

Effects of Offshoring and Country Substitution on Measurement of Prices and Productivity

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September 2013

Recent decades have seen substantial migration of the production of the goods consumed in the US to low wage offshore locations. Much of the substitution of varieties produced in low wage locations for varieties produced in the US or other high wage locations has been driven by lower prices, but the methods used to construct the import price indexes for the US are likely to miss declines in prices resulting from country substitution. The US consumer price indexes are however, likely to capture much of these price reductions in cases of goods used for personal consumption. Using detailed data from BEA's annual industry accounts, we identify items used for final consumption of persons that are supplied at least partly from imports, which we aggregate into product categories using weights that reflect the composition of personal consumption. We also construct wholesale and retail purchaser's price indexes combine import price indexes and US producer price indexes. We find that the import price indexes and the purchaser's price indexes have higher growth rates than the CPIs for apparel and textile products and for other durable goods, but not for nondurable goods. After adjusting for the influence of tariffs and methodological differences, the lower growth rate of the CPIs implies unmeasured gains to buyers of imports from substitution to low-wage sources of supply of 0.6 percent per year for apparel and textile products and 1.3 percent per year for other durable goods in 1997-2007. The implied upward bias in measured real GDP growth is under 0.1 percent per year, however, because the shares of the affected imports in GDP are relatively small.

* An earlier version of this paper was presented at the 2009 Conference on Measurement Issues Arising from the Growth of Globalization sponsored by W.E. Upjohn Institute for Employment Research and the National Academy of Public Administration. The views in this paper are those of the authors and should not be attributed to the Bureau of Economic Analysis. We are grateful for the assistance of Brian Lindberg. Corresponding author: Marshall.Reinsdorf@BEA.gov.

1. Introduction

Since 1970 growth in the international engagement of the US economy has transformed it from an economy that was relatively closed to one in which foreign products and foreign markets play major roles. Imports of nonpetroleum goods have grown particularly rapidly, rising from less than 4 percent of US GDP in 1970-71 to nearly 12 percent of GDP in 2006-08. Compared to the relatively sluggish growth of domestic absorption of nonpetroleum goods, import growth for these goods is even more remarkable: from a starting point of just 8 percent of domestic absorption of nonpetroleum goods in 1970-71, imports of these goods grew to 18 percent in 1990 and to 30 percent in 2008 (figure 1).¹ Imports of types of finished goods used for personal consumption expenditures (PCE) exhibited similar growth. Between 1969 and 2009, at free on board (fob) prices imports 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).

Many factors have contributed to the growth of US imports. Falling communication costs, advances in managing the logistics of fragmented supply chains, trade liberalization agreements, expanding membership of the WTO to include China and many other emerging economies, scale economies, and entry of new varieties have fostered new and expanding trade flows as part of the process of globalization. Furthermore, emerging economies such as China have experienced economic reforms, capital deepening, labor reallocation from agriculture to manufacturing, and rising productivity, resulting in dramatic increases in their production of tradable goods. Finally, after the Asian currency crisis of 1997, reserve accumulation by Asian countries seeking to self-insure against sudden stops (Durda, Mendoza and Terrones, 2009) lowered exchange rates and made these countries' exports cheaper in dollar terms.

¹ Domestic absorption of nonpetroleum goods is calculated as personal consumption expenditures on goods excluding energy products, plus private and government gross investment. Imports are at fob prices.

The widespread substitution of imports for local production has occurred at a time when lower wage countries were replacing high wage countries as sources of imports. Imports of nonpetroleum goods expressed as a percent of domestic absorption nonpetroleum goods (where domestic absorption of goods is defined as domestic final uses of goods for consumption or investment) rose by almost 12 percentage points between 1990 and 2008 (figure 1). Almost all of this rise in imports can be attributed to lower wage countries. Consistent with this, 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 2010.² At the same time, China increased its share of US non-petroleum goods imports from 3.4 percent to 23 percent.³

This paper explains why price declines occurring when import buyers substitute to new countries of origin are likely to be missed by the US import price index (MPI) and then estimates the size of the resulting bias in the indexes for final goods used for personal consumption. If the MPI has failed to capture price declines realized by sourcing in low wage countries, US output and productivity growth may have been overstated. Also, some inferences about effects of import growth on economic trends such as rising wage inequality may have to be revisited. For example, the fact that MPIs for the labor-intensive products did not decline relative to MPIs for skill-intensive products in times of rapid growth of imports from low wage countries has been viewed as showing that international trade was not a cause of rising wage inequality (Lawrence and Slaughter, 1993, p. 198). Yet some key elements of the price competition that US producers have faced from imports from emerging economies may be invisible in the US MPI because of the way that it is constructed.

² Country breakdowns for imports must be interpreted with care. The Chinese *content* of US imports as a whole is less than share of imports directly sourced from China because of the intermediate inputs from other countries embodied in imports coming from China. Ying and Detert (2010) illustrate this point using the example of the iPhone. The estimates of the shares of non-petroleum good imports are calculated from data on fob values of imports by country of origin and Enduse code from the US International Trade Commission.

³ The cost of manufacturing labor in China was much lower than in the US in period of these import share gains: Banister and Cook's (2011) estimate of compensation at market exchange rates of manufacturing workers in China implies that in 2008 compensation costs in China were 4 percent of their US level.

2. How the MPI Treats Price Level Differences when the Production Shifts to a Different Country

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 by the MPI (Mandel, 2007 and 2009, and Houseman *et al.*, 2010a, 2010b and 2011). When an item that has been offshored enters as a new import, the new import is left out of the calculation of the MPI until prices from two months are available. Then the change in the import price is included in the calculation of the average price change for the good in question.

In the case of a product whose production shifts between two foreign locations, prices from both the initial and current time period may be available. Nevertheless, a product that has begun to be imported from a new location is likely to be linked into the MPI rather than treated as a continuation of the previous version of the product. Linking is a procedure used in matched model indexes to handle exits and entries; in a matched model index, only the unique items that are present in both the current and preceding month are used to calculate the index's change for the month. Nakamura and Steinsson (2012) discuss the bias in the MPI (and the export price index) that arises because they use linking to handle product replacements. In effect, price changes that occur when new product versions replace existing ones are handled like missing values.

Relocation of production to countries where costs are lower has been an important source of changes in import prices that would be unmeasured by a matched model type of import index. This effect also has the distinction of being long term and broad based—other possible sources of product replacement bias in the MPI tend to be either specific to certain kinds of items, such as items undergoing rapid technological progress, or easily reversible, such as exchange rate movements. The behavior of the MPI during the period of rapid growth in imports from low wage countries is consistent with the hypothesis that declines in prices paid by import buyers when they substitute to suppliers in these countries have been linked out of the index. Comparisons of MPIs and US producer price indexes (PPIs) that cover six or more years are possible for seven products.

In one case (footwear in figure 2) a downward trend in import prices relative to the PPI is apparent, but in six cases the MPI usually matches or grows faster than the PPI (figures 3-8).

3. Country Substitution and Offshoring as Sources of Bias

The problem of unmeasured changes in the average price paid by import buyers when foreign countries with lower costs enter and replace higher cost foreign countries as suppliers of an imported item 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 therefore be termed “country substitution bias”.

New kinds of imports from low wage countries can also be substituted for local production in the US. Although offshoring can result in important declines in prices paid by the buyers of a product, these declines are not in scope for the import price index. Nevertheless, they can cause bias in measures of real GDP and productivity growth and of the real value added of industries that use imported intermediate inputs. One way to avoid these biases would be to deflate imports using an extended import price index that includes price changes from offshoring.

In a model of how changes in sourcing affect measurement of an industry’s cost of intermediate inputs, Diewert and Nakamura (2010, 249) find that in measuring an industry’s real value added country substitution bias and offshoring can both be handled by the same sort of unit value import index. In this index, the intermediate input that was produced locally in the initial time period and offshore in the final period is included in the unit value for the initial period just as though it had been an import. Because this index includes items that start out as locally supplied items, it will be termed an extended imports index.

Similarly, for purposes of measuring real GDP, an extended imports index that includes offshored items must be used to deflate the imports component of GDP when GDP is measured using the final expenditures approach as domestic absorption plus exports minus imports. The imports index used to measure real GDP should have the property that changes in the imports and

domestic absorption components of the GDP deflator cancel out when import prices changes and those changes are passed through to domestic absorption prices. Price changes associated with shifts in sourcing from local to offshore production must be treated like changes in the price of an imported item in the extended import price index because they affect the domestic absorption price index the similar way. If the quality does not change when the item is offshored, unit values that include the offshored item both before and after it began to be imported are used for extending import index.

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

A model in which two groups of countries produce an item whose quality does not vary provides a simple way to calculate plausible ranges for offshoring and country substitution bias using unit value indexes. This approach is best suited for gauging the upper bounds for what the bias could be, because unit value indexes have a tendency to overstate the bias for reasons that will be discussed in the next section.

In period 0 let the item's price be p_0^H if it comes from a high wage country and $p_0^L < p_0^H$ if it comes from a low wage country. The value shares of high wage and low wage countries in overall imports of the item are, respectively, s_0^H and s_0^L . In period 1, the value share of imports from the low wage countries increases to s_1^L . Also, both prices change by a factor of r between period 0 and period 1. The linked index therefore equals r in period 1.

Because the versions of the product from low wage and high wage countries are of the same quality, the true price index is a ratio of unit values:

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

The bias of the linked index is $r - \frac{\bar{p}_1}{\bar{p}_0}$. As discussed above, offshoring can be handled in this index by including in q_0^H the quantity of the offshored item that was produced locally in period 0.

Diewert and Nakamura (2010, p. 247) derive a formula for the bias in the linked index in which the change in the *quantity* share of the low priced country is multiplied by its price discount $1 - p_1^L/p_1^H$ and also by the linked index itself. In empirical applications, however, data on quantity shares are likely to be unavailable. A possible solution to this problem is to approximate the bias by replacing the quantity share change with the change in value shares, resulting in the bias formula $(s_1^L - s_0^L)(1 - p_1^L/p_1^H)r$; for example, Houseman, Kurz, Lengermann and Mandel (2011, p. 121) use this approach.

