sigma)}$ corrects the matched model index for variety entry and exit. For example, let $\sigma$ equal 4.8 and let the year t share of the new source countries exceed the year t–1 market share of the exiting countries by 1 percent. Then the estimate of the bias in the matched model import index is +0.264 percentage points.

formula in Feenstra (1994) would imply a bias estimate slightly less than half as large as equation

(4) evaluated with $\frac{p_0^L}{p_0^H} = 0.5$.

## 6. CPIs as Benchmarks for Measuring Price Effects of Sourcing Substitution

As a solution to the problem of tracking items as they move between local and offshore

production, Alterman (2010, 2013) proposes a buyer's price index for intermediate inputs and

explains how such an index could be produced. Yet for goods bought by consumers, a proxy for a

buyer's index is already available. The consumer price index (CPI) reflects buyers' purchasing

patterns in its composition and weighting (albeit with some lags and sampling error) and it does

not distinguish between items based on their production location. In particular, price changes that

occur when the production of an item moves offshore are captured by the CPI unless the offshored

version of item has significant quality changes that cannot be adjusted for. The CPI often uses

quality adjustment techniques to compare items that are not precisely identical, or treats an item

replacement with minor changes in characteristics as a continuation of the original item. [10]

Some empirical evidence that CPIs for products supplied by imports have indeed captured

the price declines associated with offshoring comes from a comparison of CPIs for products that

were more subject to offshored to CPIs for products less subject to offshoring. The correlation

between changes in import shares in 1959-2009 (from McCully, 2011, table 4) and changes in

prices for major types of consumer products (from NIPA table 2.3.4) is –0.71. Of course, factors

other than import penetration also influenced the relative inflation rate of some of the major

product types, but these factors do not seem to play a role in this correlation. Excluding types of

products whose prices are subject to identifiable special factors has virtually no effect the

correlation. (The excluded product types are services, which may have comparatively high price

growth because of low productivity growth, recreational goods, which contains computers and

---

[10] A detailed analysis of CPI micro data on durable goods by Bils (2009) shows that a large proportion of changes in unit prices associated with the entry of new models are, indeed, included in the CPI. Bils argues that this has resulted in under-correction for quality change for types of durable goods that have benefitted from improving technology.

other products with rapid technological progress, and petroleum products.) The product
exclusions do reduce the magnitude of the regression coefficient on import growth, but not by
much. With the product exclusions, the coefficient estimate implies that a 10 point increase over
1959-2009 in the percent of overall supply coming from imports reduces a product's price growth
by –0.83 percent per year.

Nonetheless, estimates of the effects of sourcing substitution based on growth rate
comparisons with CPIs have some weaknesses. First, growth rate comparisons of MPIs and CPIs
are influenced by random errors caused by differences in the mix of detailed products and varieties
that they include. This problem can, however, be mitigated by making the comparisons at a higher
level of aggregation. Purely random errors can be expected to result in a mix of positive and
negative contributions to growth rate gaps for individual products that tend to cancel out in when
they are average to form broader aggregates.

Estimates of sourcing substitution based on comparisons with CPIs are also subject to
some systematic effects that may cause them to underestimate the impact of sourcing substitution
on prices paid by wholesale level buyers. The CPI may not capture all the price reductions
associated with sourcing substitution if the sourcing change is accompanied by changes in
characteristics that cannot be adjusted for or a switch in retail distribution channels. Comparisons
with CPIs will also understate the decline in prices paid by wholesale buyers if price reductions
from sourcing substitution are not completely passed through to the retail level. However, the
gains from sourcing substitution are probably understated by the less than the full amount of the
cost savings that are not passed through to consumers. Items from the new source country may
require more distribution services, and the extra cost of these services represents a quality decline.

Finally, to avoid the risk of overestimating sourcing substitution bias, allowances must be
made for the effect of changing tariffs and the effects of certain methods used in the CPI. Tariffs
have fallen because of trade liberalization agreements, but the prices used in the MPI do not
include tariffs. The CPI methods that may tend to produce lower index estimates than the methods

used in the MPI are the geometric mean formula for lower-level indexes and the hedonic or hedonic-like quality adjustment procedures that the CPI uses for computers and some other durable goods with changing technology, such as major appliances, televisions and video equipment.[11]  These and similar kinds of durable goods have tend to have technological progress leading to the entry of new models with lower quality-adjusted prices.  The product replacement bias in the MPI from this source is upward.

### 7.  Constructing Wholesale Purchaser and Retail Purchaser Price Indexes

Many imported products are used for personal consumption expenditures, yet, as noted above, only a handful of detailed MPIs can be matched to a corresponding CPI.  One reason for this is that the MPI and CPI programs use different product classification systems to define their detailed products.  This means that the lower level indexes must be aggregated up to a level where the differences in product classification schemes become relatively unimportant.  To form these aggregates, we identified all of the products used for personal consumption expenditures that are imported using detailed "use" tables from BEA's Annual Industry Accounts (AIAs) and used shares of these products in personal consumption expenditures as weights in a Fisher index formula.  After excluding a few products that could not be matched to a CPI or that had zero imports in the first or last year included in the analysis (1997 or 2007), 458 detailed products in 209 product groups remained in the sample. These detailed products comprise about 20 percent of personal consumption expenditures on non-energy goods.

Another issue in using CPIs as benchmarks for estimating sourcing substitution bias is that many broadly-defined products that are imported also have some local production.  To take the prices for the locally supplied products into account, we construct wholesale purchaser's indexes

---

[11] Special quality adjustment procedures are also used in the CPI for apparel and automobiles.  Apparel prices behave differently in retail markets than in wholesale markets for imports, and the hedonics and other special procedures for apparel in the CPI help to avoid the downward bias that would occur in a pure matched model index of retail prices.  For automobiles, the procedures used in the MPI and the PPI are similar to those used in the CPI.

that include a PPI component.  The weights for the MPI and PPI in these indexes are the shares of imports and local production in the overall supply of each product.  The assumption in using these weights to construct indexes to compare with CPIs is that the personal consumption component of the overall uses of a product has the same sourcing pattern as the overall uses of the product.

The wholesale purchaser's indexes can be treated as weighted averages of MPIs and PPIs (though in reality they are constructed as Fisher indexes).  Assuming that the CPI is unbiased and that the random error introduced by sampling and variety mix differences is zero, the growth rate gap between a wholesale purchaser's index and a CPI is a weighted average of the effect of sourcing substitution on an extended MPI and any bias that may exist in the PPI.  Thus, if the PPI bias is smaller than the sourcing substitution bias in the extended MPI, the gap between the wholesale purchaser's index and the CPI will underestimate the bias in the extended import index. In table 1, for example, the bias in the extended index exceeds the biases in the domestic absorption index by the amount implied by the assumption that the bias in the PPI is zero.

Nevertheless, we will treat estimates of sourcing substitution bias in the wholesale purchaser's index as estimates of that bias in the extended imports index.  The PPI may have an upward bias relative to an economic buyers' index.  It does not take buyers' substitution between producers into account and it uses linking to bring new US producers into the index.  These new producers tend to have lower prices than established US producers (Foster, Haltiwanger and Syverson, 2008).  Furthermore, in practice, in the case of apparel, the PPIs tend to have similar growth rates to MPIs, and for other nondurable goods they often have higher growth rates. To be sure, PPIs do have lower growth rates than corresponding MPIs for some durable goods, but the extra bias that is present in the MPIs for durable goods is impossible to estimate.

Retail prices equal wholesale prices times one plus a markup rate to cover transportation and distribution services.  The growth rate of the CPI could differ from that of the wholesale purchaser's price index solely because the markups for local transportation and distribution services are not constant over time.  To allow for changes in these markups, we also calculate a set

of retail purchaser's indexes that incorporate local transportation margins and trade margins using price indexes and values for transportation margins and wholesale and retail trade margins from the AIAs. In a retail purchaser's index, each component of the costs that add up to a product's final retail price is weighted by its share in those final costs.

Note, however, that even though a retail purchaser's price index is conceptually more suitable to compare with a CPI than a wholesale purchaser's index is, measuring price changes for transportation and trade margins is difficult in practice. Also, the available margin indexes are not specific to the particular products that are imported. Thus it is unclear that adjusting for changes in these margins is better in actual practice than assuming that the margins are constant.

It is also worth remembering that differences in detailed index composition and weighting between the CPI aggregate for a product group and the MPI and PPI aggregates for that product group may affect their relative growth rates. As an example of a difference in detailed composition, luxury vehicles have a larger weight in the MPI for new motor vehicles than they do in the PPI, and it has been suggested that 2001-2007 luxury vehicles had larger price increases than non-luxury vehicles.[12] The differences in mix of varieties composing the indexes mean that taken by itself, a discrepancy between the CPI for an individual product and the supplier and purchaser price indexes to which it is matched would not be indicative of a bias in the product's MPI. The effects of variety mix and weighting differences for detailed products should tend to average out to zero as the number of detailed indexes included in the aggregate becomes large.

