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OFFSHORING, SOURCING SUBSTITUTION BIAS, AND THE MEASUREMENT OF GROWTH IN U.S. GROSS DOMESTIC PRODUCT AND PRODUCTIVITY

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The decade before the financial crisis of 2008 was a time of large changes in sourcing patterns for manufactured goods, particularly after China's entry into the WTO in 2001. Sourcing substitution reduced the prices paid by wholesale level buyers of these goods, but these price reductions were mostly not captured in the U.S. import price indexes and the U.S. GDP deflator. To find plausible values for sourcing bias we first use data on changes in sourcing patterns over 1997–2007 to predict the effect of the reported price discount from the new emerging market suppliers. Next, we compare adjusted import price indexes for products used for household consumption with consumer price indexes. In the GDP deflator for apparel imports, sourcing bias is found to average 0.6 percent per year, and for durable goods it averages 1 percent per year. During the decade of rapidly changing sourcing patterns, a tenth of the reported speedup in multifactor productivity growth of the U.S. private business sector may have come from sourcing bias in the deflators for imports.

JEL Codes: C43, E01, O47

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INTRODUCTION

The decade before the financial crisis of 2008 saw rapid growth of manufacturing in emerging market economies, particularly after China joined the World Trade Organization (WTO) in 2001. Wholesale buyers of manufactured products were able to pay lower prices by sourcing from new suppliers in emerging market economies. In the case of the U.S., much of this shift involved offshoring of domestic production. For example, McCully (2011) examines sources of supply for categories of U.S. personal consumption expenditures (PCE) in 1999 and 2009 and finds that imports grew from 13.6 percent to 19.6 percent of PCE on furnishings and durable household equipment, and from 28.0 percent to 31.9 percent of

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PCE on clothing and footwear.[1] This shift in sourcing was an important contributor to the decline of U.S. employment in manufacturing (as measured in the Current Population Survey) from almost 21 million in 1997 to a low of 16.3 million in 2005.[2]

When offshoring (substitution of an import for local production) occurs, the change in the price paid by the buyer is beyond the scope of what the import price index (MPI) seeks to measure. Offshoring is, however, a source of bias for the purpose of measuring the deflators for imports used to calculate GDP volume growth. Furthermore, at the same time as manufacturing of goods used in the U.S. was moving offshore, the mix of countries supplying U.S. imports was changing in favor of countries with lower labor costs. In particular, China's share of U.S. imports of non-energy goods rose from 7.8 percent in 1997 to 20.3 percent in 2007 (though the Chinese "value added" embodied in U.S. imports would be lower). Substitution between two different suppliers of imports is always appropriate to include in the MPI.

These changes in sourcing for imports had an effect on the U.S. import deflators similar to outlet substitution bias in a consumer price index (CPI), which has been studied by Reinsdorf (1993), Hausman and Leibtag (2009), and Greenlees and McClelland (2011). When the buyers of an imported item start to obtain it from a new supplier whose price is lower, the reduction in the price paid by the buyers is generally not captured in the MPI. The new supplier may enter the MPI sample either during a regularly scheduled sample rotation or as a replacement for an exiting supplier. Either way, prices from the new and previous supplier are not compared. In the sample rotation case, both the old and new samples are priced in an overlap month. In the following month the new sample is linked into the chained index, and the price changes in the new sample start to be used to find the change in the price index. In the replacement case, the first time a price is collected from the new supplier, that observation is not used. Rather, an imputed price for the old supplier in the current month is calculated by moving forward the old supplier's previous price by the change in a price index calculated from the observations in common between the current and previous month. Then, when a second price observation from the new supplier is available, the imputed price for the old supplier begins to be moved forward by the change in the replacement supplier's price.[3] We will use the term "linked index" for an index whose change since the preceding month is calculated from just the common set of individual items present in the sample in both the current and preceding month.

The change in sourcing patterns for manufactured products towards countries with lower costs tended to result in an upward bias in the U.S. MPI. This paper seeks to estimate the sourcing bias in U.S. GDP and productivity growth

[1]These percentages would be much higher if the import prices were marked up to include the trade margins, internal transport margins, and taxes included in final prices to consumers reflected in PCE.

[2]With a conservative technique, Autor *et al*. (2013) find that 26 percent of the U.S. manufacturing job losses over 2000–07 were caused by competition from Chinese imports.

[3]Nakamura and Steinsson (2012) find that linking procedures result in many changes in detailed product prices being missed because the price changes tend to occur at times of product replacements in the MPI.

during the period of rapid change in sourcing patterns from 1997 to 2007. Two approaches are used. The first approach looks at data on changes in product sourcing patterns and makes an assumption about the average price reduction offered by the new supplying countries. The second approach focuses on imported products that are used for household consumption and compares the behavior of CPIs and adjusted MPIs for these products.

1. Sourcing Bias from Offshoring and from Substitution Between Countries of Origin

Items shifting from local production to offshore production must be included in the deflator for imports when calculating GDP volume change using the expenditure approach.[4] It is clear that these items must be included when calculating the deflators for intermediate inputs used in estimating GDP by the production approach, as the deflators for intermediate inputs track the prices paid for those inputs regardless of where they are sourced. For the expenditure approach to give the same estimate of GDP volume growth as the production approach, the changes in the price paid when sourcing moves offshore must likewise be reflected in the deflator for the imports.