The Diewert-Nakamura formula can be modified to incorporate value shares, however. To transform the quantity share of the low wage countries into a value share, imports from low wage countries must be valued at the high price, then the transformed shares must be renormalized so that they add up to 1.⁴ The factor β that transforms the quantity share of the low wage countries into a value share can be written as:

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

Here it is worth pausing to note that the distinction between quantity shares and value shares is also relevant if unit value indexes for a product's domestic absorption and its imports are aggregated in a price index for GDP that takes account of the effects of offshoring. Normally the Paasche price index for GDP has weights proportional to the values in the final period, and the Laspeyres index has weights proportional to values in the initial period. Yet if the effect of offshoring production of a product is modeled by unit value indexes for both imports and domestic absorption, the ratio of the weight on the imports of the product in the price index for GDP to the weight on domestic absorption of the product should equal the ratio the *quantity* imported to the *quantity* used for domestic absorption (which may be partly supplied from local production). This

⁴ The adjustment to convert value shares to quantity shares that is mentioned above at the end of the preceding section is an inverse of this sort of transformation, but instead of a ratio of the high price to the low price, it would involve a ratio of the average price of the local and imported supply of an item to the average price for imports of the item.

is more a theoretical problem than a practical problem, however. The difference between quantity weights and value weights is likely to be small: instead of the ratio of the high price to the low price used in equation (2), the adjustment factor at the higher level of aggregation will depend on the ratio of two price averages, one for the consumption of the product as part of domestic absorption and the other for imports of the product. Also, if the total quantity of the item that is imported remains constant as production is reallocated between countries, and the total quantity of the item that is used for domestic absorption is similarly constant, the distinction between quantity weights and value weights will not matter.

Returning to the problem of the changing country shares on the unit value index, express the unit value index that has value shares as weights as a ratio of harmonic means:

$$\begin{aligned} \frac{\bar{p}_1}{\bar{p}_0} &= \frac{\frac{s_0^H}{p_0^H} + \frac{s_0^L}{p_0^L}}{\frac{s_1^H}{p_1^H} + \frac{s_1^L}{p_1^L}} \\ &= r \frac{\frac{s_0^H}{p_0^H} + \frac{s_0^L}{p_0^L}}{\frac{s_1^H}{p_0^H} + \frac{s_1^L}{p_0^L}} \end{aligned} \quad (3)$$

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 formula for the unit value index from r then gives a bias formula of $s_1^L (1 - p_1^L/p_1^H) r \beta$.

In the case when $s_0^L > 0$, the bias in the linked index also 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 β of equation (2), we have:

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

$$\begin{aligned}
&= r \frac{(s_1^L - s_0^L) \left(\frac{p_0^H}{p_0^L} - 1 \right)}{s_1^H + s_1^L \frac{p_0^H}{p_0^L}} \\
&= (s_1^L - s_0^L) \left(1 - p_0^L / p_0^H \right) r \beta. \tag{4}
\end{aligned}$$

The share of US imports of items in a product group coming from low wage countries can be calculated from trade data available from the US International Trade Commission. Using a broad definition of low wage countries as Asia other than Japan, Latin American, Africa, Eastern Europe and former Soviet Republics implies that low wage countries made considerable gains in supplying imports of consumer durables and apparel and footwear over 1996-2007. Their value shares rose by 18.3 percentage points for computers and consumer durable goods other than motor vehicles, by 10 percentage points for motor vehicles, and by 5.1 percentage points for apparel and footwear (table 1). China accounted for most of the gains in the cases of consumer durables and apparel.

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.⁵ For purposes of finding an upper bound for the plausible range of offshoring and country substitution bias, this number can be used to calibrate equation (4). Letting r equal 1, the upper bound estimates for the country substitution bias in the import price indexes are then about a quarter percent per year for apparel and footwear, about 0.7 per year for motor vehicles, and slightly under 1 percent per year for consumer durable goods including computers and excluding motor vehicles (first column of numbers in table 1).

⁵ 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, I treat the middle income countries like developing countries. China, which was not a middle income country, is the dominant source of the market share gains for consumer durable goods other than motor vehicles and for apparel and footwear.

On the other hand, for imports of food and beverages, the bias is zero. This shows that the products with high bounds for their bias in table 1 should not be presumed to representative of other kinds of products. Expenditures on the two products found to have the largest potential for bias in table 1 (computers plus consumer durables excluding motor vehicles and apparel) accounted for 7.8 percent of overall domestic absorption in 2007.

To investigate the combined effect of offshoring and country substitution requires an extended import index that incorporates the quantity that switched from being sourced locally in the US and to being source offshore. Although the effect on the extended imports index does not itself represent a bias, it is of interest because in measuring real GDP the extended imports index must be used to deflate imports to controlling for the effects of offshoring and country substitution on domestic absorption prices.

To estimate the amount offshored, assume that in the initial period the share of domestic absorption of a product supplied by imports of finished goods plus the local production that was subsequently offshored equals the final period share of imports of finished goods of that product in domestic absorption. (Note that the shares of product imports in domestic absorption are held down by the presence of internal transportation margins and wholesale and retail trade margins in the prices paid by final consumers but not in fob import prices.) In the extended imports index, the denominator used to calculate the share of low wage countries in imports of the product should be multiplied by the ratio of the initial period share of imports in domestic absorption to the final period share of imports in domestic absorption. Imports account for growing shares of the overall supply of the products covered by table 1, so for these products the initial period share coming from low wage countries is lower in the extended import index than in the pure import index. The change in the share of group L countries is thus $s_1^L - s_0^L \left(\frac{s_0^M}{s_1^M} \right)$ in the case of the extended imports index.

Comparing the effects in middle column of table 1 to bias figures in the first column of numbers shows that offshoring has a large impact on the extended index for apparel and footwear, raising the bound for the annual growth rate effect to over 1.5 percent per year. In this product category, imports grew rapidly but the mix of country types within imports changed only slightly. The upper bounds for the annual growth rate effect on the index that includes offshoring are 1.8 percent per year for computers and consumer durable goods and over 1 percent per year for motor vehicles. For food and beverages, bringing in offshoring raises the bound for the effect from 0 to a still-small 0.3 percent per year.

The reason to calculate an extended imports index is that it can be used to control for the effects of sourcing changes on the index for domestic absorption in constructing a price index for GDP. The last column of table 1 looks at the effect on the product-level domestic absorption index directly. Multiplying the imports as a share domestic absorption by the share of low wage countries within imports gives an estimate of the overall share of domestic absorption sourced from low wage 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. Approaches with Imperfectly Substitutable Varieties

The estimates in table 1 confirm that substantial biases from offshoring and country substitution are not implausible. They are, however, indicators of the upper bound for how large the bias could be, not point estimates. Treating varieties from different countries as imperfect substitutes would imply smaller bias estimates than the unit value index approach.

Unit values are generally the appropriate way to aggregate varieties from the different suppliers of a product (or purchased at different points in time during the accounting period) that have the same level of quality. Under an assumption of uniform quality the correct quantity index for the product tracks changes in the total quantity purchased. This form for the quantity index then implies a unit value index as the measure of price change.

To make its quality assumption explicit, the unit value index of equation (1) can be derived as a cost of living index (COLI) that uses the quantities of the Paasche price index and that assumes that no quality adjustment is needed to measure buyers' gains from substitution. To begin, write the ordinary Paasche price index as $V_1/(V_1 - E_p)$, where V_1 is the actual value of the quantities purchased in the final period and E_p is a pure price change effect equal to the change in the cost of the period 1 basket given the changes in prices between period 0 and period 1. Under the assumptions of equation (1), $V_1 = p_1^H q_1^H + p_1^L q_1^L = \bar{p}_1(q_1^H + q_1^L)$, and $V_1 - E_p = p_0^H q_1^H + p_0^L q_1^L$. A cost of living index (COLI) also includes a substitution effect E_s representing buyers' gains from substitution; in the Paasche-perspective case, E_s is measured at the prices of period 0 and the COLI is $V_1/[V_1 - E_p + E_s]$. If no quality must be sacrificed to obtain a lower price, buyers' gains are $(p_0^H - p_0^L)(q_0^H - q_1^H)$ on the $q_0^H - q_1^H$ units for which they substitute to a source in the low wage country. In addition, suppose that new buyers purchase $(q_1^H + q_1^L) - (q_0^H + q_0^L)$ units from the low wage country and none from the high wage country. Had they purchased in period 0, these buyers would have had the average purchasing pattern of that period and paid an average

price of \bar{p}_0 , so they have imputed gains from substitution equal to $(\bar{p}_0 - p_0^L)[(q_1^H + q_1^L) - (q_0^H + q_0^L)]$. With these imputed gains from substitution in E_s , the denominator of the COLI is:

$$\begin{aligned}
V_1 - E_p + E_s &= p_0^H q_1^H + p_0^L q_1^L + (p_0^H - p_0^L)(q_0^H - q_1^H) + (\bar{p}_0 - p_0^L)[(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= p_0^H q_0^H + p_0^L [q_1^L - (q_1^L - q_0^L)] + \bar{p}_0 [(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= p_0^H q_0^H + p_0^L q_0^L + \bar{p}_0 [(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= \bar{p}_0 (q_0^H + q_0^L) + \bar{p}_0 [(q_1^H + q_1^L) - (q_0^H + q_0^L)] \\
&= \bar{p}_0 (q_1^H + q_1^L).
\end{aligned} \tag{5}$$

The numerator of the Paasche-perspective COLI equals $\bar{p}_1 (q_1^H + q_1^L)$. Dividing by the expression for its denominator derived in equation (5) shows that the COLI equals the unit value index.

The assumption of uniform quality generally implies that price dispersion is present and that buyers' choices are inconsistent with static optimization because of factors like costly or imperfect information, long term contracts or supplier relationships, capacity constraints and lagged adjustment. Yet even when such factors are at work, quality differences are also likely to play a role in price differentials between sellers. In particular, the assumption that new imports from low wage countries are of the same quality as the version of the product that was produced locally probably overstates import buyers' gains from offshoring. Even if the physical characteristics match, some allowance for a quality decline may be needed to account for higher transportation costs, communication inefficiencies, and longer delays in receiving shipments.

Quality differences mean that varieties from different locations are imperfect substitutes. One situation where imperfect substitutability plays an important role is when a low priced variety enters the market and buyers have a range of perceptions of the value of the extra quality offered by the higher-priced incumbent. The proportion of buyers whose willingness-to-pay for the incumbent's higher quality exceeds the price gap becomes smaller as the price gap becomes larger. In the aggregate, the purchasing patterns imply a representative consumer with a

downward-sloping demand curve for the entering variety that is positioned so that the quantity demanded is zero at a price equal to the incumbent's price.

Griliches and Cockburn (1994) use this approach to measure the effect on a buyer's price index of the entry of a cheaper generic version of a branded pharmaceutical that has gone off patent. They find that the price index the drug can be approximated using the quantities from a Paasche price index and making a quality adjustment to the price of the generic that closes half of the gap between its price and that of the branded drug. The assumption of a uniform distribution for willingness-to-pay for brandedness implies that in the aggregate buyers behave as though there were a representative consumer with a straight line demand curve for brandedness. The average value of the quality difference is then measured by half of the difference between the branded and generic prices. (This approximation is similar in spirit to the use of the Fisher index to approximate the cost of living index, as it averages the consumer surpluses that are implicitly assumed by the Laspeyres and Paasche indexes of the original, unadjusted prices.)