---

[12] Bustinza, *et al.*, (2008, p. 26) suggest that this explains the higher rate of growth of the MPI. They also note that manufacturers' incentives, such as rebates, are captured in the PPI but not in the MPI. Direct payment of rebates by the overseas parent would, however, violate IRS rules on transfer pricing, so the import price would have to be low enough so that the local affiliate could afford to pay the rebates. Clausing (2003) finds that transfer prices for imports have higher levels than arm's length prices, but not higher growth rates.

## 8. Empirical Results

### 8.1 Differences between Wholesale Purchaser's Indexes and CPIs

Over the period of 1997 to 2007 the wholesale purchaser's indexes for major product groups grow substantially faster than the corresponding CPIs in the cases of the product groups with relatively large upper bound estimates of sourcing substitution bias in table 1. Furthermore, the growth rate gaps are near zero for product groups with bounds near zero in table 1. Thus, the estimates of sourcing substitution bias implied by the growth rate gaps have a pattern that is consistent with the data on sourcing substitution itself.

In the first column of numbers in table 2, nondurable goods other than apparel and tobacco exhibit a small growth rate difference. (Comparisons that include tobacco are not meaningful because of the strong effect of rising excise taxes on this product's CPI.) Within this broad category, food and alcoholic beverages have a growth rate difference of zero. On the other hand, for motor vehicles—whose bound was around 0.4 percent per year in domestic absorption column of table 1—in table 2 the growth rate gap is 0.3 or 0.4 percent per year, depending on whether parts are included. For apparel and textiles, the growth rate gap is 1.5 percent per year, far above the bound of 0.8 in table 1. For durable goods as a whole, the growth rate gap is 2 percent per year, compared with a bound of 1 percent in table 1.

Rather than using the wholesale purchaser indexes to estimate the price effect of the movement of production to low cost locations, an alternative approach is to directly compare MPIs and CPIs. In the case of motor vehicles, the growth rate gap becomes larger under this approach, at 0.7 percent per year (third column of numbers in table 2. Table 2 also implies that differences in variety mix caused by the luxury models in the MPI are not the explanation of the relatively high growth rate of the MPI. The wholesale purchaser's index gives the appropriate weight to the non-luxury varieties produced in the US and it still rises faster than the CPI.

The product groups other than motor vehicles do not pose a dilemma over which approach to use because for them the MPI and the wholesale purchaser's index have almost the same growth

rate. The growth rate gaps for the MPIs imply that nondurable goods were not subject to sourcing substitution bias, but the MPI gaps average 1.5 percentage points for apparel and textiles, the same for the wholesale purchaser's indexes. For durable goods excluding computers, the MPIs have a slightly larger growth rate gap than the wholesale purchaser's indexes.

## 8.2 Differences between Retail Purchaser's Price Index and CPIs

Changes in margins for transportation within the US and for wholesale and retail distribution services affect the prices that are measured by the CPI, so retailer purchaser's price indexes in which transport and distribution margin prices are included with the appropriate weights are, in theory, better suited for comparisons with CPIs than wholesale purchaser's price indexes. In practice, however, price changes for the "margin" industries are difficult to measure with precision, and the available, highly aggregated indexes for the margin industries could behave differently from customized price indexes for transportation and distribution of durable goods or apparel. Thus, the retail purchaser's prices may not be better in actual practice.[13]

In the cases of durable goods and apparel, there is no need to decide whether the retail purchaser's indexes are really more accurate than the wholesaler purchaser's index because the two indexes are very similar. In those cases, the average growth rate gap in table 2 changes by just 0.1 percent per year when the retail purchaser's indexes are used instead of the wholesale purchaser's indexes. Nondurable goods, however, have a negative growth rate gap using the retail purchaser's indexes. This causes the average growth rate gap for all products except tobacco to fall to 0.6 percent per year using the retail purchaser's indexes..

---

[13] An alternative to calculating these indexes is to treat the price indexes for distribution and transportation margins as unknown and solve for the value required for them to be able to explain the growth rate gap between the wholesale purchaser's index and the CPI. The required growth rates for the price of distribution and transportation services for apparel and for durable goods turn out to be implausibly large negative numbers.

### 8.3  Adjustments for Effects of Tariffs, and the Use of Geometric Means and Hedonics in the CPI

As explained above, declining tariffs tend to reduce the growth rate of the CPI compared with the MPI.  The geometric means used for lower-level indexes in the CPI and the hedonic or hedonic-like quality adjustments in the CPI may also have this kind of effect.  Although the growth rate gaps associated with uses of geometric means and hedonics may also represent biases in the MPI, we wish to estimate the bias from sourcing substitution in isolation.  Plausible sizes for the effects that should be excluded from estimates of sourcing substitution bias can be inferred from prior research on the MPI and the CPI.  They are reported in table 3.

For tariffs, FMRS (2011, p.84) find that using tariff-inclusive import prices reduces the growth of the MPI by 0.08 percent per year over 1996-2006.  Rounding up to 0.1 percentage points gives the adjustment for falling tariffs that we subtract from the growth rate gap between the wholesale purchaser's indexes and the CPIs..

To adjustment for the effect of the geometric mean formula used in the CPI we average estimates of the effect of using geometric means for MPIs and estimates of the effect of using geometric means for CPIs.  FMRS find that switching from a Laspeyres (arithmetic mean) formula to a Törnqvist (geometric mean) formula lowers the average annual growth rate of MPI for non-petroleum goods by 0.67 percentage points when semiconductors, which are not a consumer good, are excluded.  The Törnqvist indexes constructed by FMRS (2011) cover broader aggregates than the geometric mean indexes of the CPI and the formula effect tends to be larger for broader aggregates, so a plausible estimate of the effect of geometric means on nonpetroleum goods in general is 0.6 percent per year. In the case of apparel and textiles, however, FMRS find an effect of just 0.3 percent per year.

The effect on CPI growth rates of the adoption of the geometric mean formula in Stewart and Reed (2009, pp. 36-37) varies from about 0.25 percentage points for the "other goods and services category" and 0.3-0.4 percentage points food and beverages to a maximum of 1.4

percentage points for apparel. (Items with large variances of their price relatives have larger effects.) The "other goods and services" category is the best match for durable goods, and averaging the effect of 0.25 percent for the CPI and 0.6 percent for the MPI and rounding gives an adjustment for geometric means of 0.4 percentage points for durable goods. For apparel and textiles, averaging the 0.3 percent per year effect of the Törnqvist index found by FMRS (2011) and the 1.4 percent per year effect of geometric means in Stewart and Reed (2009) and rounding down gives an allowance of 0.8 percent per year for the effect of CPI's use of geometric means. After making this adjustment and the adjustment for falling tariffs, the growth rate gap for apparel in table 3 becomes 0.6 percent per year.

In the case of durable goods, an adjustment is also needed for the hedonic or hedonic-like procedures used to handle quality changes in computers and some other products, such as major appliances, televisions and video equipment. These procedures have had the largest effect on the CPI for computers. For them, hedonic regressions or implied values of quality attributes from online prices have been used in the CPI for computers since 1998. The wholesale purchaser's index for computers and computer equipment grows 6.4 percentage points faster than the CPI, while for other electric equipment the difference is 4.2 percentage points. Using the growth rate gap for other electric equipment as a proxy for computers reduces the growth rate gap for durables as a whole by 0.2 percentage points. Although this adjustment may seem modest, Bils (2009, p. 648) finds that incorporating hedonically adjusted prices of new models did not reduce the growth rate of a simulated CPI for computers.

The growth rate gap for a few other kinds of durable goods may also be affected by the use of hedonic or hedonic-like quality adjustments in the CPI. The results in Erickson and Pakes (2011) suggest that this effect may be small, however; their table 12 shows that handling item replacements in the CPI for non-computer electric durables by treating them as comparable, or using hedonics or class mean imputation can have either a positive or a negative effect compared to a pure matched models index. We add an additional 0.1 percentage points to the adjustment for

the use of hedonic or hedonic like procedures in the CPI for items other than computers, bringing the total adjustment up to 0.3 percentage points.

Together the three adjustments bring the growth rate gap for consumer durables down to 1.2 percent per year, a figure that exceeds the upper bound in table 1 for the effect of sourcing substitution bias on the domestic absorption index for durable goods by 0.2 percentage points. This suggests that the effect of the price reductions due to technological progress that were measured in the CPI but not the MPI amounted to more than 0.3 percentage points. Kim and Reinsdorf (2014) estimate hedonic price indexes for televisions and cameras using MPI micro data and find that unmeasured declines in quality-adjusted prices due to technological progress contribute more than country substitution bias to the overall bias in matched model import indexes for these goods. The experimental hedonic indexes of Kim and Reinsdorf (2014) may make larger quality adjustments than methods used in the CPI, and televisions and cameras are not representative of durable goods imports in general. Nonetheless, their results show that the declines in quality adjusted prices due to technological progress that are not measured by the MPIs for durable goods could be substantial. An adjustment of 0.5 percentage points of the growth rate gap for the durable goods for this effect would therefore be plausible, and it would bring the estimate of sourcing substitution bias for durable goods down to 1 percent.