As a simplified illustration of how offshoring affects the measurement of GDP volume, assume that in the initial period two units of an intermediate input item are produced in the domestic economy at a price of \$100 each. In the next period one unit of the item starts to be imported at a price of \$50, while the other is still produced at home at a price of \$100. The labor and capital originally used to produce the offshored unit are redeployed and now produce \$100 worth of other items. GDP volume is thus conceptually unchanged, which means that the change in domestic absorption plus exports less imports measured in constant prices must equal zero. However, at constant prices of the initial period, the sum of domestic absorption and exports rises by \$100. For the measure of GDP at constant prices to be unchanged, the deflator for imports must therefore include the change from \$100 to \$50 in the price of the offshored item.

In practice, however, changes in prices paid for intermediate inputs caused by offshoring are not tracked in any index. The U.S. Bureau of Economic Analysis (BEA) uses producer price indexes (PPIs) to deflate the domestically sourced items and MPIs to deflate foreign sourced items, but neither of these indexes would follow an item as it moved from domestic production to offshore production (Mandel, 2007 and 2009). Houseman *et al*. (2010a, 2010b, and 2011) argue that declines in prices paid for intermediate inputs caused by offshoring have been an important source of upward bias in the measured growth rate of U.S. manufacturing output.

Another kind of substitution that may enable buyers of an imported item to pay a lower price is switching to a new supplying country. In this case, the MPI could potentially treat the version of the item from the new country of origin as a

[4]The expenditure approach calculates GDP as domestic final expenditures plus exports less imports, while the production approach calculates GDP as the sum of value added over every industry plus taxes on products.

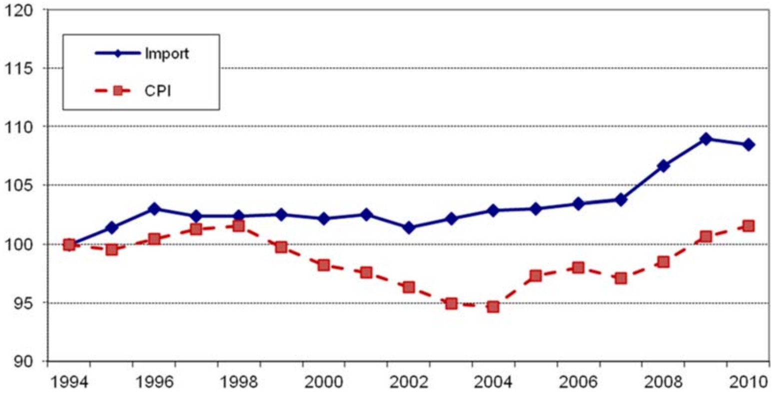

Figure 1. Import and Consumer Price Indexes for Footware [Colour figure can be viewed at wileyonlinelibrary.com]

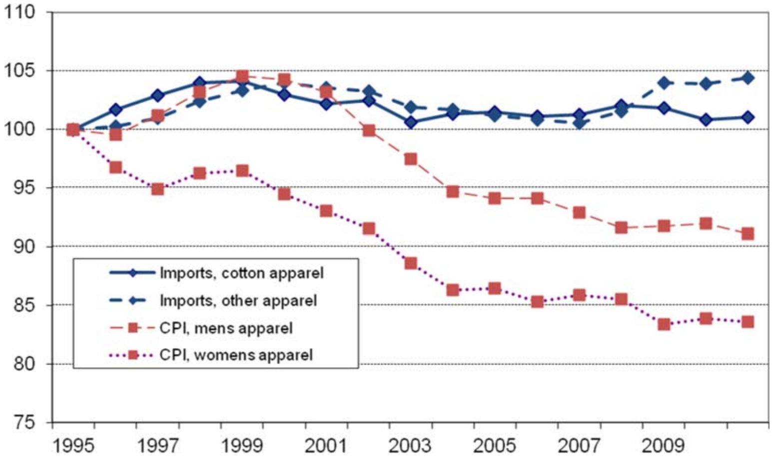

Figure 2. Import and Consumer Price Indexes for Apparel [Colour figure can be viewed at wileyonlinelibrary.com]

continuation of the previous version, and include the price change in the index calculation. In practice, however, prices from the different countries are usually not compared.[5]

Following Nakamura *et al*. (2015), we use the term *sourcing bias* for the combined effects of offshoring and substitution between source countries for items that were already imported. Simple comparisons of the MPI and the CPI for those items for which both indexes are available provide preliminary evidence of sourcing bias. As explained below, the CPI should capture most of the effects of substitution to lower priced source countries, while the MPI does not. Both a CPI and an MPI are available for five detailed products, shown in figures 1–5. In every case, the MPI rises faster, or falls more slowly, than the CPI.

[5]The U.S. MPI, CPI and PPI are produced by the Bureau of Labor Statistics (BLS), and the procedures for calculating them are documented in BLS (1997) and BLS (2008).

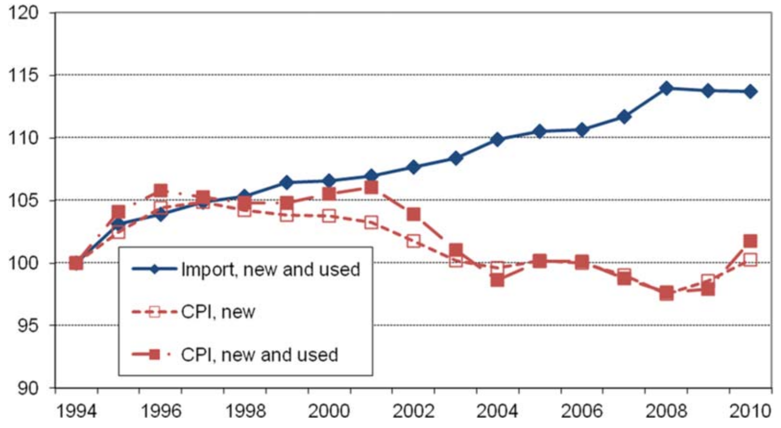

Figure 3. Import and Consumer Price Indexes for Vehicles [Colour figure can be viewed at wileyonlinelibrary.com]