Substitution to an offshore source of supply in a low wage country is in some respects analogous to substitution to a newly available generic pharmaceutical. If import buyers' marginal valuation of the extra quality of the version of the product coming from high wage countries rises smoothly from zero for the first unit substituted to the entire price gap for the last unit substituted, a quality adjustment to the low price equal to half the price gap will provide an acceptable approximation to an economic buyer's index (which is a generalization of the COLI). Such a quality adjustment would yield point estimates equal to halve of the bounds in table 1. With half of the assumed price difference between high wage and low wage countries treated as due to lower quality, the bounds for the effects on the domestic absorption indexes falls to 0.5 percent per year, 0.2 percent per year, and 0.4 per year for the indexes for domestic absorption of computers and consumer durables, motor vehicles, and apparel and footwear, respectively. Although a quality adjustment equal to half of the price savings may overstate the average quality difference, the 50

percent price difference between high wage and low wage countries assumed in table 1 is also likely to be an overestimate of the average difference.

Another implication of imperfect substitutability is that the availability of more varieties leads to gains in consumer welfare. A taste for variety on the part of import buyers can enable a new supplier of a differentiated product to enter by producing a version of the product with different characteristics that appeal to some buyers. Thus not all the growth in imports from low wage countries can be attributed to their ability to offer lower prices for product versions that are substitutes—either perfect or imperfect—for those produced in high wage countries. Estimates of effects of taste for variety include the impact of entry by new countries within the high wage group and the negative impact of exits.

Suppose that import buyers' tastes for varieties of a product are described by a CES model with an elasticity of substitution σ that is greater than 1. In this model, higher expenditure shares correspond to lower quality-adjusted prices, so if a variety exits and a replacement variety enters and garners a higher expenditure share than the exiting variety had, its quality-adjusted price must be lower than that of the variety that exited adjusted for the overall price change of the product between the two time periods. The net bias in a matched model index from buyers' gains and losses from new and disappearing varieties or quality changes in existing varieties is measured by a formula developed by Feenstra (1994). Let λ_t be 1 minus the expenditure share of the varieties that are present in period t but not in period $t-1$, and let λ_{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, letting σ equal 4.8 (the average of the mean estimates of σ excluding commodities for 1990 to 2001 in table VI of Broda and Weinstein, 2006), if the period t market share of new supplying countries exceeds the period $t-1$ market share of the exiting countries by 1 percent, the bias in the growth rate of the matched model index is 0.264 percent.

Feenstra, Mandel, Reinsdorf and Slaughter (2011; hereafter FMRS) estimate the effect of variety entry and exit on the MPI treating countries as suppliers of different varieties. The results imply that new supplying countries had quality-adjusted prices that were comparatively low: the net effect of the entry and exit of countries supplying imports on the nonpetroleum MPI averages about 0.6 percent per year in 1995-2006. Although this estimate includes effects of higher quality or distinctive features of some new varieties, effects of lower prices for similar quality levels from new sources of supply are an important part of this “variety bias” estimate.

6. CPI Benchmarks for Measuring Effects of Offshoring and Country Substitution

As a practical 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 final goods that are bought by consumers, a buyers’ price index exists already in the form of the consumer price index (CPI). The CPI index does not distinguish between items based on their country of production, and it often uses quality adjustment techniques to compare items that are not precisely identical. If price savings from country substitution and offshoring are passed through to the retail level, the combined effects of offshoring and country substitution on prices paid by buyers at the wholesale level can be estimated for goods used for personal consumption by means of growth rate comparisons with CPIs.

Cross-sectional correlations between the import growth estimates of McCully (2011, table 4) and price indexes for the major types of consumer products in NIPA table 2.3.4 (which are constructed from more detailed CPIs) show that products whose production moved offshore had lower price growth. The correlation between the change in imports as a share of final sales in 1959-2009 and the average rate of price change over that period is -0.71 . Special factors that influenced the relative inflation rate of product groups with unusually high or low import growth could, of course, play a role in this correlation, but excluding types of products whose prices are

subject to identifiable special factors has virtually no effect. (The excluded product types are services, which may have comparatively high price growth because of low productivity growth, recreational goods, the product group that contains computers and other products with rapid technological progress, and petroleum products.) Nevertheless, the product exclusions do affect the coefficient on import growth in a regression explaining price growth. With the product exclusions, this coefficient implies that a 10 point increase over 1959-2009 in the percent of overall supply coming from imports reduced a product's price growth by -0.83 percent per year, whereas using the full sample the implied reduction is -1.24 percent per year.

Comparisons of CPIs and MPIs for matched products are affected by two factors that may cause them to underestimate the impact of offshoring and country substitution on prices paid by wholesale level buyers. One is that pass-through to the retail level of price reductions resulting from offshoring and country substitution is likely to be incomplete for reasons other than quality differences, such as higher markups for reasons unrelated to costs. If imports from new sources require more distribution services to get to consumers, that would cause incomplete pass-through of the price difference but not imply an understatement of the buyers' gains because the extra distribution costs would represent a quality difference.

The other possible source of underestimation of the effect of offshoring and country substitution is that some price changes caused by shifts in the location of production may be linked out of the CPI in the same way as they are from the MPI because the version from the new location is not treated as a continuation of the original version. The CPI may therefore miss some of the price changes due to offshoring and country substitution that are missed by the MPI. Nevertheless, the CPI can be expected to capture more of the price changes caused by changes in the location of production than the MPI. The CPI can continue tracking the price of an item when its production moves offshore, and it can also continue tracking items that are handled by a different importers when their production shifts to a new foreign location. The CPI treats an item from the new country of origin as a continuation of the original item if its physical characteristics

are the same or changes in ways that have only a minor effect on the price. Finally, for some types of products, the use of hedonic regressions (in the apparel indexes, for example) or manufacturers' cost estimates (chiefly in the motor vehicle indexes) allows the CPI to avoid linking. The analysis of CPI micro data in Bils (2009) confirms that a large proportion of the changes in unit prices associated with the entry of new models are included in the CPIs for durable goods products.⁶

There are also two factors that need to be controlled for to avoid overestimating the effects of offshoring and country substitution. One of them is the effect of tariff reductions. They can be presumed to have been at least partly passed through to prices measured by the CPI, but tariffs are excluded from the prices measured by the MPI. FMRS (2011, p.84) find that including tariffs reduces the growth of the MPI by 0.08 percent per year over 1996-2006.

The other factor that we need to control for is methodological differences that may tend to push down the growth rate of the CPI relative to the MPI. These include the hedonic or hedonic-like quality adjustment procedures that are used in the CPI for apparel and computers, along with the geometric mean formula that is used to combine individual price observations into indexes for products in many parts of the CPI. The geometric mean formula was adopted as a solution to the upward "formula bias" in the CPI caused by arithmetic averaging of price relatives (Reinsdorf, 1998), and it may also avoid the lower-level substitution bias caused by consumer behavior. FMRS (2011) find that switching from a Laspyeres (weighted arithmetic mean) formula to a Törnqvist (weighted geometric mean) formula lowers the import index for non-petroleum goods by an average of 0.77 percent per year. However, the impact falls to 0.67 percent per year when semiconductors, which are not a consumer good, are excluded. Also, the Törnqvist indexes constructed by FMRS (2011) cover broader aggregates than the geometric mean indexes of the CPI, so the effect of using geometric mean indexes in the MPI would probably be smaller if they

⁶ Although here, and in the outlet substitution bias literature, directly measuring price changes associated with entry is viewed as making the index more accurate, Bils (2009) argues that in practice the CPI has under-corrected for quality change in cases of durable goods products with improving technology and that a pure matched models index would have been more accurate for these products.

were applied at the more detailed level of aggregation used in the CPI. Another estimate of the effect of the geometric mean formula on comparisons of MPIs and CPIs comes from the effect of the adoption of geometric means on the CPI. Stewart and Reed (2009, pp. 36-37) report that the effect on the CPI's annual rate of change was in the range of 0.3-0.4 percent for food and beverages, 0.6 percent for entertainment, 1.4 percent for apparel, and about 0.25 percent for all other affected goods and services. The estimated effect for apparel may, however, reflect some other differences besides the formulas themselves: for apparel imports, FMRS (2011) find that the effect of changing from a Laspeyres formula (which is a weighted arithmetic mean) to a Törnqvist formula is just 0.3 percent per year.

7 Constructing Wholesale Purchaser and Retail Purchaser Price Indexes

A great many imported products are used for personal consumption expenditures, yet, as noted in section 2 above, only a handful of detailed MPIs can be matched to a corresponding CPI. The difficulty in matching MPIs to CPIs is that the published lower level indexes for imports and consumers use different product classification systems to group together detailed products into lower level aggregates.

The solution to this problem is to aggregate the lower level indexes up to a level where the differences in product classification schemes become relatively unimportant. Making comparisons at a higher level of aggregation also allows nearly all of the non-petroleum products used for personal consumption expenditures (PCE) that are imported to be included in the analysis. These products were identified from detailed "use" tables from BEA's Annual Industry Accounts (AIAs). 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 assessing the effects of offshoring and country substitution is that most products that are supplied by imports also have some local production. To model the combined effect of import and domestic producer prices we constructed wholesale purchaser's indexes as chained Fisher indexes that combined MPI and PPI component indexes using weights that reflected the shares of imports and local production in the overall supply of each product. Value share weights were also used for aggregation of detailed products into product groups. The component price indexes came from detailed product level deflators from the AIAs, which are constructed from MPIs or PPIs. If the proportion of imports in the uses of each product for personal consumption matches the proportion of imports in the overall supply of that product and the markup rates for local transportation and distribution services do not change over time, the wholesale purchaser's price index for a product group should match the growth rate of the CPI for that product group.

The wholesale purchaser's indexes can be thought of 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 can be viewed as a weighted average of the effect of offshoring and country substitution on an extended MPI and any bias that may exist in the PPI. Thus, if the PPI bias is smaller than the effect on the extended MPI, the gap between the wholesale purchaser's index and the CPI will underestimate that effect, and if the PPI bias is zero, to adjust for influence of the PPI on the gap between the wholesale purchaser's index and the CPI, we should divide by the share weight of imports in the wholesale purchasers' index. We will make no adjustment for this possible source of underestimation of the effect on the extended MPI, however, because the PPI may, indeed, have some upward bias relative to an economic buyers' index. The PPI does not take buyers' substitution between producers into account and it links in entering US producers, which tend to have lower prices than established US producers (Foster, Haltiwanger and Syverson, 2008). In practice, for durable goods the PPIs tend to have lower

growth rates than the corresponding MPIs, for apparel PPIs tend to have similar growth rates, and for other nondurable goods PPIs often have higher growth rates.