A larger adjustment for the effect of the quality change methods in the CPI than the one shown in table 3 might also be justifiable for apparel. The CPI has special procedures for handling quality change for this product, and the indexes calculated by Brown and Stockburger (2006) imply that hedonic adjustment reduces the growth rate of the CPI for apparel by 0.2 percentage points. An adjustment of this magnitude would bring the estimate of sourcing substitution bias for apparel down to 0.4 percentage points. Nevertheless, import prices for apparel behave very differently from retail prices, which are subject to frequent sales and large mark-downs. Imports of apparel may not behave in a way that makes hedonic adjustment necessary, and taken as a whole, the special procedures used for the apparel indexes in the CPI

have the effect of raising their growth rate compared to a matched models index. Furthermore, the bound in table 1 for sourcing substitution bias for apparel is almost 0.8 percentage points.

## 9. Effect of Import Growth on Wholesale and Retail Distribution Margins

Price reductions that are realized by substituting offshore sources of supply for local ones are unlikely to be completely passed on to consumers. Wider margins may be retained by the wholesale and retail distribution industries to cover the higher costs of managing complex international supply chains, holding larger inventories, and using more transportation and insurance services. In addition, wholesalers and retailers may be able to expand their profit margins when they source from the offshore supplier.

To test whether higher proportions of imports in the overall domestic supply of a commodity are associated with higher distribution margins, we regress trade margin levels and growth rates on import share levels and growth rates. The regression implies that a 10 percent increase in the share of domestic supply sourced from imports is associated with a 1.3 percentage point expansion in the distribution margin, with a t statistic of 4.3 (table 4).

The regression in levels could, however, be biased if the types of commodities that are heavily imported—such as apparel—have characteristics that require unusually high distribution services. To control for effects of commodity type, we also test the specification that has growth of distribution margins as the dependent variable. The results show that growth in imports also has a statistically significant effect on growth in distribution margins, with a t statistic of 2.8 (table 5). The coefficient estimates imply that a product whose import share grew by 10 percentage points would have an extra 0.93 percentage points of growth in its distribution margin compared with a product whose import share was stable.

## 10. Implications for the Measurement of Output and Productivity

As explained above, we treat the estimates of the bias in the wholesale purchaser's index as estimates of the bias in the extended imports index. This treatment implicitly attributes part of the growth rate gap compared the CPI to upward bias in the PPI component of the wholesale purchaser's index. It therefore the results in conservative estimates of the effect of sourcing substitution bias in the extended imports index on measured real GDP.[14] Another assumption that we make in calculating the effects on measured growth rate of real GDP is that goods used as intermediate inputs that are similar to a consumer good have the same bias as the consumer good that they resemble. However we exclude capital goods from the bias calculation for real GDP growth because MPIs are part of the deflator for investment. If an MPI is used to deflate both imports of a capital good and uses for investment of that capital good, the bias of that MPI will have no effect of the estimate of real GDP.

Imports of manufactured durable goods amounted to 5 percent of GDP in 2007, so multiplying their share weight by the sourcing substitution bias estimate of 1.2 percentage points implies a contribution to the measured growth rate of real GDP of 0.06 percentage points. This contribution rises to 0.075 percentage points when the bias in the MPI from under-adjustment in quality change in computers and other products with high rates of technological progress is also included. Imports of apparel, footwear and textiles amount to just under 1 percent of GDP in 2007, so their contribution of 0.006 percentage points brings the bias up to 0.066 percentage points from sourcing substitution, or 0.08 percentage points when unmeasured gains from technological progress are included.

Sourcing substitution bias has larger effects on measures of US productivity growth. An upward bias in the deflator for imports of capital goods causes under-measurement of the capital

---

[14] The alternative assumption that the PPI component of the wholesale purchaser's index contributes nothing to the bias in that index would imply that the bias in the wholesale purchasers's index must be divided by share weight for imports to find the bias in the extended imports index. This would make the bias estimate for the apparel extended import index about 40 percent larger and more than double the size of the estimate of the bias in durable goods extended import index.

stock and hence an upward bias in measured multifactor productivity (MFP), so capital goods are included in the bias calculation for productivity.  Also, imports of manufactured durable goods and apparel and textiles are larger shares of private business value added (on which the broadest productivity measures are based) than they are of GDP.[15]  Imports of manufactured durable goods and capital goods amounted to 10.4 percent of the gross value added of private business in 2007, so a sourcing substitution bias of 1.2 percentage points for these goods implies a bias of 0.125 percentage points in measured rate of MFP growth of private business.  Sourcing substitution bias for apparel and textiles causes an additional 0.007 percentage points of upward bias in this MFP measure, so the total bias in the MFP growth rate is slightly more than 0.13 percentage points; when unmeasured gains from technological progress are included  this bias estimate rises to 0.16 percentage points.  This amount of bias is significant compared to the average rate of MFP growth in 1997-2007 of 1.5 percent per year.  Furthermore, sourcing substitution bias seems to account for a significant share of the measured speedup in US productivity growth over the period of 1996-2006, a period that approximately coincides with the period of rapid sourcing substitution.

The sourcing substitution bias estimate of 0.13 percent per year for business sector multifactor productivity seems consistent with the lower bound estimates of offshoring bias for multifactor productivity of manufacturing in Houseman *et al.* (2011, p. 126) using conservative assumptions.  These bias estimates are 0.18 percent per year using the "switchers" sample, or 0.14 percent per year using the assumptions of a 30 percent discount from developing and a 15 percent discount from intermediate countries.  The effects of offshoring of intermediate inputs on measured MFP for manufacturing are greater than for business as a whole because manufacturing uses more intermediate inputs.

Finally, it is important to note that not all of the effects of sourcing substitution have gone unmeasured in the official indexes.  Although prices from suppliers in different locations are not

---

[15] We treat the private business sector used by BLS for productivity measurement as equivalent to the business sector in the NIPAs.  The two sectors differ because the value added of government enterprises is not included in the private business sector.  But the difference amounts to only around 1 percent of the value added of the business sector.

directly compared in constructing these indexes, existing suppliers reduced their prices to compete with the new suppliers from low cost locations (Mandel, 2013), and these reductions would have been captured by the official indexes. Thus, the index for nonpetroleum imports in the NIPAs declined relative to the price indexes for exports and domestic absorption during the period of rapid growth in imports from emerging economies. Indeed, according to the trading gains index for the US in NIPA table 1.8.6, over 1995-2007 the relatively low price growth of nonpetroleum imports completely offset the impact of sharply rising prices for petroleum imports.

## 11. Conclusion

From the mid-1990s to 2007, the goods used in the US had large shifts in sourcing away from high cost countries and to low cost countries, particularly China. Changes in prices paid by buyers arising from substitution between source countries for imports are generally not captured by the MPI, and the price reductions associated with substitution from US producers to imports are out of scope for this index. Thus, the direct effect of sourcing substitution on prices paid by buyers has generally not been reflected in the deflator for imports used in calculating real output growth.

To quantify the bias, we construct wholesale and retail purchasers' index from MPIs and PPIs for products that are imported and used for household consumption and compare these indexes to corresponding CPIs at the level of product groups. For nondurable goods, which experienced little sourcing substitution, the indexes based on MPIs are in close agreement with the CPIs, but for durable goods and apparel they have substantially higher growth rates than the corresponding CPIs.

Falling tariffs, differences in index formulas, and differences in quality adjustment procedures may contribute to the size of the growth rate gaps between the CPI aggregates and the aggregates containing MPIs. After adjusting for these factors, sourcing substitution bias is estimated to add 1.2 percentage points to the average growth rate of the extended imports index

per year for durable goods in 1997-2007, and 0.6 percentage points to the average growth of the extended imports index for apparel and textile products. The adjustments for effects of index formula and quality adjustment procedures are subject to a range of uncertainty. Nevertheless, bigger adjustments would not imply a smaller overall bias, but rather would attribute more of the observed growth rate gaps to bias from formula or quality adjustment procedures.

The effect of the sourcing substitution biases on the average annual growth rate of real GDP is less than 0.1 percentage points. Also, offsetting (though probably smaller) effects may have been present on the export side. At the same time as new trading relationships with emerging economies were bringing down the average price paid by buyers of importable products, or offshored items, they may also have lowered the average price received by US exporters (Harrigan, Ma and Shlychko, 2011). Lower prices offered to new customers in emerging economies may not have been reflected in the US export price index, which would offset some of the effect of the bias in the import price index in calculations of real GDP. In addition, the index formula and quality adjustment procedures used to construct the US export price index are similar to those in the import price index.

On the other hand, sourcing substitution bias did have a significant effect on productivity measurement. It may account for a tenth of measured productivity growth of US private business in the period investigated.

# References

Alterman, William. 2010. "Producing an Input Price Index." Paper presented at the conference "Measurement Issues Arising from the Growth of Globalization," Washington, DC, November, 2009. Accessed at: www.upjohninstitute.org/measurement/alterman-final.pdf.