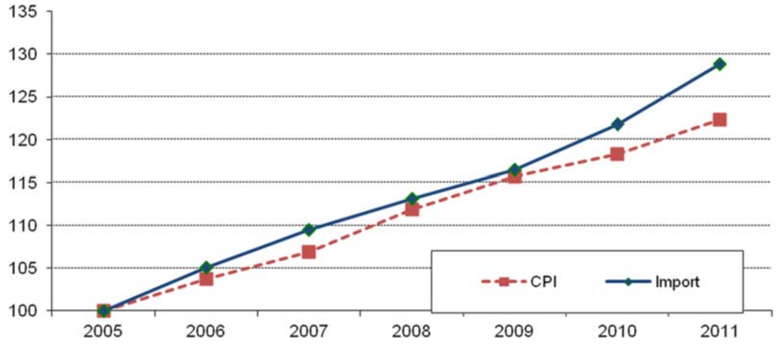

Figure 4. Import and Consumer Price Indexes for Tires [Colour figure can be viewed at wileyonlinelibrary.com]

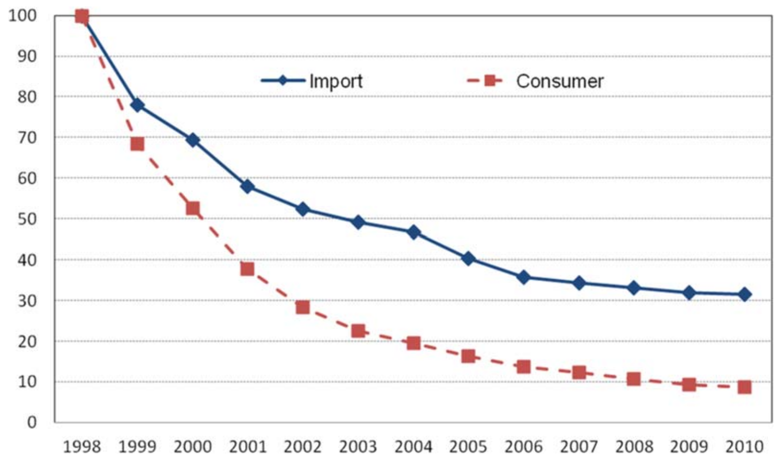

Figure 5. Import and Consumer Price Indexes for Computers [Colour figure can be viewed at wileyonlinelibrary.com]

2. Unit Value Indexes as Benchmarks for Measuring Sourcing Bias

2.1. *The Extended Import Price Index*

A unit value index can serve as a benchmark for estimating the bias implied by changes in sourcing patterns because the observations that are not in common between the time periods are included in the unit values. In the case of substitution from a local producer to an offshore producer, the imported version of the item is included in the unit value for the latter period, and the locally produced version is included in the unit value for the previous period. Unit value indexes track the average price paid for the item and assume that versions of the item from different sellers do not vary in quality.

To derive an approximate formula for sourcing bias, assume that the world's economies can be divided into two groups, H and L. The item's price in period 0 is p_0^H if it is sourced from a high wage economy and p_0^L if it is sourced from a low wage economy. The quantities are q_0^H and q_0^L, and the versions of the item from the two groups are assumed to be of the same quality.[6] The local production in period 0 of the item whose production moves offshore in period 1 is included in group H in period 0. The unit value index equals:

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

The standard method of calculating price indexes based on subsamples of the items in common to the two periods being compared gives an index that averages the within-group price changes. Assume that the period 1 price equals r times the period 0 price in both groups. Then the matched samples index equals r and its bias equals $r - \frac{\bar{p}_1}{\bar{p}_0}$.

Unit values use quantity shares as weights to average the prices. If r equals 1, the fact that the change in the share of group H equals minus the change in the share of group L can be used to show that $\bar{p}_1 - \bar{p}_0$ equals the change in the *quantity* share of group L multiplied by $p_0^L - p_0^H$. The online appendix derives an expression for the bias in terms of the change in the *value* share of the low cost countries, $s_1^L - s_0^L$. If β is the factor that converts this value share change into a quantity share change, the expression for the bias in the linked index is:

$$r - \frac{\bar{p}_1}{\bar{p}_0} = \left(s_1^L - s_0^L\right)\left(1 - \frac{p_0^L}{p_0^H}\right) r\beta. \tag{2}$$

The formula for β marks up the price used to value the imports from group L to group H price, and then normalizes to make the quantity shares add up to 1:

[6]Models with quality differences as factors slowing substitution might imply lower bias estimates. For example, in the constant elasticity of substitution (CES) model of Feenstra (1994), the new variety that gains market share is not a perfect substitute for the older varieties. Elasticities of substitution in the range that is commonly found give a lower estimate of the bias implied by a given market share gain for new entrants than equation (2). But if information costs or switching costs, such as those found by Byrne *et al.* (2013), retard the substitution to the lowest priced seller, the CES model will underestimate the bias in the linked index.

(3) $$\beta = \frac{p_1^H/p_1^L}{1 + s_1^L\left(\frac{p_1^H}{p_1^L} - 1\right)}.$$

Based on estimates in the literature of typical price differentials between high wage and developing countries for traded items, Houseman *et al.* (2011) argue that the ratio of the low wage economy price to the high wage economy price can be assumed to be 0.5. Even allowing for a gap in productivity levels, the differences in labor costs were great enough in the time period that we investigate for 0.5 to be plausible. The estimates in Banister and Cook (2011) imply that in 2008 manufacturing labor in China cost about 4 percent of what it cost in the U.S.