Besides the wholesale purchaser's price indexes, we can also calculate retail purchaser's indexes whose comparability with the CPIs does not depend on the assumption of constant markup rates for transportation and distribution services. These indexes 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 constructing the retail purchaser's index, each component of the costs that add up to a product's final retail price was weighted by its share in those final costs. Note, however, that even though the retail purchaser's price indexes are conceptually more appropriate to compare with CPIs, the measuring price change for transportation and trade margins is difficult in practice, and these indexes are not specific to the particular products that are imported for use in personal consumption.

It is also worth noting that differences in index composition in terms of variety mix and weighting of detailed products 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 variety mix difference, luxury vehicles have a larger weight in the MPI for new motor vehicles than they do in the PPI, and in 2001-2007 luxury vehicles could have had larger price increases than non-luxury vehicles.⁷ The differences in variety mix 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 be non-systematic, however, and they may tend to average out to zero as the number of detailed indexes included in the aggregate becomes large.

⁷ 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, be likely to 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 but not higher growth rates.

7. Empirical Results

7.1 Differences between Wholesale Purchaser's Indexes and CPIs

Growth rate differences over the period 1997-2007 between wholesale purchaser's indexes and corresponding CPIs for major product groups are shown in the first column of numbers of table 2. For nondurable goods other than apparel and tobacco, the differences are generally small; indeed, for food and for alcoholic beverages, they round to zero. (Comparisons that include tobacco are not meaningful because of the strong effect of excise taxes on the CPI for this product.) The bounds based the unit value indexes in the last column of table 1 also show that food and beverage prices were unaffected by offshoring and country substitution.

On the other hand, for the types of goods that have significantly positive bounds in table 1, the growth rate of the wholesale purchaser's index exceeds that of the matched CPI. 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, and 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 is to directly compare MPIs and CPIs. In the case of motor vehicles, the MPI has a substantially larger growth rate gap than wholesale purchaser index, at 0.7 percent per year (third column of numbers in table 2), suggesting that the effects of offshoring and country substitution are greater than was implied by the wholesale purchaser's index. 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. Moreover the PPI underweights luxury varieties compared to the CPI and it does not rise any more slowly than the CPI.

The product groups other than motor vehicles do not pose any dilemma over which growth rate gap to use because for them the MPI has about the same growth rate as the wholesale purchaser's index. The growth rate gaps for the MPIs imply that offshoring and country substitution effects are absent for nondurable goods, and for apparel and textiles, they average 1.5 percent per year, the same as the wholesale purchaser's indexes. For durable goods excluding computers, the MPIs have a slightly larger average growth rate gap.

7.2 Results for Retail Purchaser's Price Index

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 in theory, retailer purchaser's price indexes in which transport and distribution margin prices are included with the appropriate weights are better suited for comparisons with CPIs than wholesale purchaser's price indexes. In practice, however, measuring price change for the "margin" industries can be difficult, and the aggregate indexes for these industries that are available could behave differently from a customized price index for transportation and distribution of durable goods or apparel. Therefore, whether the superiority in theory of the retail purchaser's price for purposes of comparisons with CPIs translates into superiority in practice is not obvious.⁸

In any event, at least in the cases of durable goods and apparel, the retail purchaser's indexes are very similar to the wholesale purchaser's indexes. 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 significantly smaller growth rate gap using the retail purchaser's indexes, causing the average growth rate for all products combined except tobacco to fall from 1.1 to 0.6 percent per year when the retail purchaser's indexes are used.

⁸ An alternative to calculating these indexes would be 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.

7.3 Adjustments for Influence of Tariffs and Methodological Differences

The results in FMRS (2011) imply that the contribution of declining tariffs to these growth rate gaps is around 0.1 percent per year. Another contributor to the growth rate gaps for durable goods other than motor vehicles in table 2 is methodological differences. (For motor vehicles, the methodological difference in the way that model year changeovers are handled adds to the growth rate of the CPI, so the adjustments for it and for the use of geometric means in the CPI would approximate offset one another.) For durable goods the effect of the methodological differences may be in the range of 0.6 percent per year. The treatment of quality changes in computers is one important difference. The MPI for computers is a pure “model models” index, but hedonic regressions or market information on values of quality attributes have been used to quality adjust the CPI for computers since 1998. Although Bils (2009, p. 648) finds including hedonically adjusted prices of new models did not reduce the growth rate of the CPI for computers compared to an alternative of using a pure matched models approach, hedonic adjustment based on (Grimm, 1998) clearly had a negative effect on the growth rate of an import index for semiconductors. Thus it seems likely that the lack of hedonic adjustment for computers in the MPI does contribute to the growth rate gap for this product. The wholesale purchaser’s index for computers and computer equipment grows 6.4 percent per year faster than the CPI, while for other electric equipment the difference is 4.2 percent per year. Using the growth rate gap for the non-computer electric equipment to estimate the effect of substitution between countries of origin for computers would reduce the growth rate gap for durables as a whole by 0.2 percent per year.⁹

In addition, the use of the geometric mean formula in the CPI probably adds between 0.25 percent per year (based on results for the CPI) and 0.6 percent per year (based on results in FMRS) to the growth rate gap for durable goods. Using the rounded average of these two figures of 0.4

⁹ There are also methodological differences for non-computer electric goods, but they do not seem to have a systematic effect on the indexes’ growth rates. For some of these products the CPI uses hedonic adjustment or class mean imputation (Erickson and Pakes, 2011, pp. 1733-4). However, the results in table 12 of Erickson and Pakes (2011) suggest that the use of comparable substitutions, hedonics and class mean imputation in the CPI for non-computer electric durables can have either a positive or a negative effect compared to a pure matched models index.

percent per year for the effect of geometric means, and deducting a further 0.2 percent per year for the effect of computer methods in the CPI, and 0.1 percent per year for the effect of falling tariffs gives an adjusted growth rate gap of 1.3 percent per year (table 3). This estimate of the effects of offshoring and country substitution based exceeds the upper bound in table 1 by 0.3 percentage points. Technological progress has led to falling quality-adjusted prices for many durable goods products, and many of the product-level CPIs in this category have negative growth rates. A pure matched models index like the MPI would be susceptible to upward bias in cases of negative price change caused the technological progress. Another possibility is that differences in variety mix and product weighting may have added to the growth rate gap between the wholesale purchaser's index and the CPI for durable goods.

For apparel and textiles, rounding down the average of 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) gives an allowance of 0.8 percent per year for the effect of CPI's use of geometric means. The adjusted growth rate gap for apparel then becomes 0.6 percent per year.¹⁰

8. 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 because the wholesale and retail distribution sectors may take advantage of these reductions to expand their margins and because real inputs of distribution services may actually be higher. More distribution services may be required to set up and manage international supply chains that locate production in low cost countries and costs for holding inventories, communication and transportation may be higher. In addition, distributors may need to earn a risk premium when sourcing from distant suppliers.

¹⁰ For CPIs for apparel fashion goods, procedures are in place to prevent markdowns during the selling season from causing downward bias. In Brown and Stockburger (2006) an alternative to the hedonic adjustment element of these procedures raised the growth rate of these apparel indexes by 0.2 percent per year.

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 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 the 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). A commodity with a 10 percentage point increase in its import share would have 0.93 percentage points more growth in its margin rate than a commodity with no change in its import share. Thus, rising imports do coincide with rising margins received by the distribution industries.

9. Implications for the Measurement of Output and Productivity

The results presented above imply that unmeasured effects of offshoring and country substitution have caused the output and productivity growth of the US economy to be overstated. Note, however, that some of the price effects of the shifting location of production have been captured by the official indexes. Although prices from suppliers in different locations are not directly compared in the official indexes, existing suppliers may reduce their prices (or forgo price increases) to compete with the new sources of supply can cause that are captured by the MPI. Consequently, the official index for nonpetroleum imports declines relative to the price indexes for exports and domestic absorption over the period of rapid growth in imports from emerging

economies, and this decline is big enough to offset the impact on overall US trading gains of steep rises in the price of US petroleum imports.¹¹

The size of the overestimate of GDP growth in the period when production of many goods was moving to low wage countries is modest because the weights on the affected imports in the GDP deflator are relatively small. These weights can be approximated by the value shares in GDP in 2007 of the consumer goods investigated above together with similar kinds of nonconsumer goods. For consumer durable goods, computers and other fabricated durable goods excluding capital goods, imports in 2007 amounted to 5 percent of GDP. Imports of apparel and textile products were another 1 percent of GDP. The adjusted growth rate gaps from table 3 are 1.3 percent per year for durable goods, and 0.6 percent per year for apparel and textile products. The approximate upward bias in the GDP deflator is therefore 0.086 percent per year. However, additional nonfood imports that could also be affected by offshoring and country substitution amount over 1 percent of GDP, and a modest allowance for some effects from these imports brings the estimate of the bias in the GDP deflator up to 0.09 percent per year.

The effects on measured productivity growth are a bit larger than on measured GDP growth. For labor productivity, the broadest measure calculated by BLS is for the business sector. Assuming that imports of durable goods and of textiles and apparel are all used by (or distributed by) the business sector, the weights of these imports in the gross value added of the business sector, which is the output measure in the productivity calculation, are over 30 percent larger than their weights in GDP. These larger weights imply a bias in the measured growth rate of the real gross value added of the business sector of 0.12 percent per year, which translates directly into a similar bias in the measured rate of labor productivity growth.

Imported capital goods are excluded from the bias calculations for GDP and labor productivity because in the US national accounts import indexes are used to deflate the

¹¹ NIPA table 1.8.6 (lines 15 and 18) shows a relative decline in nonpetroleum import prices that offset rising petroleum prices, leaving overall trading gains for the US unchanged over 1995-2007.

expenditures on these capital goods when calculating the fixed investment component of real domestic absorption. If the deflator for these imports is too high, real investment and real imports will both be underestimated so the measurement of GDP and labor productivity will be unaffected.

Measurement of multifactor productivity will be affected, however. Low estimates of real investment result in low estimates of the growth of capital services inputs.¹² Imports of capital goods amounted to 3.8 percent of gross value added of business in 2007. Multiplying this weight by the motor vehicle effect of 0.7 percent per year (which is assumed to be applicable to all capital goods) and adding this capital services contribution to the bias estimate for labor productivity implies that multifactor productivity growth was overstated by 0.15 percent per year during the years when production was shifting to low wage countries. The average growth rate of multifactor productivity over the twenty year interval ending in 2010 would then be 0.97 percent per year instead of the 1.12 percent per year published in the BLS multifactor productivity news release of May 19, 2011.