Alterman, William. 2013. Methods and challenges in constructing an input price index: What can purchasing managers tell us? Paper presented at the conference "Measuring the Effects of Globalization", Washington, DC, February 28–March 1. Accessed at: www.upjohn.org/MEG/papers/Alterman_input_price_index.pdf .

Banister, Judith and George Cook. 2011. "China's employment and compensation costs in manufacturing through 2008." *Monthly Labor Review* 134 (March): 39-52.

Broda, Christian and David E. Weinstein, 2006, "Globalization and the Gains from Variety," *Quarterly Journal of Economics* 121 (May): 541-585.

Brown, Craig and Anya Stockburger, 2006. "Item replacement and quality change in apparel price indexes." *Monthly Labor Review* 129 (December): 35-45.

Bureau of Labor Statistics, 1997. *BLS Handbook of Methods*. Accessed at: http://stats.bls.gov/opub/hom/.

Bureau of Labor Statistics, 2008. "How BLS Measures Price Change for Personal Computers and Peripheral Equipment in the Consumer Price Index." Accessed in August 2011 at www.bls.gov/cpi/cpifaccomp.htm.

Bureau of Labor Statistics News Release, March 8, 2011. "International Comparisons of Hourly Compensation Costs in Manufacturing, 2009." Accessed in May2011 at www.bls.gov/news.release/pdf/ichcc.pdf.

Bustinza, Maria, Daniel Chow, Thaddious Foster, Todd Reese and David Yochum. 2008. "Price Measures of New Vehicles: a Comparison." *Monthly Labor Review* (July): 19-32.

Byrne, David, Brian K. Kovak, and Ryan Michaels. "Pricing and Product Sourcing in an Offshoring Market: Evidence from Semiconductor Production Services." 2011.

Clausing, Kimberly A. 2003. "Tax Motivated Transfer Pricing and US Intrafirm Trade Prices." *Journal of Public Economics* 87, 2207-2223.

Durda, Ceyhun Bora, Enrique G. Mendoza and Marco E. Terrones. 2009. "Precautionary Demand for Foreign Assets in Sudden Stop Economies: An Assessment of the New Mercantilism." *Journal of Development Economics*, 89, Issue 2, (July): 194-209.

Diewert, W. Erwin and Catherine J. Morrison. 1986. "Adjusting Outputs and Productivity Indexes for Changes in the Terms of Trade." Economic Journal 96, 659-679.

Diewert, W. Erwin, and Alice O. Nakamura. 2010. "Bias Due to Input Source Substitutions: Can it be Measured?" In *Measurement Issues Arising from the Growth of Globalization*., Susan Houseman and Kenneth Ryder, editors. Washington: National Academy of Public Administration, pp. 237–265. Accessed at http://www.bea.gov/papers/pdf/bea_2010_conference%20papers_final.pdf .

Erickson, Tim and Arial Pakes. Feenstra, Robert C. 1994. "New Product Varieties and the Measurement of International Prices." *American Economic Review* 101 (August): 1707-1738.

Feenstra, Robert C., Benjamin R. Mandel, Marshall B. Reinsdorf and Matthew J. Slaughter. 2011. "Effects of Terms of Trade Gains and Tariff Changes on the Measurement of U.S. Productivity Growth." Revised version of NBER Working Paper 15592 (December 2009).

Feenstra, Robert, Robert Lipsey, Lee Branstetter, C. Fritz Foley, James Harrigan, J. Bradford Jensen, Lori Kletzer, Catherine Mann, Peter Schott, and Greg C. Wright. 2010. "Report on the State of Available Data for the Study of International Trade and Foreign Direct Investment." NBER Working Paper 16254.

Foster, Lucia, John Haltiwanger, and Chad Syverson. 2008. "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?" *American Economic Review*, 98(1): 394–425.

Griliches, Zvi and Iain Cockburn. 1994. "Generics and New Goods in Pharmaceutical Price Indexes." *American Economic Review* 84 (December): 1213-1232.

Grimm, Bruce. 1998. "Price Indexes for Selected Semiconductors, 1974–96." *Survey of Current Business* 78 (February): 8-24.

Greenlees, John and Robert McClelland. 2011. "New Evidence on Outlet Substitution Effects in Consumer Price Index Data." *Review of Ecomomics and Statistics.*

Harrigan, James, Xiangjun Ma and Victor Shlychkov. 2011. "Export Prices of US Firms". NBER Working Paper 17706. (Revised June 2012).

Hausman, Jerry. 2003. "Sources of Bias and Solutions to Bias in the CPI." *Journal of Economic Perspectives* 17(1): 23-44.

Hausman, Jerry and Ephraim Leibtag. 2009. "CPI Bias from Supercenters: Does the BLS know that Wal-Mart Exists?" In *Price Index Concepts and Measurement*, Studies in Income and Wealth Vol. 70, W. Erwin Diewert, John Greenlees and Charles Hulten, eds. Chicago: Univ.0 of Chicago Press for the National Bureau of Economic Research, 203-231.

Houseman, Susan N. 2011. "Offshoring and Import Price Measurement." *Survey of Current Business* 91 (February): 7-11.

Houseman, Susan, Christopher Kurz, Paul Lengermann, and Benjamin Mandel. 2010a. "Offshoring and the State of American Manufacturing." Upjohn Institute Working Paper No. 10-166.

Houseman, Susan, Christopher Kurz, Paul Lengermann, and Benjamin Mandel. 2010b. "Offshoring Bias in U.S. Manufacturing: Implications for Productivity and Value Added." Board of Governors of the Federal Reserve, International Finance Discussion Papers No. 1007.

Houseman, Susan, Christopher Kurz, Paul Lengermann, and Benjamin Mandel. 2011. "Offshoring Bias in U.S. Manufacturing." *Journal of Economic Perspectives* 25 (Spring): 111-132.

Kamin, Steven B., Mario Marazzi, and John W. Schindler. 2004. "Is China 'Exporting Deflation'?" Board of Governors of the Federal Reserve International Finance Discussion Paper Number 791.

Kamin, Steven B., Mario Marazzi, and John W. Schindler. 2004. "The Impact of Chinese Exports on Global Import Prices" *Review of International Economics*, 14(2), 179–201, 2006.

Kohli, Ulrich. 2004. "Real GDP, Real Domestic Income, and Terms-of-trade Changes." *Journal of International Economics* 62, 83-106.

Lawrence, Robert and Matthew Slaugher. 1993. "International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup?" *Brookings Papers on Economic Activity. Microeconomics*, Vol. 1993, No. 2., pp. 161-226.

Mandel, Michael. 2007. "The Real Costs of Offshoring." *Business Week*, June 18. http://www.businessweek.com/magazine/content/07_25/b4039001.htm

Mandel, Michael. 2009. "Growth: Why the Stats Are Misleading." *Business Week*, June 3. http://www.businessweek.com/magazine/content/09_24/b4135000594984.htm

Mandel, Benjamin R. 2013. "Chinese Exports and U.S. Import Prices." Federal Reserve Bank of New York Staff Reports, no. 591 (January).

McCully, Clinton P. 2011. "Trends in Consumer Spending and Personal Saving, 1959–2009." *Survey of Current Business* 91 (June): 14-22.

Moses, Karin and Brent Moulton. 1997. Addressing the quality change issue in the consumer price index. *Brookings Papers on Economic Activity* 1: 305-49.

Nakamura, Alice O., W. Erwin Diewert, John S. Greenlees, Leonard I. Nakamura. 2014. "Sourcing Substitution and Related Price Index Biases", manuscript.

Nakamura, Emi and Jon Steinsson. 2012. "Lost in Transit: Product Replacement Bias and Pricing to Market". *American Economic Review* 102 (December): 3277–3316.

Reinsdorf, Marshall. 1993. "The Effect of Outlet Price Differentials in the U.S. Consumer Price Index." In Price Measurements and Their Use, ed. Murray F. Foss, Marylin E. Manser, and Allan H.Young, 227–254. Chicago: University of Chicago Press.

Reinsdorf, Marshall, Paul Liegey and Kenneth Stewart. 1996. "New Ways of Handling Quality Change in the US CPI." BLS Working Paper 276.

Reinsdorf, Marshall. 1998. "Formula Bias and Within-Stratum Substitution Bias in the U.S. Consumer Price Index." *Review of Economics and Statistics* 80, no. 2, May, pp. 175-87.

Steward, Kenneth and Stephen Reed. 1999. "Consumer Price Index research series using current methods, 1978-98" *Monthly Labor Review* (June): 29-38.

Thomas, Charles P., Jaime Marquez, and Sean Fahle. 2008. Measuring U.S. International Relative Prices: A WARP View of the World International Finance Discussion Papers No. 917.