Share changes of group L in U.S. imports of four types of goods between 1996 and 2007 (calculated from data published by the U.S. International Trade Commission) and the implied sourcing biases are shown in the first column of Table 1. Based on country wage levels in the late 1990s, group L is defined as Asia other than Japan, Latin America, Africa, Eastern Europe and the former Soviet republics.[7] The group had significant gains in import shares in three cases. For computers and consumer durable goods other than motor vehicles the share rose by 18.3 percentage points, for motor vehicles the share rose by 10 percentage points, and for apparel and footwear the share rose by 5.1 percentage points.

The first column of bias estimates in table 1 shows only the effect of substitution between source countries for imports. With r set equal to 1, the bias implied by equation (2) is about 0.25 percent per year for apparel and footwear, about 0.7 percent per year for motor vehicles, and slightly under 1 percent for computers and other consumer durable goods excluding vehicles. For food and beverages, which are included as a control group that was not strongly affected by country substitution, the bias estimate is, reassuringly, zero.

The second column of table 1 considers the combined effects of offshoring and substitution between import-supplying countries on the extended import index. Assume that the change between periods 0 and 1 in the imported share of the final uses of the good reflects substitution of offshore producers for local producers. Let $\tilde{s}_0^L$ equal imports from low wage countries in period 0 as a share of the total of imports and local production that will be replaced by imports. Also, let $\hat{s}_0^M$ and $\hat{s}_1^M$ be the shares of the good supplied by imports from anywhere in periods 0 and 1. Then $\tilde{s}_0^L$ equals the share of low wage countries in imports of the good in period 0 divided by the change in the share of the final uses of the good supplied by imports:

(4) $$\tilde{s}_0^L = \frac{s_0^L}{\frac{\hat{s}_1^M}{\hat{s}_0^M}}.$$

[7]The results are not sensitive to the definition of the low wage country group because China alone accounts for most of the share changes except in the case of motor vehicles. Houseman *et al.* also assume 0.7 for the ratio of the price from middle income countries to that from high wage countries. The unit value estimates are not precise estimates of sourcing bias, so to keep things simple we include the middle income countries with the low wage countries.

TABLE 1

Sourcing Bias in the Imports Index and in an Extended Imports Index that Includes Offshored Items, 1996–2007[a]

	Imports Index	Extended Imports Index
Computers and consumer durable goods, excluding motor vehicles		
Import share, 1996	1	0.761
Low wage country share, 1996	0.653	0.497
Change in share of low wage countries from1996 to 2007	0.183	0.339
β from equation (3)	1.09	1.09
Effect on 2007 index (percentage points)	9.98	18.47
Effect on annual growth rate	0.95	1.84
Effect on 2007 index (percentage points)	9.98	18.47
Effect on annual growth rate	0.95	1.84
Motor vehicles		
Import share, 1996	1	0.742
Low wage country share, 1996	0.232	0.172
Change in share of low wage countries from 1996 to 2007	0.100	0.160
β from equation (3)	1.50	1.50
Effect on index for 2007	7.50	11.99
Effect on annual growth rate	0.71	1.15
Apparel and footwear		
Import share, 1996	1	0.707
Low wage country share, 1996	0.886	0.627
Change in share of low wage countries from 1996 to 2007	0.051	0.310
β from equation (3)	1.03	1.03
Effect on index for 2007	2.61	16.02
Effect on average growth rate	0.24	1.57
Food and beverages		
Import share, 1996	1	0.918
Low wage country share, 1996	0.536	0.492
Change in share of low wage countries from 1996 to 2007	0.008	0.052
β from equation (3)	1.30	1.30
Effect on index for 2007	0.53	3.38
Effect on average growth rate	0.00	0.31

[a]Trade data source is the U.S. International Trade Commission. Estimates make the assumption that $p^L = 0.5p^H$, as explained in the text.

Sourcing bias including the effects of offshoring can then be calculated as $\left(s_1^L - \tilde{s}_0^L\right)\left(1 - p_0^L/p_0^H\right)\beta$.

For apparel and footwear, sourcing bias has an effect of 1.57 percent per year on the growth rate of the extended index, mostly from substitution of imports for local production. Offshoring also has a substantial effect on the extended import index for computers and other consumer durables, accounting for almost half of the total effect of 1.84 percent per year. For food and beverages, maintaining the hypothesis that group L prices are half of group H prices for illustrative purposes, offshoring has an effect of only of about 0.3 percent per year.

2.2. *Projected Effect of Sourcing Substitution on Consumer Prices*

Under the assumption of complete pass through of the cost savings to the retail level, the effect of sourcing substitution on the CPI for a good can be estimated from the difference between Paasche price indexes for the inputs into final sales of the good that do, and do not, correct for sourcing bias. In the Paasche

TABLE 2
Effect of Sourcing Substitution on the Average Growth Rate of the Price Index for Final Uses, 1996–2007

	Sourcing bias in extended MPI, cumulative over 1996–2007 (percentage points)	Imports as a share of final uses, 2007	Effect of sourcing change on the growth rate of the price index for final uses (percent per year)
Computers and consumer durable goods, excluding motor vehicles	18.47	0.421	−0.82
Motor vehicles	11.99	0.339	−0.41
Apparel and footwear	16.02	0.349	−0.58
Food and beverages	3.38	0.072	−0.02

indexes, the ratio of the imports of the good to the final uses of the good in the ending period is used as the weight on the imports index.