The bias estimate of 0.15 percent per year for multifactor productivity is in the range of the “conservative assumption” estimates in Hausman *et al* (2011, p. 126) for multifactor productivity of manufacturing, which were 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. Manufacturing is, of course, a heavier user of intermediate inputs (which are partly supplied by imports) than the business sector as a whole, but on the other hand, the estimates in Hausman *et al* exclude the effects of mismeasured imports of capital goods.

10. Conclusion

The period from the mid-1990s to 2007 saw the entry of many new suppliers located in low wage countries, large shifts in sources for many US imports, and rapid growth of US imports

¹² For multifactor productivity the broadest measure that BLS calculates covers private business, but the distinction between the business sector and the private business sector can be ignored. The government enterprises in the business sector account for only around 1 percent of the value added of this sector.

as production moved offshore. Unfortunately most reductions in prices paid by import buyers associated with substitution to a different country of origin were not captured by the US import price index, and the price reductions associated with substitution from a local source of supply to an offshore one are out of scope for the imports index. As a result, country substitution and offshoring tended to cause an overstatement of growth of US real output and productivity.

This paper first uses information on shifting trade patterns for imports and changes in the share of domestic absorption sourced from imports to bound the size of the price effects from country substitution and offshoring. It then uses CPIs for products that are supplied at least partly by imports to estimate the size of these effects. The CPI should capture most of the price effects of country substitution and offshoring, so for those products comparisons of CPIs and purchaser's price indexes that combine MPIs and PPIs with appropriate weights provide evidence on the bias in an extended imports index. For most nondurable goods, the CPI is not lower than the purchaser's indexes or the MPIs themselves, so for these goods there is no evidence of unmeasured price effects. For durable goods and apparel, however, the CPIs have substantially lower growth rates. After adjusting for the contributions of falling tariffs and methodological differences to the growth rate gaps, the effects attributed to country substitution and offshoring are 1.3 percent per year for durable goods and 0.6 percent per year for apparel and textile products. Nevertheless, imports of these goods are relatively small compared to US GDP, so the implied upward bias in the measure of GDP growth is under 0.1 percent per year, and implied biases in the broad measures of productivity growth are between 0.1 and 0.2 percent per year.

The estimates of the effects of country substitution and offshoring from the CPI comparisons are consistent with the bounds calculated from the trade pattern data. It should, however, be noted that they are subject to some potential sources of error. The mix of product varieties and detailed products in the CPI benchmarks is usually not the same as the mix in the purchaser's price index or MPI to which the CPI is compared. Furthermore, the adjustments for the influence of tariff changes and methodological differences rely to some extent on assumptions.

It should also be noted that export price indexes and the price indexes for domestic absorption, which have not been investigated in this paper, could be subject to sources of bias that might offset some of the effects on the GDP deflator of the import price measurement problems investigated here. For example, some of the growth in US exports could have been achieved by offering unmeasured price reductions to buyers in new export destinations.

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 May 2011 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 Ariel 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 Economics and Statistics*.

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. of Chicago Press for the National Bureau of Economic Research, 203-231.

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.

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, Emi and Jón Steinsson. 2009. "Lost in Transit: Product Replacement Bias and Pricing to Market." NBER Working Paper 15592.

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

Hausman, Jerry, and Leibtag, Ephraim. 2009. "CPI Bias from Supercenters: Does the BLS know that Walmart Exists?" In *Price Index Concepts and Measurement*, W.E. Diewert, John S. Greenlees and Charles R. Hulten, eds., Studies in Income and Wealth Vol. 70, Chicago: U. of Chicago Press, 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.

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

Lawrence, Robert and Matthew Slaughter. 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

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

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, Marilyn 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/>

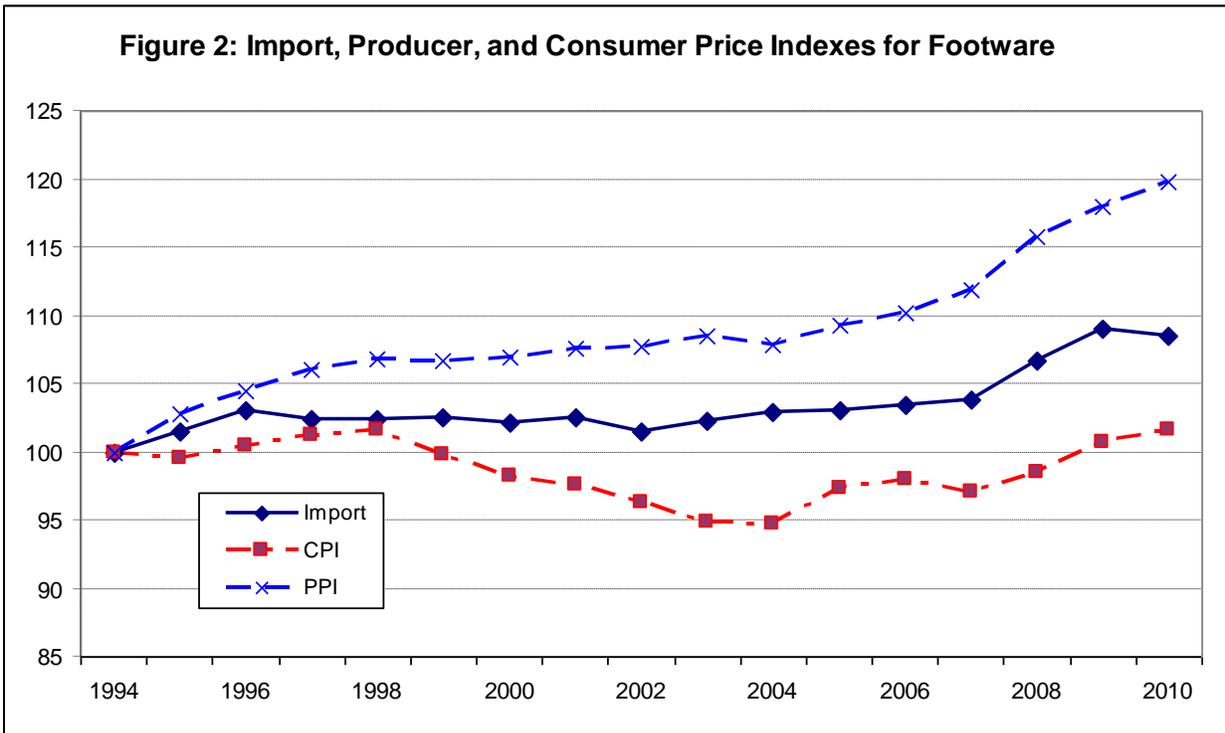
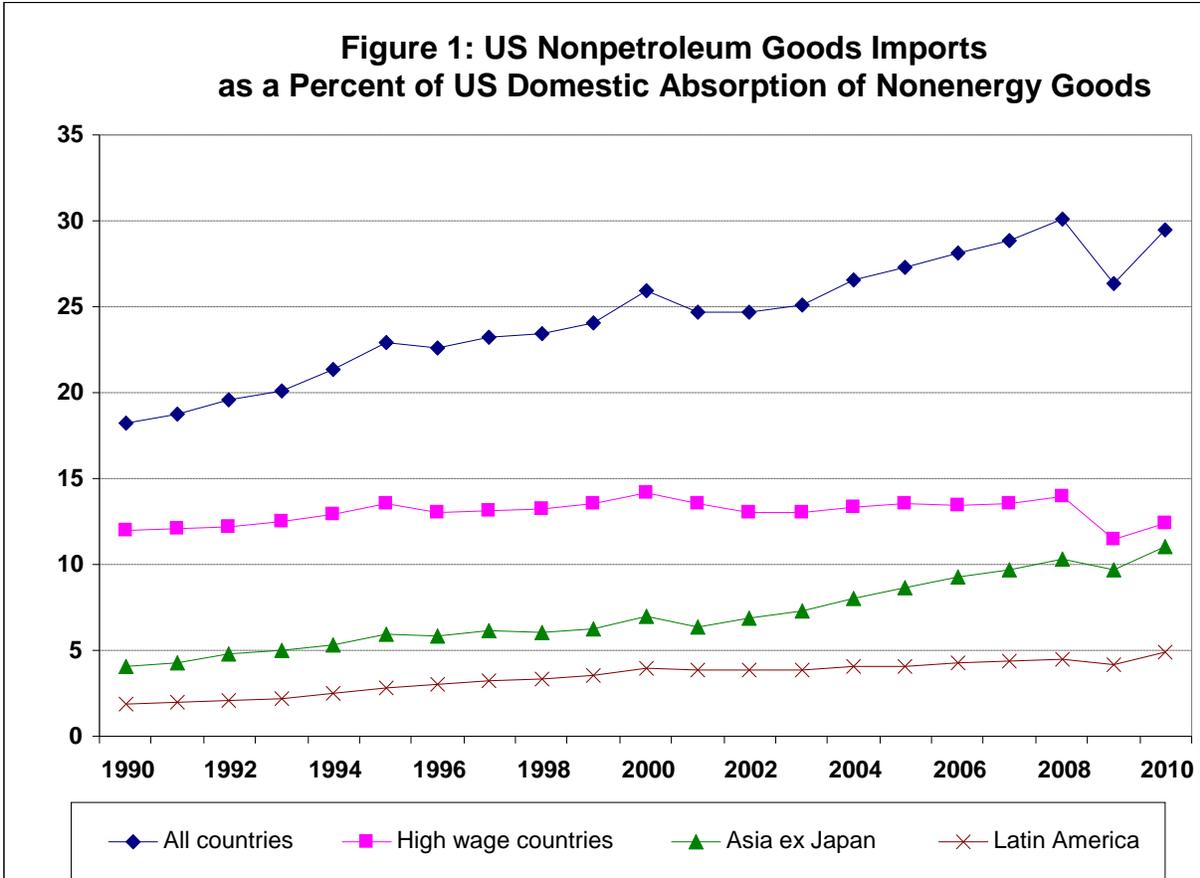