Xing, Y., and N. Detert. 2010. How the iPhone Widens the United States Trade Deficit with the People's Republic of China. ADBI Working Paper 257. Tokyo: Asian Development Bank Institute. Available: http://www.adbi.org/working-paper/2010/12/14/4236.iphone.widens.us.trade.deficit.prc/

**Figure 1: US Nonpetroleum Goods Imports as a Percent of US Domestic Absorption of Nonenergy Goods**

Legend: All countries — High wage countries — Asia ex Japan — Latin America



**Figure 2: Import, Producer, and Consumer Price Indexes for Footware**

Legend: Import — CPI — PPI
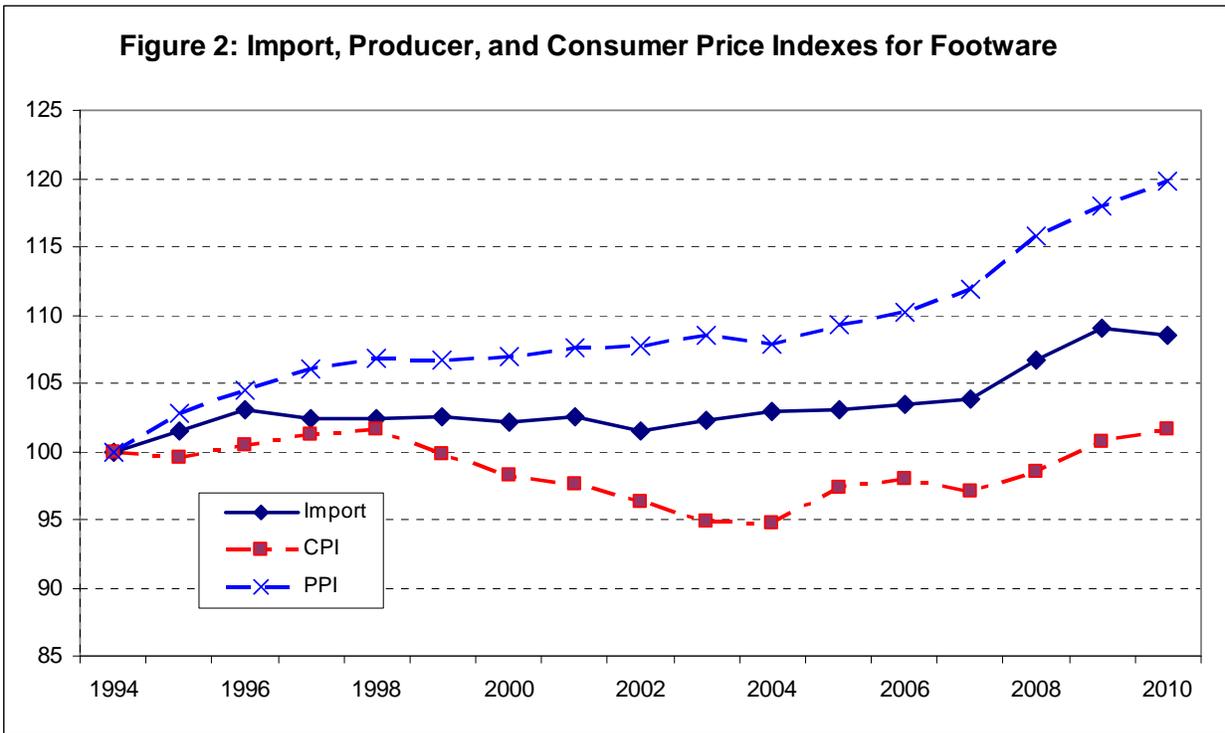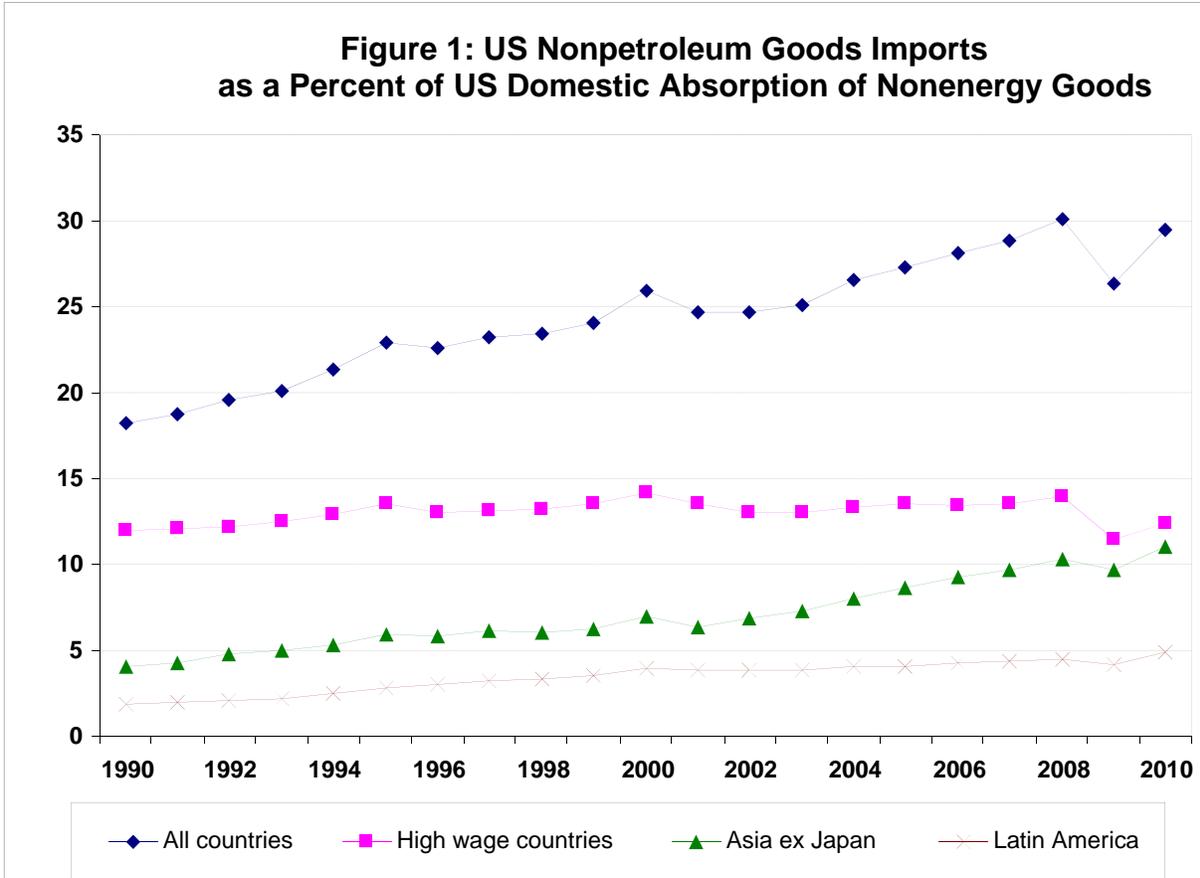
**Figure 3: Import and Consumer Prices Indexes for Apparel**

- Imports, cotton apparel
- Imports, other apparel
- CPI, mens apparel
- CPI, womens apparel
- PPI, apparel
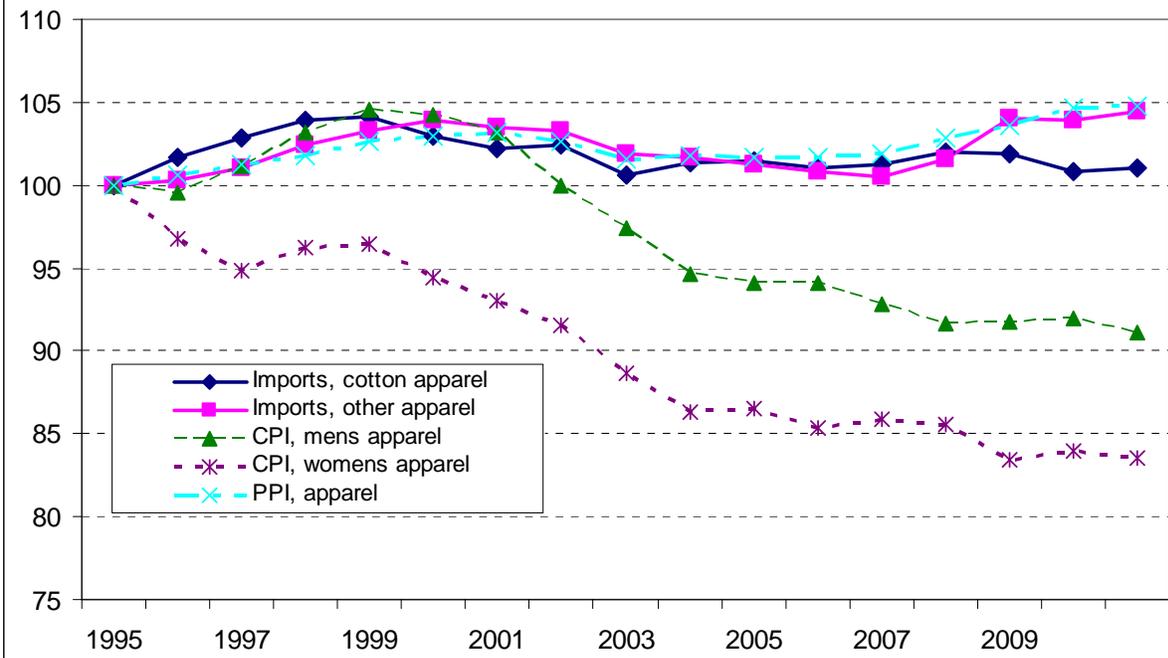