The resulting estimates of effects on consumer prices are shown in Table 2. For computers and consumer durable goods other than motor vehicles, the effect is fairly large at −0.82 percent per year. The estimated effect of sourcing substitution on consumer prices for apparel and footwear is nearly −0.6 percent per year. In contrast, for food and beverages the effect is near zero.

3. CPIs as Benchmarks for Measuring Sourcing Bias

As a solution to the problem of tracking items as they move between local and offshore production, Alterman (2015) proposes a buyer's price index for intermediate inputs. Yet for goods bought by consumers, a buyer's price index is already available. It is called the CPI. The CPI weights reflect buyers' purchasing patterns, and the CPI for an item tracks the price change when an item starts to be sourced offshore or imported from a different country as long as the physical characteristics do not change in a material way.[8] And even when the physical characteristics differ, the CPI often adjusts for the quality differences (Moulton and Moses, 1997).

Some evidence that CPIs did capture the price declines associated with offshoring comes from the negative correlation of the growth rates of the CPIs for products and a measure of offshoring from Table 4 in McCully (2011). Changes in imports of products as a share of the consumption by households of those products over 1959–2009 have a correlation of −0.71 with growth rates of the products' prices in National Income and Product Account (NIPA) Table 2.3.4. (The NIPA price indexes are constructed from CPIs.)

Although the CPIs are generally well-suited to serving as benchmarks for measuring sourcing bias, they have some weaknesses that should be recognized.

[8]Bils (2009) performed an analysis of CPI micro data on durable goods and found that a large proportion of changes in unit prices associated with the entry of new models were included in the CPI. This suggests that direct price comparisons of items with minor differences in characteristics are common. Bils argues that this has resulted in under-correction for quality change in cases of improving technology for durable goods.

First, comparisons of CPIs and MPIs are affected by random differences in the detailed products and varieties represented in the two series. There is one case in which a variety mix effect has been identified as increasing the relative growth rate of the MPI. Luxury vehicles have a larger weight in the MPI for new motor vehicles than in the corresponding PPI, and Bustinza *et al.* (2008) suggest that this explains the higher growth rate of the MPI in 2001–07.[9] However, there is no reason to believe that variety mix effects have a systematic tendency to raise the relative growth rate of the MPI. If the variety mix differences are random, their effects should tend to zero as the number of individual products included in a broader aggregate gets larger. The differences in varieties mean only that, taken in isolation, a comparison of a CPI and an MPI for an individual product is not a reliable measure of sourcing bias.

Another problem that tends to cause the comparisons with CPIs to underestimate sourcing bias is that the CPI may itself fail to capture all the price reductions associated with sourcing substitution. Some shifts in sourcing may coincide with changes in item characteristics that prevent the CPI from comparing the price of the version of the item from the new location with the version from the previous location. In constructing the GDP deflator, this kind of bias in the CPI would tend to have offsetting effects to the bias in the MPI. However, it is also likely that price reductions from sourcing substitution are not completely passed through to the retail level.

There are also three systematic effects that go in the other direction, tending to cause the comparisons with CPIs to overestimate sourcing bias. First, the price concept used in the MPI does not include tariffs, so the MPI does not reflect the tariff declines that occurred because of trade liberalization agreements. This effect is small. Second, the CPI uses a geometric mean formula to aggregate individual prices into lower-level indexes, and this formula tends to yield lower estimates of price growth than the Laspeyres formula of the MPI. Third, the CPI uses hedonic or hedonic-like quality adjustment procedures for computers and some other durable goods that have frequent quality improvements as a result of technological progress, such as major appliances, televisions and video equipment.[10] To avoid overestimating sourcing bias, we will adjust the growth rate comparisons for these three effects.

4. Constructing Wholesale Purchasers' and Retail Purchasers' Price Indexes

Differences between the classification systems used in the MPI and CPI mean that only a few detailed MPI items can be matched to a corresponding CPI item. For this reason, and to reduce the influence of differences in the mix of product varieties, the matches must be made at higher levels of aggregation.

[9]They also note that manufacturers' incentives, such as rebates, are captured in the PPI but not in the MPI. Yet direct payment of rebates by the overseas parent would violate tax regulations on transfer pricing.

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

Our first step in forming comparable aggregates of detailed MPIs and of detailed CPIs was to identify the products used for personal consumption expenditures that are imported using detailed "use" table data from BEA's Annual Industry Accounts (AIAs). We then used household consumption expenditures on these products to construct the weights that we used to form Fisher indexes. After excluding a few products that could not be matched to a CPI or that had zero imports in the first or last year included in the analysis (1997 or 2007), 458 detailed products in 209 product groups remained in the sample. These detailed products comprise about 20 percent of personal consumption expenditures on non-energy goods.

Another issue in using CPIs as benchmarks for estimating sourcing substitution bias is that many broadly-defined products that are imported also have some local production. To account for the influence of prices of locally supplied products, we used weighted combinations of PPIs and MPIs for a wholesale purchasers' index. The weights for the MPI and PPI in these indexes are the shares of imports and local production in the overall supply of each product. The assumption behind these weights is that the overall sourcing pattern for a product is also the sourcing pattern of households' uses of the product.