Figure 3: Import and Consumer Prices Indexes for Apparel

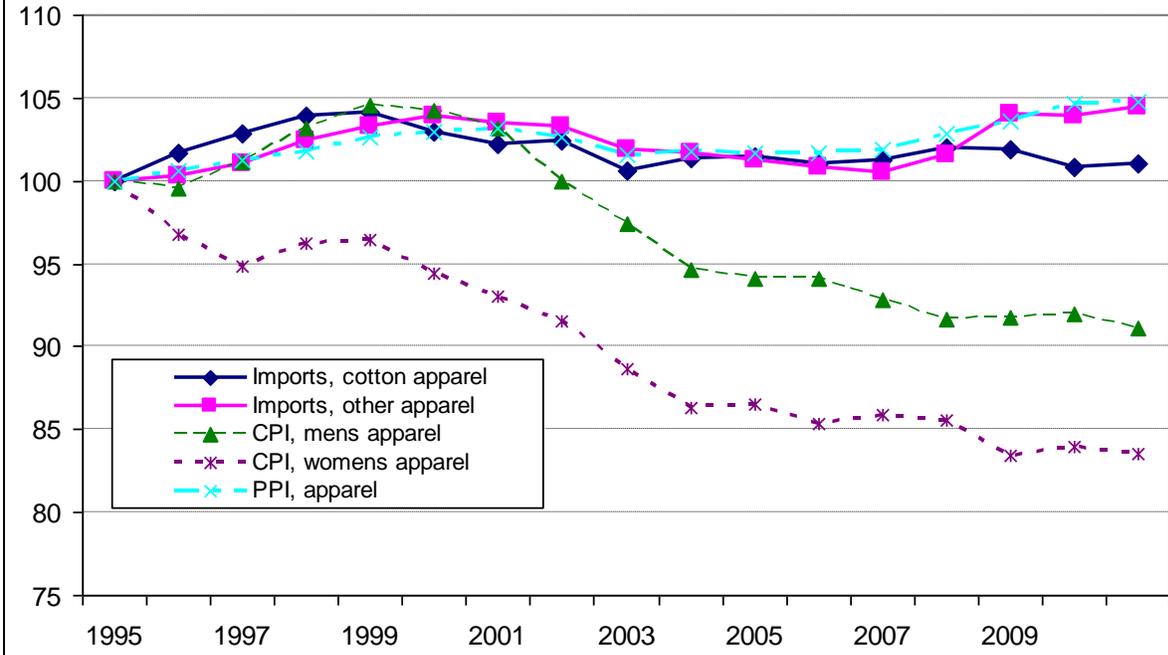
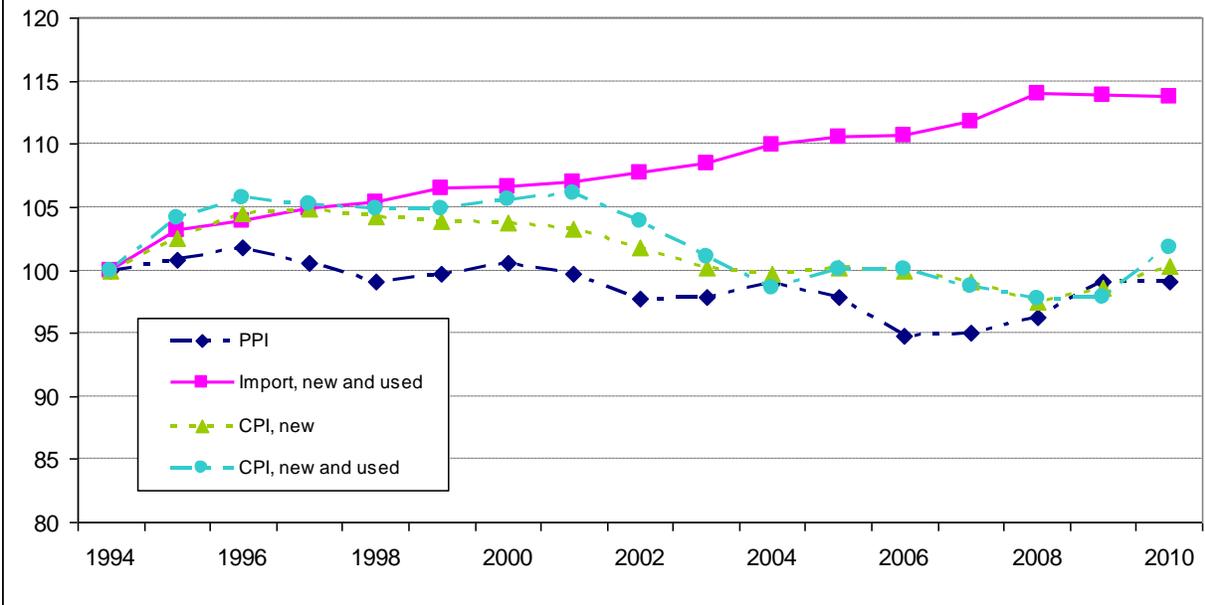


Figure 4: Import, Producer and Consumer Price Indexes for Vehicles



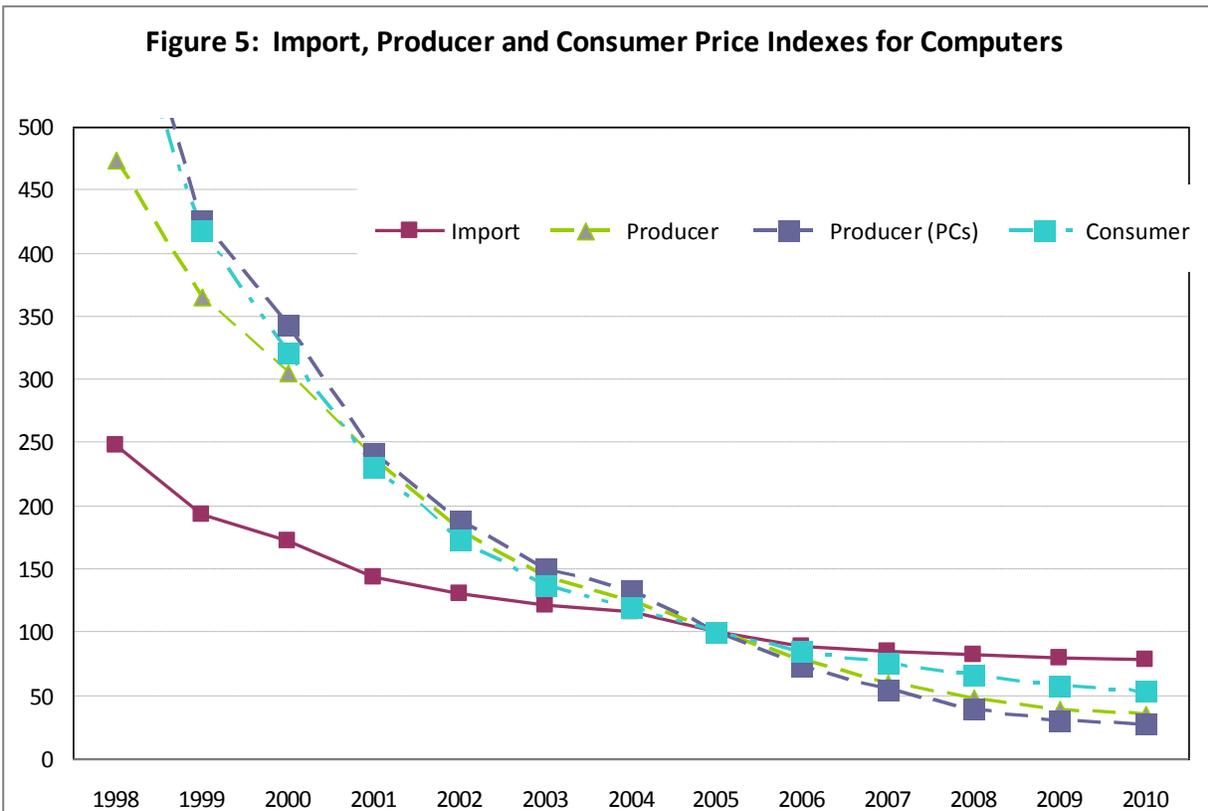
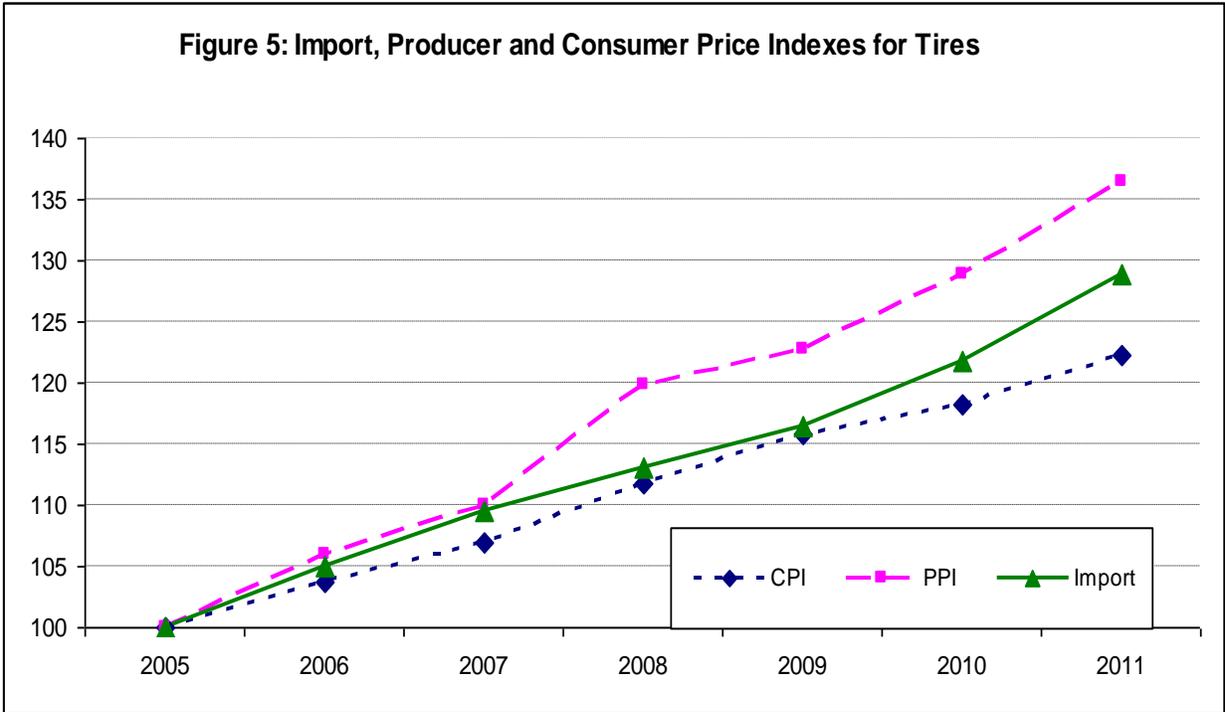