**Figure 4: Import, Producer and Consumer Price Indexes for Vehicles**

- PPI
- Import, new and used
- CPI, new
- CPI, new and used

Figure 5: Import, Producer and Consumer Price Indexes for Tires



Figure 5: Import, Producer and Consumer Price Indexes for Computers
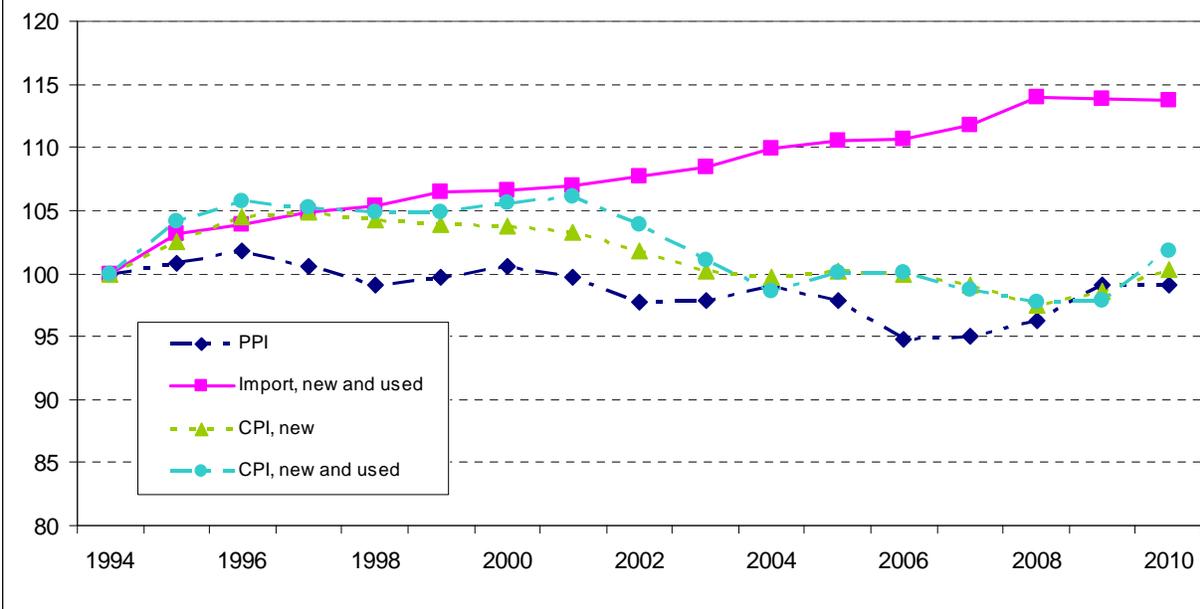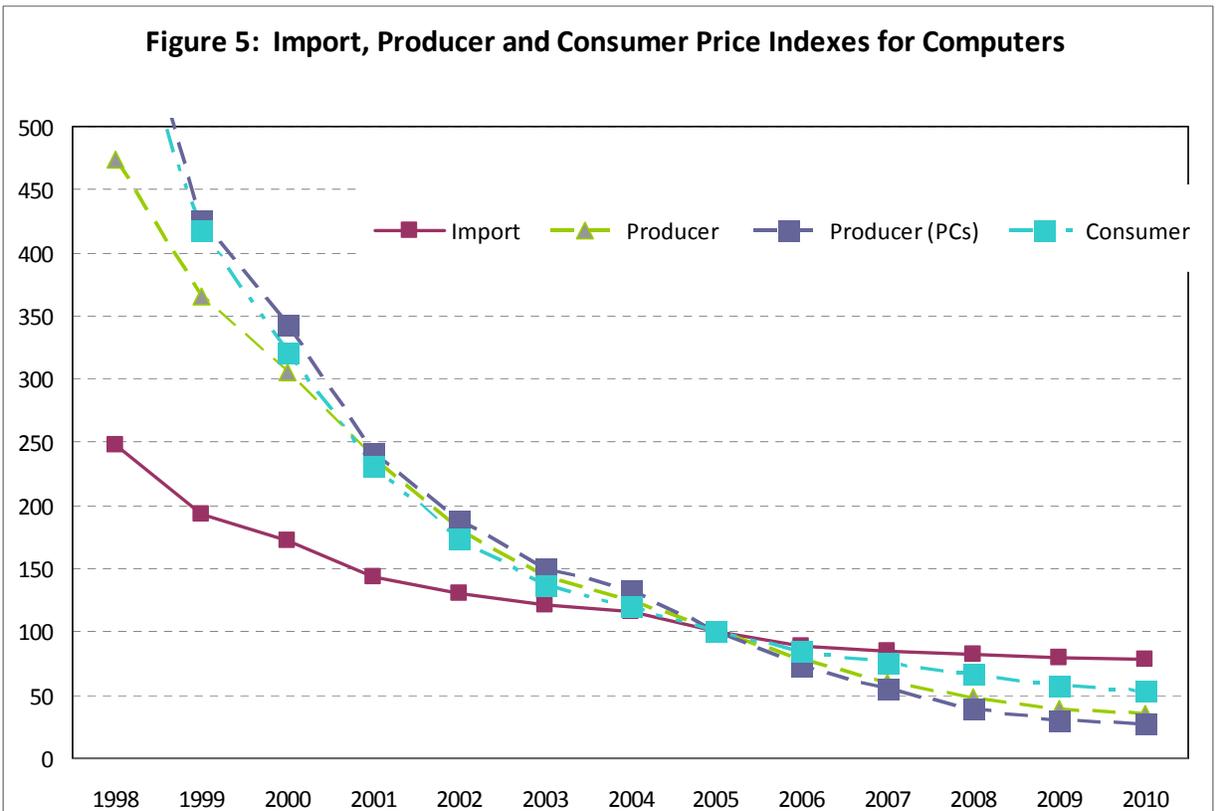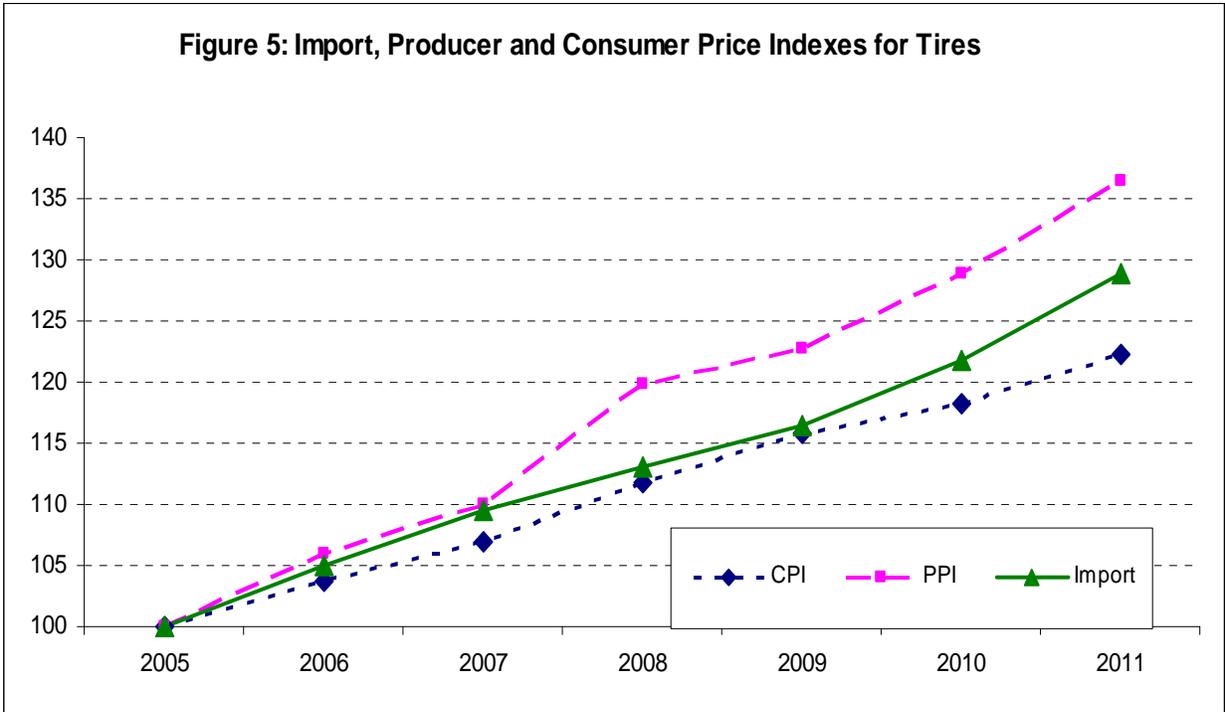
## Figure 7: Import and Producer Prices for Computers, peripherals and parts