The presence of local production implies that the effect of offshoring on the extended imports index is larger than the gap g between the wholesale purchasers' index I^W and the CPI.[11] If the PPIs are unbiased and the weight on imports in a Paasche formula for the wholesale purchasers' index is $\hat{s}_1^M$, then the bias in the extended imports index for purposes of deflating imports in GDP equals $g/\left[1-\left(1-\hat{s}_1^M\right)\right]I^W \approx g/\left(1-\hat{s}_1^M\right)$. However, applying a conversion factor of $1/\left(1-\hat{s}_1^M\right)$ to convert g into a sourcing bias in the extended imports index assumes that no measurement effects are present that tend to make the PPI rise relative to the CPI. In the cases of apparel and durable goods, the gaps between the PPI and the CPI are as large, or nearly as large, as the gaps between the MPI and the CPI, and measurement problems may contribute to the PPI growth rate gaps.[12] Foster *et al.* (2008) find that new producers tend to have lower prices, and if the new producers are linked into the PPI samples these price declines will not be captured. Also, the PPI does not use geometric means. To allow for the influence of measurement factors in the gap between the PPIs and CPIs, we will use a low conversion factor of 1.2, which corresponds to the value of 0.83 for $\hat{s}_1^M$, in converting wholesale purchasers' price growth rate gaps into estimates of sourcing bias in the extended imports index.

Another issue is the markups to cover local transportation and distribution services that are included in retail prices. If the markup rates for transportation and distribution do not remain constant, that could cause the CPI to have a different growth rate from the wholesale purchasers' price index. To allow for the possibility of changing markup rates, in addition to the wholesale purchasers'

[11]This assumes that the PPI does not have more measurement bias than the MPI. There is no reason to believe that measurement problems in the PPIs make their growth gaps compared with the CPI larger than those of the MPIs.

[12]Lawrence and Slaughter (1993) looked at MPIs for labor-intensive products during an earlier period of rising imports of these products from low wage countries and found no evidence of relative declines in the MPIs for those products compared to PPIs.

TABLE 3
Growth Rate Differences from Matched CPIs, 1997–2007

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

index we construct a retail purchasers' index that incorporates local transportation margins and trade margins. (The price indexes and values for transportation margins and wholesale and retail trade margins come from the AIAs). In constructing the retail purchasers' index, imports of the good, local supply of the good, local transportation services and distribution services are each weighted by their shares in the value of final uses of the good.

But even though the retail purchasers' price index is conceptually well-suited to compare with a CPI, adjusting for changes in transportation and distribution margins may not improve the comparisons in actual practice. Measuring price changes for transportation and trade margins is difficult, and the available margin indexes are not specific to the particular products that are imported.

5. Empirical Results

5.1. *Differences between Wholesale Purchasers' Indexes and CPIs*

The differences between wholesale purchasers' indexes and CPIs, shown in the second column of Table 3, have a similar pattern to the estimates of sourcing bias in Table 2. Food and alcoholic beverages have a growth rate difference near zero. Motor vehicles have a growth rate gap in Table 3 of 0.3 or 0.4 percent per year, depending on whether parts are included, close to the sourcing substitution effect of around 0.4 percent per year in Table 2. For durable goods and for apparel and textiles the growth rate gaps in Table 3, at 2 percent and 1.5 percent per year, respectively, are larger than the sourcing bias estimates in Table 2, but these growth rate gaps partly reflect the effects of falling tariffs and methodological differences in the CPI. For all imported consumer products in the aggregate except tobacco (which is excluded because rising excise taxes added to its CPI growth), the growth rate gap between the wholesale purchasers' index and the CPI is 1.1 percent per year.

The effects that generate sourcing bias should cause the MPI itself to rise relative to the CPI. To verify that the slower growth of the wholesale purchasers' index is not due to its PPI component, MPIs are compared to CPIs in the fourth column of Table 3. For most product groups, the MPI and the wholesale purchasers' index are similar. The growth rate gap for apparel and textiles is still 1.5 percent per year using the MPI, and for durable goods excluding computers, the growth rate gap is only slightly larger. On the other hand, in the case of motor vehicles, using just the MPI makes the growth rate gap significantly larger, at 0.7 percent per year. The faster growth of the MPI for vehicles may be due in part to rising relative prices of luxury vehicles. Also, for computers, using just the MPI makes the growth rate gap much larger. The MPI rarely uses hedonic adjustment procedures, whereas hedonic or cost-based quality adjustment procedures are often used in the PPI.

5.2. *Differences between Retail Purchasers' Price Index and CPIs*

Margins for transportation within the U.S. and for retail distribution services are included in the prices paid by consumers. Indexes that incorporate transportation and distribution margins would measure retail purchasers' prices indexes and would, at least in theory, be better suited for comparisons with CPIs than wholesale purchasers' price indexes. Prices for the distribution services are, however, difficult to measure, and the available indexes for distribution and transportation margins are highly aggregated. In practice, therefore, retail purchasers' indexes are probably not measured with sufficient precision to be superior for comparisons with CPIs.

Fortunately, there is usually no need to choose between the retail and wholesale purchasers' indexes because often they are similar. In particular, for durable goods, and for apparel and textiles, the growth rate gap between the retail purchasers' indexes and the CPI in the third column of Table 3 is close to the growth rate gap of the wholesale purchasers' index. For nondurable goods, however, the growth rate gap becomes negative using the retail purchasers' indexes. This reduces the aggregate growth rate gap for all products except computers to 0.6 percent per year. Also, some differences emerge at the level of detailed types of goods, most notably for computers.