Figure 7: Import and Producer Prices for Computers, peripherals and parts

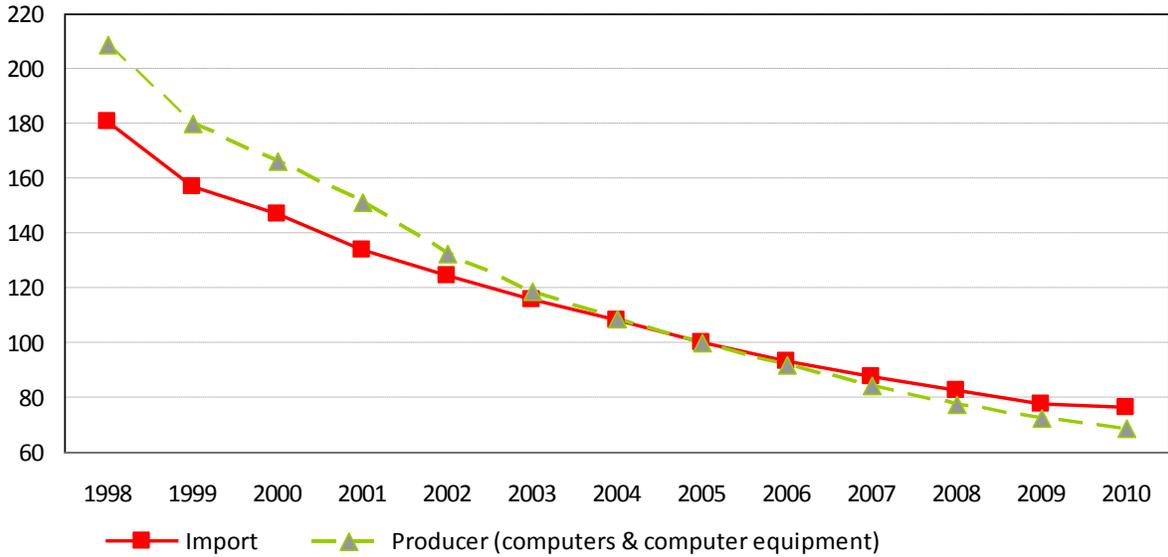


Figure 8: Import and Producer Price Indexes for Semiconductors

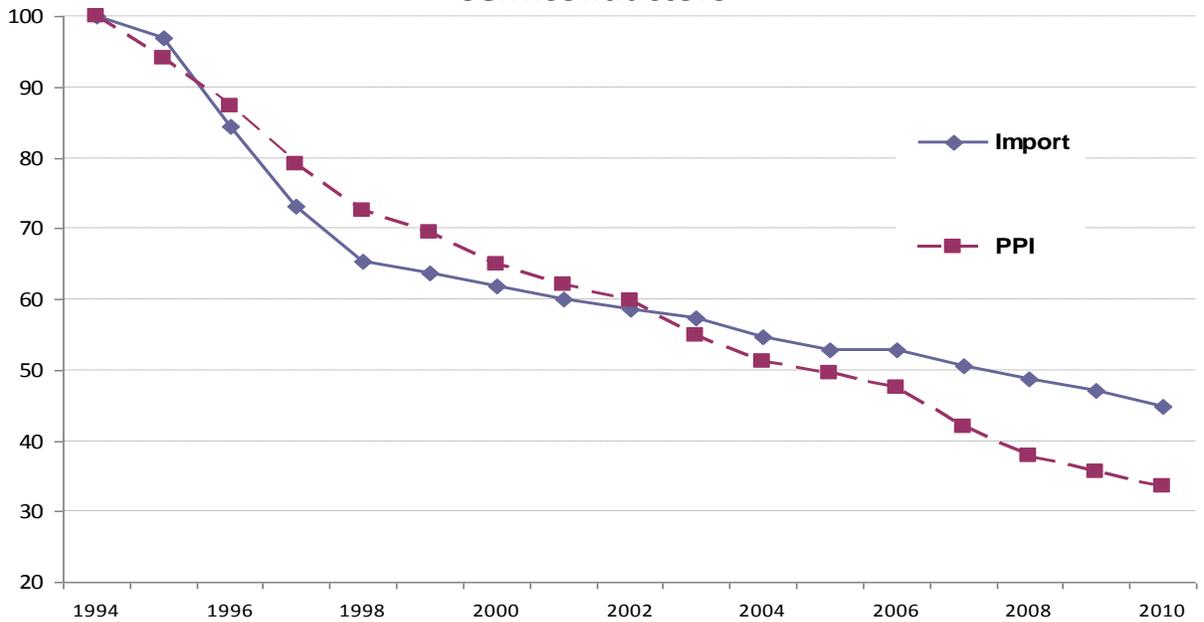


Figure 9: Prices of Consumer Good Imports and Prices of Personal Consumption Goods ex Energy

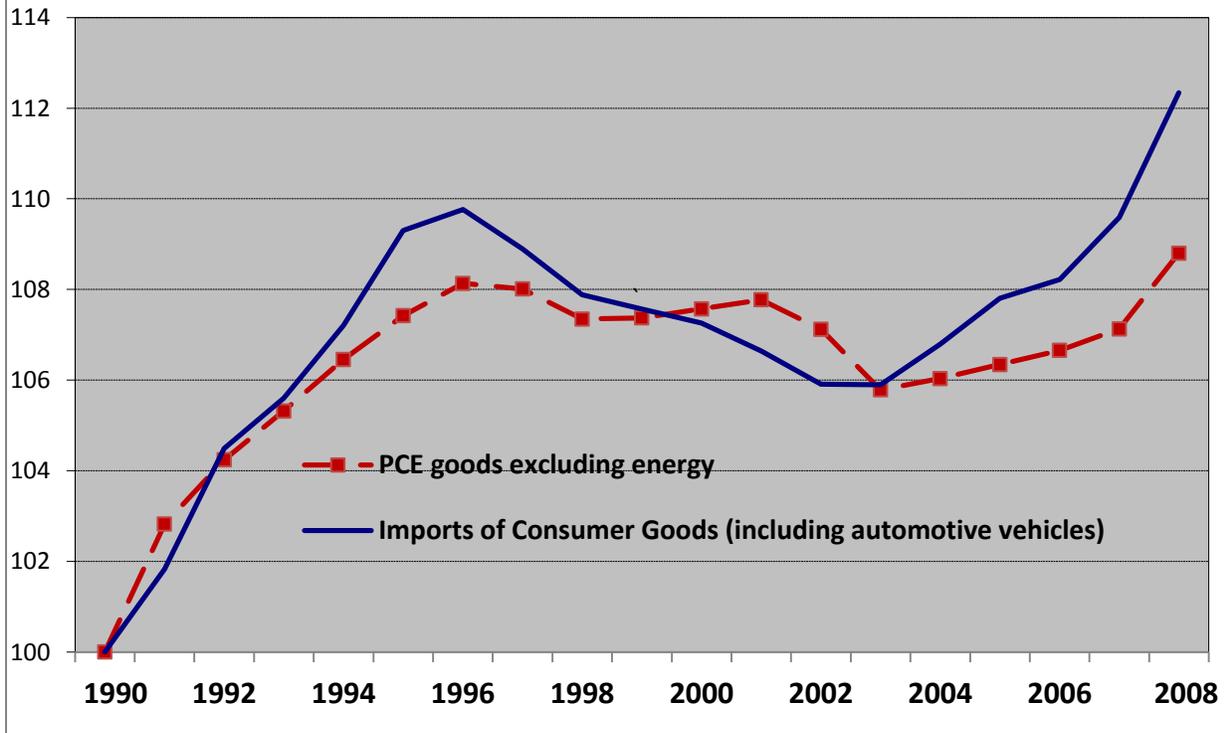


Table 1: Upper Bounds for Effect of Offshoring and Country Substitution over 1996-2007^a

	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
β 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
β 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
β 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
β 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

- Bounds are based on assumption that $p^L = 0.5p^H$.
- 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	1.5
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
Clocks and watches	1.8	1.7	1.8	1.9	-1.4
Tools, hardware and supplies	1.8	0.9	1.7	1.7	-0.2
Other durables	3.0	1.9	3.1	2.4	-0.8
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	0.7	0.9
Declining tariffs	0.1	0.1
Geometric mean formula for elementary aggregates of the CPI	0.4	0.8
Differences in quality adjustment methods for computers	0.2	NA
Adjusted Growth Rate Gap	1.3	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: Linking as an Implicit Quality Adjustment Technique

Linking is the standard procedure for handling changes in sample composition when constructing a price index for a product. A product-level index that relies exclusively on linking to control for changes in the sample is known as a “matched models” index, because only the models that match between time periods are included in the calculation of the product’s price change. In this section we show that chaining can be viewed as quality adjustment technique that embodies an assumption of no price dispersion in the link month.

Let w_{i0} represent the expenditure share of item i in base period 0, the chained index formula for a lower-level aggregate in the MPI (known as a “classification group”).¹³ Also, let s_t represent the subsample of items whose price p is observed in both time $t-1$ and time t , and let s_{t-1} represent the subsample for which prices are observed in both time $t-2$ and time $t-1$. Then the chained index from time $t-2$ to time t equals:

$$I_{t-2,t}^C = \frac{\sum_{i \in s_{t-1}} w_{i0} (p_{i,t-1}/p_{i0})}{\sum_{i \in s_{t-1}} w_{i0} (p_{i,t-2}/p_{i0})} \frac{\sum_{i \in s_t} w_{i0} (p_{it}/p_{i0})}{\sum_{i \in s_t} w_{i0} (p_{i,t-1}/p_{i0})}. \quad (\text{A-1})$$

If no items exit in period t or enter in period $t-1$, the chained index reduces to the direct index:

$$I_{t-2,t} = \frac{\sum_{i \in s_{t-1}} w_{i0} (p_{it}/p_{i0})}{\sum_{i \in s_{t-1}} w_{i0} (p_{i,t-2}/p_{i0})}. \quad (\text{A-2})$$

The chained index formula can be written as a function of within-sample price changes, which shows that differences in price level between the items that enter (exit) and the items

¹³ The MPI actually uses a three-tiered hierarchical weighting structure in constructing its lower level aggregates. Weights are assigned to detailed categories of varieties, to establishments within detailed categories, and to unique items that are priced within an establishment (BLS, 1991, Chapter 15). To avoid needlessly complicating the explanation, the steps that generate the ultimate weight w_{it} of a unique item within the lower level aggregate are not shown.

previously present (continuing to be present) do not affect the index's value. Define the $w_{i,t-1}$ as weights that have been updated for price change and normalized to sum to 1:

$$w_{i,t-1} = \frac{w_{i0}(p_{i,t-1}/p_{i0})}{\sum_{j \in S_{t-1}} w_{j0}(p_{j,t-1}/p_{j0})}. \quad (\text{A-3})$$

The denominator on the right side of equation (3) equals the Laspeyres index $I_{0,t-1}$. With the weights $w_{i,t-2}$ defined analogously to the $w_{i,t-1}$ in equation (3), equation (1) can be written as:

$$\begin{aligned} I_{t-2,t}^C &= \left[\sum_{i \in S_{t-1}} w_{i,t-2}(p_{i,t-1}/p_{i,t-2}) \right] \left[\sum_{i \in S_t} w_{i,t-1}(p_{it}/p_{i,t-1}) \right] \\ &= I_{t-2,t-1} I_{t-1,t}. \end{aligned} \quad (\text{A-4})$$

Chaining can be viewed as a quality adjustment technique that implicitly assumes that the value of the quality difference between the item that is chained into the index for a product and a pre-existing item or set of items can be measured by the cross-sectional price difference in the link month. In the case of an item that enters the index as a replacement for an item that has disappeared (or been deliberately dropped), the implicit assumption is that the difference in price between the entering item and the item that it replaces is due to quality. In the case of an item that is added as part of an augmentation of the index basket, the implicit assumption is that the difference between the price of the added item and the *average* price of the originally present items is due to quality. A similar result can also be derived for the case of item that is chained out of the index rather than replaced.