Legend: ■ Import   ▲ Producer (computers & computer equipment)
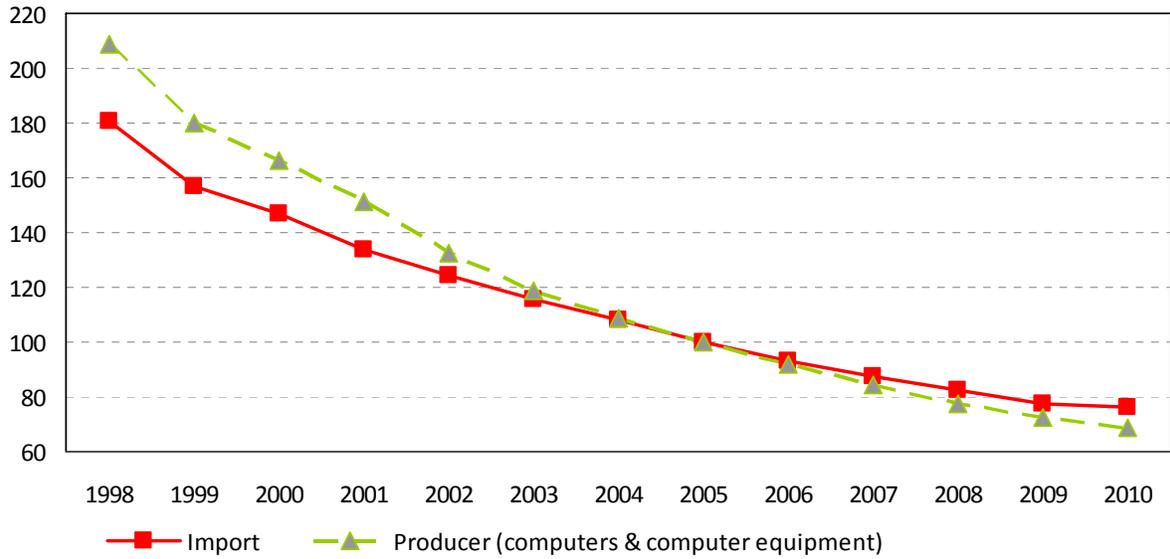
## Figure 8: Import and Producer Price Indexes for Semiconductors



Legend: ◆ Import   ■ PPI
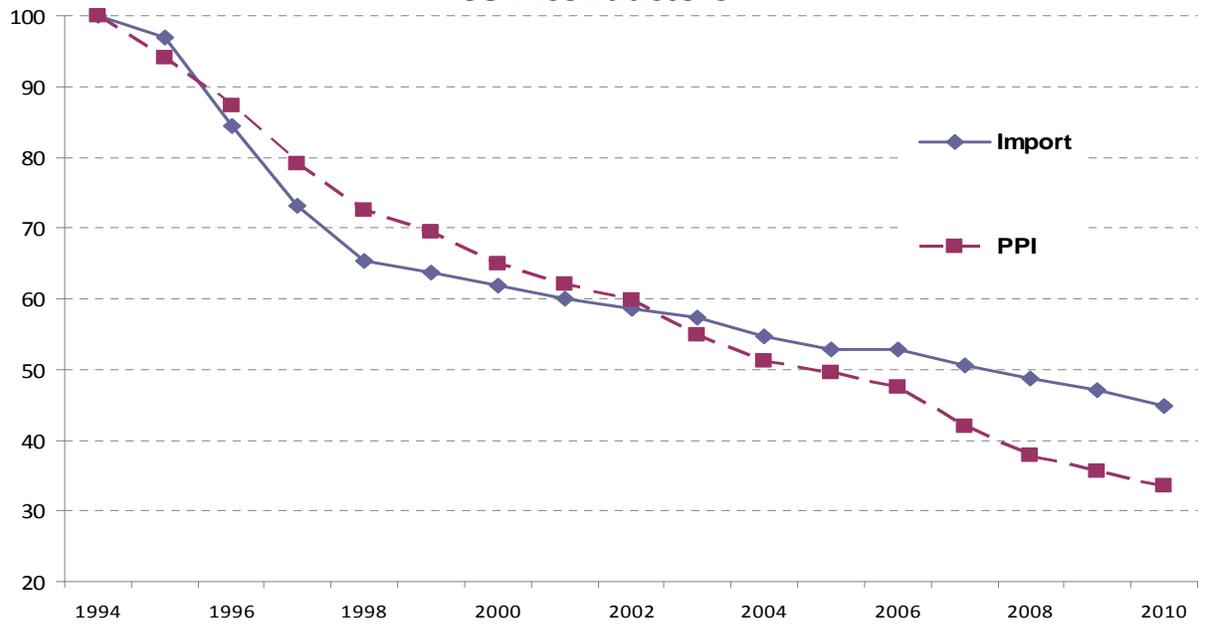
Figure 9: Prices of Consumer Good Imports and Prices of Personal Consumption Goods ex Energy
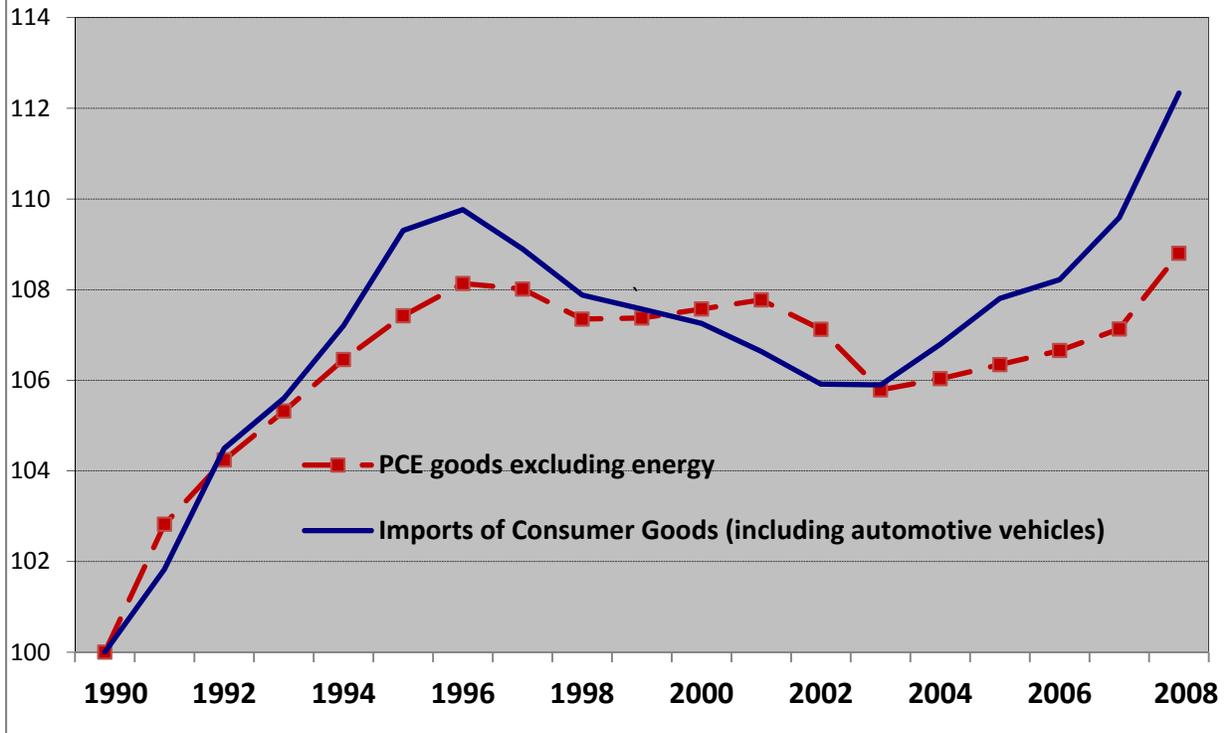
**Table 1: Upper Bounds for Effect of Offshoring and Country Substitution over 1996-2007[a]**