5.3 *Adjusting for Falling Tariffs and Use of Geometric Means and Hedonics in the CPI*

Adjustments for effects other than sourcing bias that contributed to growth rate gaps between the wholesale purchasers' indexes and the CPI are shown in

Table 4. First, declining tariffs tend to add to the growth rate gap between the MPI and the CPI because the prices used in the MPI exclude tariffs. Feenstra, Mandel, Reinsdorf and Slaughter (FMRS, 2013) find that including tariffs in import prices reduces the average growth for the MPI over 1996–2006 by 0.08 percent. Rounding implies an adjustment of 0.1 percent per year for the effects of declining tariffs.

Second, the CPI uses geometric means to construct lower-level indexes. In FMRS (2013) the average annual growth rate of MPI excluding petroleum and semiconductors (which are not consumer goods) falls by 0.67 percent per year when a Törnqvist formula is substituted for a Laspeyres formula. The Törnqvist indexes use geometric means, but they cover broader aggregates than the geometric mean indexes of the CPI, so a plausible estimate of the effect of geometric means on an MPI excluding petroleum and semiconductors is 0.6 percent per year. The effect of the geometric mean indexes on the CPI is investigated by Stewart and Reed (2009). The "other goods and services" category is the best match for the durable goods category of Table 3. Averaging the effect of 0.25 percent for the CPI and 0.6 percent for the MPI and then rounding gives the adjustment for the geometric means of the CPI of 0.4 percent per year shown for durable goods in Table 4.

For apparel and textiles, FMRS (2013) find that the effect of Törnqvist indexes on the MPI is 0.3 percent per year, while in Stewart and Reed (2009) apparel is an outlier, with an effect of 1.4 percent per year. Averaging the 0.3 percent per year estimate of the effect on the MPI in FMRS (2013) and the 1.4 percent per year effect on the CPI in Stewart and Reed (2009) and rounding gives an estimate of 0.8 percent per year for the effect of geometric means for apparel and textiles.

Third, hedonic regressions or other quality adjustment methods with similar effects have been used in the CPI for computers since 1998, and the CPI also uses hedonics for some other durable goods, such as major appliances, televisions and video equipment. Kim and Reinsdorf (2015) found that using hedonic indexes for

TABLE 4

Adjusted Growth Rate Gaps for Wholesale Purchasers Price Indexes for Durable Goods and Apparel[a], 1997–2007 (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	**1.0**	**0.9**
Declining tariffs	0.1	0.1
Geometric mean formula for elementary aggregates of the CPI	0.4	0.8
Hedonic quality adjustment methods in the CPI	0.5	0[a]
Adjusted Growth Rate Gap	**1.0**	**0.6**

[a]Hedonic regressions are used in the CPI for apparel, but the characteristics of these indexes are different from durable goods.

televisions in the MPI combining video monitors and televisions reduced that index's growth rate in 2000–10 by 0.4 or 0.6 percent per year, depending on the specification used. The implied effect on the MPI for televisions in isolation was around 1 percent per year.

Turning to CPI evidence, without the CPI's hedonic adjustment, the growth rate gap for computers of 6.4 percent per year in Table 3 might be the same as that of all other durable goods at 3.1 percent per year. The growth rate gap for electric equipment exc. computers of 4.2 percent per year might also be the same as that of all other durable goods. Reducing the growth rate gaps for computers and other electric equipment to 3.1 percent per year causes the growth rate gap for durable goods as a whole to fall by 0.5 percentage points.[13] This value is used as the effect of hedonic adjustment in the CPI on the growth rate gap for durable goods.

Hedonic regressions are also used in the CPIs for apparel, and the indexes calculated by Brown and Stockburger (2006) imply that hedonic adjustment reduces the growth rate of these indexes by 0.2 percent per year. Nevertheless, on the whole, the special procedures in the CPI for apparel for handling entry and exit of individual items have the effect of raising this index's growth rate (Reinsdorf *et al.*, 1996). We therefore make no adjustment for quality change procedures of the apparel CPI.

Together the three adjustments in Table 4 bring the growth rate gap for consumer durables down to 1.0 percent per year, a figure that still exceeds the estimate in Table 2 of the effect of sourcing substitution on the index for final uses of durable goods by 0.2 percent per year. The two adjustments to the growth rate gap for apparel bring this gap down to 0.6 percent per year, which is quite close in magnitude to the effect of sourcing substitution shown in Table 2.

6. Effect On Wholesale and Retail Distribution Margins

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

To test whether higher proportions of imports in the overall domestic supply of a commodity are associated with higher distribution margins, we regress trade margin levels and growth rates on import share levels and growth rates. The regression implies that a 10 percent increase in the share of domestic supply sourced from imports is associated with a 1.3 percentage point expansion in the distribution margin, with a t statistic of 4.3 (Table 5).

[13]The results in Erickson and Pakes (2011) suggest that this effect may be small; their table 12 shows that handling item replacements in the CPI for non-computer electric durables by treating them as comparable, or using hedonics or class mean imputation, can have either a positive or a negative effect compared to a pure matched model index.

TABLE 5

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 6

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

The regression in levels could, however, be biased if the types of commodities that are heavily imported—such as apparel—have characteristics that require unusually high distribution services. To control for effects of commodity type, we also test the specification that has growth of distribution margins as the dependent variable. The results show that growth in imports also has a statistically significant effect on growth in distribution margins, with a t statistic of 2.8 (Table 6). The coefficient estimates imply that a product whose import share grew by 10 percentage points would have an extra 0.93 percentage points of growth in its distribution margin compared with a product whose import share was stable.