The equivalence of chaining to making an explicit quality adjustment based on price level differences in link month is shown in the Proposition 1 for the case of the replacement item and in Proposition 2 for the case of an item add that is added to the sample.

PROPOSITION 1: In the index for a product, assume that an item disappears and that its weight is transferred to a replacement item. Also, let the average price of the product after the

item replacement be calculated by quality adjusting the price of the replacement item using the ratio of imputed price of the disappearing item in the link month to the price of the replacement item in that period. Then the change in the average price of the product from the period before the item replacement to the period after the item replacement equals the change in the chained index.

PROOF: Let item k be the replacement item, and let j denote the item that disappears in period $t-1$. The imputed price of item j in period $t-1$ is $\hat{p}_{j,t-1} = p_{j,t-2} I_{t-2,t-1}$, where $I_{t-2,t-1}$ is calculated from the sample of continuing items s_{t-1} . Finally, the chained index is defined as:

$$I_{t-2,t}^C = I_{t-2,t-1} [w_{k,t-1} (p_{kt}/p_{k,t-1}) + \sum_{i \neq j,k} w_{i,t-1} (p_{it}/p_{i,t-1})] \quad (\text{A-5})$$

The weight updating formula of equation (3) implies that $w_{i,t-1} = w_{i,t-2} (p_{i,t-1}/p_{i,t-2}) / I_{t-2,t-1}$. Substituting this latter expression into equation (5), we have:

$$\begin{aligned} I_{t-2,t}^C &= w_{j,t-2} (\hat{p}_{j,t-1}/p_{j,t-2}) (p_{kt}/p_{k,t-1}) + \sum_{i \neq j,k} w_{i,t-2} (p_{i,t-1}/p_{i,t-2}) (p_{it}/p_{i,t-1}) \\ &= w_{j,t-2} (\hat{p}_{j,t-1}/p_{k,t-1}) (p_{kt}/p_{j,t-2}) + \sum_{i \neq j,k} w_{i,t-2} (p_{i,t-1}/p_{i,t-2}) (p_{it}/p_{i,t-1}). \end{aligned} \quad (\text{A-6})$$

By definition, for any arbitrary item n , $w_{n0} = p_{n0} q_{n0} / \sum_{i \in S_{t-1}} p_{i0} q_{i0}$, where the q_{i0} are the base period quantities. Updating the period 0 weights using the formula of equation (3) shows that $w_{n,t-2} = p_{n,t-2} q_{n0} / \sum_{i \in S_{t-1}} p_{i,t-2} q_{i0}$. Equation (6) then becomes:

$$I_{t-2,t}^C = \frac{q_{j0} (\hat{p}_{j,t-1}/p_{k,t-1}) p_{kt} + \sum_{i \neq j,k} q_{i0} p_{it}}{\sum_{i \neq k} q_{i0} p_{i,t-2}} \quad (\text{A-7})$$

Dividing numerator and denominator of equation by $\sum_{i \in S_{t-1}} q_{i0}$ transforms the numerator into a weighted average of prices in which the price of item k has been quality adjusted by $\hat{p}_{j,t-1}/p_{k,t-1}$, and it transforms the denominator into a similar average of the period $t-2$ prices. \square

PROPOSITION 2: Let a new item be added to the index for a product without altering the relative weights of the pre-existing items. Then chaining the new item into a price index results in

the same measure of cumulative price change as tracking the change in the average price of the product provided that the price of the new item is quality adjusted by multiplying by the ratio in the link period of the average price of the pre-existing items to price of the new item whenever the new item is included in the average price.

PROOF: Let item k be the item that is added to the index, and let its overlap price from period $t-1$ receive an expenditure weight in the expanded basket of $\hat{w}_{k,t-1}$. The expenditure weights of the other items in the expanded basket are then $\hat{w}_{i,t-1} = (1-\hat{w}_{k,t-1})w_{i,t-1}$ for $i \in s_{t-1}$, where the $w_{i,t-1}$ are the weights in the original basket s_{t-1} .

The rescaling of the expenditure weights of the pre-existing items in the expanded basket implies a corresponding rescaling of their base period quantities, so in this basket the quantities in the base period are assumed to be $\hat{q}_{i0} = (1-\hat{w}_{k,t-1})q_{i0}$ for $i \in s_{t-1}$ and $\hat{q}_{k0} = \hat{w}_{k,t-1}[\sum_{i \in s_{t-1}} q_{i0}]$ for item k . The chained index can therefore be written as:

$$\begin{aligned} I_{t-2,t}^C &= \frac{\sum_{i \in s_{t-1}} q_{i0} P_{i,t-1}}{\sum_{i \in s_{t-1}} q_{i0} P_{i,t-2}} \frac{\sum_{i \in s_t} \hat{q}_{i0} P_{it}}{\sum_{i \in s_t} \hat{q}_{i0} P_{i,t-1}} \\ &= \frac{\sum_{i \in s_{t-1}} q_{i0} P_{i,t-1}}{\sum_{i \in s_t} \hat{q}_{i0} P_{i,t-1}} \frac{\sum_{i \in s_t} \hat{q}_{i0} P_{it}}{\sum_{i \in s_{t-1}} q_{i0} P_{i,t-2}} \end{aligned} \quad (\text{A-8})$$

Denote the average price in the original basket in period $t-1$ by $\bar{p}_{t-1} = \sum_{i \in s_{t-1}} (p_{i,t-1} q_{i0}) / \sum_{i \in s_{t-1}} q_{i0}$, with \bar{p}_{t-2} defined analogously. Also, denote the unadjusted average price in period t by $\bar{p}_t^u = \sum_{i \in s_t} \hat{q}_{i0} P_{it} / \sum_{i \in s_t} \hat{q}_{i0}$. Then writing $\sum_{i \in s_t} \hat{q}_{i0} P_{i,t-1}$ as $\hat{w}_{k,t-1}[\sum_{i \in s_{t-1}} q_{i0}]p_{k,t-1} + (1-\hat{w}_{k,t-1})[\sum_{i \in s_{t-1}} q_{i0} p_{i,t-1}]$ and dividing every term in equation (8) by $\sum_{i \in s_{t-1}} q_{i0}$ (which equals $\sum_{i \in s_t} \hat{q}_{i0}$) gives:

$$I_{t-2,t}^C = \frac{\bar{p}_{t-1}}{\hat{w}_{k,t-1} p_{k,t-1} + (1-\hat{w}_{k,t-1})\bar{p}_{t-1}} \frac{\bar{p}_t^u}{\bar{p}_{t-2}}$$

$$= \frac{1}{\hat{w}_{k,t-1}(p_{k,t-1}/\bar{p}_{t-1}) + 1 - \hat{w}_{k,t-1}} \frac{\bar{p}_t^u}{\bar{p}_{t-2}} \quad (\text{A-9})$$

Now let \bar{p}_t^a denote the quality-adjusted average price and let λ_k be the quality adjustment factor for the price of item k . The base period quantity of item k measured in constant quality units is then \hat{q}_{k0}/λ_k , and the quality adjusted average price in period t is:

$$\begin{aligned} \bar{p}_t^a &= \frac{(\lambda_k p_{kt})(\hat{q}_{k0}/\lambda_k) + \sum_{i \neq k} p_{it} \hat{q}_{i0}}{\hat{q}_{k0}/\lambda_k + \sum_{i \neq k} \hat{q}_{i0}} \\ &= \frac{\hat{q}_{k0} + \sum_{i \neq k} \hat{q}_{i0}}{\hat{q}_{k0}/\lambda_k + \sum_{i \neq k} \hat{q}_{i0}} \bar{p}_t^u \\ &= \frac{1}{\hat{w}_{k,t-1}/\lambda_k + 1 - \hat{w}_{k,t-1}} \bar{p}_t^u. \end{aligned} \quad (\text{A-10})$$

Specifying λ_k as $\bar{p}_{t-1}/p_{k,t-1}$ makes the quality adjustment applied to \bar{p}_t^u in equation (10) identical to one in equation (9), so that $\bar{p}_t/\bar{p}_{t-2} = \Gamma_{t-2,t}^C$. \square

Chaining protects against the mistake of including quality differences in the measure of price change, but at the cost of relying on an assumption of no price dispersion. Often this assumption is violated because of imperfect information, lagged adjustment, long-term contracts, and other market imperfections. In particular, new varieties or countries of origin that gain significant market share usually do so because they offer a lower quality-adjusted price. Such systematic differences in quality-adjusted prices cause upward bias in a chained index. A *downward* bias is also possible if varieties that some buyers prefer exit, and changes in market share do not necessarily imply a bias because buyers may have changing tastes or changing access to complementary goods. In the case of the MPI, however, the emergence of low wage countries as sources of supply for many products has created opportunities for import buyers to pay lower

quality-adjusted prices, so substitution to these new sources of supply has been substantial. On balance, therefore, the net bias in the MPI from the entry of new countries of origin is almost certainly upward.

Chaining in of replacement items occurs regularly enough in the MPI for this bias to be significant. Because of the frequency of item replacements (and because prices tend to be rigid in between product replacements), over 40 percent of the items in the MPI are replaced before they have experienced a price change (Nakamura and Steinsson, 2011). Nakamura and Steinsson (2011, p. 30) estimate the amount of artificial flatness in the MPI caused by the tendency of price changes to be missed because they occur at the time of product replacements, and find that correcting for product replacement bias raises the standard deviation of the quarterly changes in log of the non-petroleum import price from 1.1 percent to 1.6 percent.¹⁴ Unmeasured price changes occurring as part of product replacements include declines in quality-adjusted prices when sourcing changes to a new country of origin, along with other sources of systematic differences in levels of quality-adjusted prices of new or replacement items.

¹⁴ In an earlier version of their paper, an assumption that that the changes in quality-adjusted prices occurring at the time of item replacements are, on average, the same as the *non-zero* price changes implied that the reported changes in the MPI should be multiplied by a factor of around 1.7 or 1.8.