| | Imports Index | Extended Imports Index | Domestic Absorption |
|---|---|---|---|
| **Computers and consumer durable goods excluding motor vehicles** | | | |
| Import share, 1996[b] | 1 | 0.761 | 0.320 |
| Low wage country share, 1996 | 0.653 | 0.497 | 0.209 |
| Change in low wage country share from 1996 to 2007 | 0.183 | 0.339 | 0.143 |
| $\beta$ from equation (2) | 1.09 | 1.09 | 1.48 |
| Effect on index for 2007 (percentage points) | 9.98 | 18.47 | 10.56 |
| Effect on annual growth rate | 0.95 | 1.84 | 1.01 |
| **Motor vehicles** | | | |
| Import share, 1996 | 1 | 0.742 | 0.252 |
| Low wage country share, 1996 | 0.232 | 0. 172 | 0.058 |
| Change in share of low wage countries from 1996 to 2007 | 0.100 | 0.160 | 0.054 |
| $\beta$ from equation (2) | 1.50 | 1.50 | 1.80 |
| Effect on index for 2007 | 7.50 | 11.99 | 4.87 |
| Effect on annual growth rate | 0.71 | 1.15 | 0.45 |
| **Apparel and footwear** | | | |
| Import share, 1996 | 1 | 0.707 | 0.247 |
| Low wage country share, 1996 | 0.886 | 0.627 | 0.219 |
| Change in share of low wage countries from 1996 to 2007 | 0.051 | 0.310 | 0.108 |
| $\beta$ from equation (2) | 1.03 | 1.03 | 1.51 |
| Effect on index for 2007 | 2.61 | 16.02 | 8.17 |
| Effect on average growth rate | 0.24 | 1.57 | 0.77 |
| **Food and beverages** | | | |
| Import share, 1996 | 1 | 0.918 | 0.066 |
| Low wage country share, 1996 | 0.536 | 0.492 | 0.035 |
| Change in share of low wage countries from 1996 to 2007 | 0.008 | 0.052 | 0.004 |
| $\beta$ from equation (2) | 1.30 | 1.30 | 1.92 |
| Effect on index for 2007 | 0.53 | 3.38 | 0.36 |
| Effect on average growth rate | 0.00 | 0.31 | 0.03 |

a. Bounds are based on assumption that $p^L = 0.5p^H$.
b. In 2007 import shares of domestic absorption of the products are: 0.421 for durables, 0.339 for motor vehicles, 0.349 for apparel and footwear, and 0.072 for food and beverages. Personal consumption of them is, respectively, 5.2, 2.6, 2.1 and 4.9 percent of domestic absorption.

**Table 2: Growth Rate Differences from Matched CPIs, 1997-2007**

| | Average Difference from Matched CPIs | | | | Growth Rate of Matched CPIs |
|---|---|---|---|---|---|
| | Wholesale purchaser's price index | Retail purchaser's price index | MPI | PPI | |
| **Nondurables** (ex. tobacco and apparel) | **0.4** | **-0.3** | **-0.1** | **0.7** | **1.7** |
| Food | 0.0 | -0.7 | 0.1 | 0.0 | 2.1 |
| Alcohol | 0.0 | -0.6 | -0.5 | 0.0 | 1.9 |
| Misc. household supplies | 0.6 | -0.1 | -0.2 | 1.3 | 1.4 |
| Paper products, books and magazines | 1.1 | 0.2 | -0.4 | 1.1 | 1.4 |
| Tobacco products | -0.6 | -3.3 | -6.6 | -0.5 | 8.1 |
| **Durable goods** | **2.0** | **2.1** | **2.3** | **1.6** | **-2.4** |
| Vehicles and parts | 0.3 | 0.2 | 0.7 | 0.0 | -0.1 |
| New cars and trucks | 0.4 | 0.5 | 1.2 | -0.2 | -0.6 |
| Electrical equipment ex. computers | 4.2 | 4.8 | 3.5 | 4.3 | -5.6 |
| Computers, peripherals and software | 6.4 | 11.7 | 11.8 | 3.8 | -20.8 |
| Furniture and wood products | 2.3 | 1.4 | 1.5 | 2.5 | -0.6 |
| Tools, hardware and supplies | 1.8 | 0.9 | 1.7 | 1.7 | -0.2 |
| All other durable goods | 3.1 | 1.9 | 3.2 | 2.4 | -0.7 |
| **Apparel and textiles** | **1.5** | **1.4** | **1.5** | **1.5** | **-1.2** |
| Women's and girls' apparel | 1.9 | 1.7 | 1.9 | 1.8 | -1.5 |
| Men's and boy's apparel | 1.3 | 1.4 | 1.4 | 0.7 | -1.5 |
| Other apparel | 2.4 | 1.7 | 2.4 | 2.4 | -1.2 |
| Footwear | 0.6 | 0.5 | 0.6 | 1.2 | -0.4 |
| Textile and sewing products | 1.5 | 1.1 | 1.4 | 1.6 | -0.8 |
| **All products** (ex. tobacco) | **1.1** | **0.7** | **1.0** | **1.1** | **-0.1** |
| **Addendum:** | | | | | |
| Durable goods without computers | 1.8 | 1.7 | 1.9 | 1.6 | -1.5 |
| All Products without computers | 1.1 | 0.6 | 0.8 | 1.1 | 0.1 |

**Table 3: Adjusted Growth Rate Gaps for Wholesale Purchaser's Price Indexes for Durable Goods and Apparel**

**(percent per year)**

|  | Durable Goods | Apparel and Textile Products |
|---|---|---|
| **Observed growth rate gap** | **2.0** | **1.5** |
| **Total of effects other than country substitution bias in the MPI** | **0.8** | **0.9** |
| Declining tariffs | 0.1 | 0.1 |
| Geometric mean formula for elementary aggregates of the CPI | 0.4 | 0.8 |
| Hedonic and similar quality adjustment methods in the CPI | 0.3 | NA |
| **Adjusted Growth Rate Gap** | **1.2** | **0.6** |

**Table 4: Regression of Average Level of Distribution Margin on Share of Domestic Supply from Imports**

|  | Coefficient | t Statistic |
|---|---|---|
| Intercept | 0.3663 | 29.8 |
| Share supplied by imports | 0.1290 | 4.3 |
| Growth of share of imports | 0.0985 | 1.4 |

**Table 5: Regression of Growth of Distribution Margin from 1997 to 2006 on Share of Domestic Supply from Imports**

|  | Coefficient | t Statistic |
|---|---|---|
| Intercept | 0.0067 | 1.2 |
| Share supplied by imports | 0.0272 | 1.9 |
| Growth of share of imports | 0.0934 | 2.8 |

## Appendix: The Unit Value Index as Cost of Living Index given Uniform Quality

Cost of living indexes (COLIs) differ from fixed basket indexes like the Paasche index by including a substitution effect $E_s$ representing buyers' gains from substitution. In the case of substitution between sellers of different versions of a product, the unit value index is equal to a cost of living index (COLI) that assumes that no quality adjustment is needed. The substitution gains simply equal the change in costs caused by the change in purchasing patterns.

For the model of equation (1), the Paasche index equals $(p_1^H q_1^H + p_1^L q_1^L)/(p_0^H q_1^H + p_0^L q_1^L)$. Let $V_1 = p_1^H q_1^H + p_1^L q_1^L$ and let the price change effect $E_p = (p_1^H - p_0^H)q_1^H + (p_1^L - p_0^L)q_1^L$, the change in the cost of the period 1 quantities as prices move from their period 0 values to their period 1 values. Then the Paasche index can be written as $V_1/(V_1 - E_p)$. To transform this index into a Paasche-perspective COLI, $E_s$ is added to the denominator. The COLI is:

$$\text{COLI} = V_1/[V_1 - E_p + E_s].$$

Consider, first, the case when the total quantity consumed remains constant as sourcing changes to country group L from country H. The increase in the quantity purchased from country L equals the decrease in the quantity purchased from country H and $E_s = (p_0^H - p_0^L)(q_0^H - q_1^H)$, the cost savings on the $q_0^H - q_1^H$ units whose sourcing is changed. The assumption that no quality must be sacrificed to obtain the lower price implies:

$$V_1 - E_p + E_s = p_0^H q_1^H + p_0^L q_1^L + p_0^H(q_0^H - q_1^H) + p_0^L(q_0^L - q_1^L)$$
$$= p_0^H q_0^H + p_0^L q_0^L$$
$$= \bar{p}_0(q_0^H + q_0^L)$$

The numerator of the COLI equals $\bar{p}_1(q_1^H + q_1^L)$, so the COLI equals the unit value index $\bar{p}_1/\bar{p}_0$.

Now suppose that buyers increase their purchases from L by **more** than they reduce their purchases from H. The additional quantity purchased equals $(q_1^H + q_1^L) - (q_0^H + q_0^L)$. Had this additional quantity been purchased in period 0, the buyers would have had the average purchasing

pattern of that period and, hence, paid an average price of $\bar{p}_0$.  The gains from substitution on the additional units thus equal:

$$(\bar{p}_0 - p_0^L)[(q_1^H + q_1^L) - (q_0^H + q_0^L)].$$

With these additional gains from substitution included in $E_s$, the denominator of the Paasche-perspective COLI is:

$$
\begin{aligned}
V_1 - E_p + E_s &= p_0^H q_1^H + p_0^L q_1^L + (p_0^H - p_0^L)(q_0^H - q_1^H) + (\bar{p}_0 - p_0^L)[(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= p_0^H q_0^H + p_0^L [q_1^L - (q_1^L - q_0^L)] + \bar{p}_0 [(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= p_0^H q_0^H + p_0^L q_0^L + \bar{p}_0 [(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= \bar{p}_0 (q_0^H + q_0^L) + \bar{p}_0 [(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= \bar{p}_0 (q_1^H + q_1^L).
\end{aligned}
$$

The numerator of the COLI equals $\bar{p}_1 (q_1^H + q_1^L)$, as before.  Thus, with the more general assumption about the total quantity purchased the COLI again equals the unit value index.