7. Implications for the Measurement of Output and Productivity

The presence of the PPI component in the wholesale purchasers' index means that the growth rate gaps between that index and the CPI may understate the bias in the extended imports index. As discussed above, 1.2 is a reasonable conversion factor for transforming the growth rate gap of the wholesale purchasers' index into an estimate of sourcing bias in the extended imports index. The adjusted growth rate gap for durable goods of 1 percentage point would then imply an estimate of sourcing substitution bias in the extended imports index of 1.2 percentage points, and an estimate of 0.7 percent per year for apparel. The more conservative alternative would be to simply use the gap between the wholesale purchasers' index and the CPI as the estimate of sourcing bias.

To determine the weights on the extended imports indexes while calculating corrected measures of GDP volume growth, we include intermediate inputs that are closely related to consumer goods. This amounts to assuming that the related intermediate inputs have the same bias as the consumer item; for example, textiles are assumed to have the same sourcing bias as apparel. (However, we exclude capital goods that are similar to consumer durable goods from the bias calculation for GDP growth because the MPIs for these goods are also used in calculating the deflator for the investment component of GDP, causing any bias in their MPI to cancel out.)

Imports of manufactured durable goods amounted to 5 percent of U.S. GDP in 2007, so multiplying their share weight by the sourcing substitution bias estimate of 1.2 percentage points implies a contribution to the measured growth rate of real GDP of 0.06 percentage points. (This contribution rises to 0.075 percentage points if the bias in the MPI from under-adjustment in quality change in computers and other durable goods with high rates of technological progress is also included). Imports of apparel, footwear and textiles amount to just under 1 percent of GDP in 2007, so they add 0.007 percentage points to sourcing bias. This brings the total estimate of the bias in GDP growth up to about 0.07 percentage points.

For productivity growth, the effects are larger. A bias in the deflator for imported capital goods affects measurement of the capital stock and hence multifactor productivity (MFP). Also, imports of manufactured durable goods and apparel and textiles are larger shares of private business value added (on which the broadest productivity measures are based) than they are of GDP.[14] Imports of manufactured durable goods and capital goods amounted to 10.4 percent of the gross value added of private business in 2007, so a sourcing substitution bias of 1.2 percentage points for these goods implies a bias of 0.125 percentage points in the measured rate of MFP growth of private business. Sourcing substitution bias for apparel and textiles causes an additional 0.01 percentage points of upward bias in this MFP measure, so the total bias in the MFP growth rate is about 0.13 percentage points.

This amount of bias is significant compared to the average rate of MFP growth in 1997–2007 of 1.5 percent per year. Furthermore, our analysis considers only offshoring of goods. Sourcing bias from services (such as the call centers that were offshored) may plausibly have added an additional 0.02 percentage points to the bias in measured MFP. As a share of the value added of private business, imports of the business, professional and technical services subject to offshoring grew by an average of 0.04 percentage points per year in 1997–2008.[15] A figure of 0.02 percent per year for services sourcing bias is consistent with the assumptions that the offshore price is half the local price and that substitution to lower cost locations for services that were already imported also resulted in unmeasured cost savings for services importers.

The sourcing substitution bias estimate of 0.13 percent per year for business sector multifactor productivity is not far from the lower bound estimates of offshoring bias for multifactor productivity of manufacturing in Houseman *et al.* (2011) using conservative assumptions. Those bias estimates are 0.18 percent per year using the "switchers" sample, or 0.14 percent per year using the assumptions of a 30 percent discount from developing countries and a 15 percent discount

[14]We treat the private business sector used by the U.S. Bureau of Labor Statistics for MFP measurement as equivalent to the business sector of the NIPAs. The sectors differ because the value added of government enterprises is not included in the private business sector. But the difference amounts to only around 1 percent of the value added of the business sector.

[15]The estimates include commodity codes 5411, 5412OP, 5415 and 561 from the "use tables" covering 1997–2014 from BEA's input-output accounts.

from intermediate countries. The effects of offshoring of intermediate inputs on measured MFP for manufacturing are greater than for business as a whole because manufacturing uses more intermediate inputs.

These bias estimates could be too small because they depend on an assumption that the CPI captured all of the price declines from sourcing substitution. It is likely that some of the prices declines were not captured by the CPI, either because pass-through was incomplete or because the CPI may itself fail to capture some price declines related to sourcing substitution.

Conversely, offsetting, though probably smaller, effects may have been present on the export side. At the same time as new trading relationships with emerging economies were bringing down the average price paid by buyers of importable products, or offshored items, they may also have lowered the average price received by U.S. exporters (Harrigan *et al.*, 2011). Lower prices offered to new customers in emerging economies not reflected in the U.S. export price index may have offset some of the effects of sourcing bias in the imports deflator in the measurement of GDP volume growth.

Finally, it is important to note that not all of the effects of sourcing substitution have gone unmeasured in the official indexes, in part because existing suppliers reduced their prices to compete with the new suppliers from low cost locations (Mandel, 2013). For example, the price index for durable goods imports in the NIPAs declined sharply relative to the index for gross domestic purchases during the period of rapid growth in imports from emerging economies. Indeed, over 1995–2007 the impact of sharply rising prices for petroleum imports on U.S. real gross domestic income was completely canceled out by the falling price of nonpetroleum imports.

6. Conclusion

The decade leading up to the 2008 financial crisis saw rapid growth of manufacturing in emerging market economies, particularly after China joined the WTO. Wholesale level buyers in the U.S. paid lower prices by sourcing from these emerging economies, and these price reductions were not captured in the MPI or in the deflator for imports in GDP.

To estimate sourcing bias in the deflator for imports used to measure U.S. GDP volume growth, we identify consumer products that are at least partly supplied by imports in BEA's input-output accounts. We then construct wholesale purchasers' indexes that aggregate MPIs and PPIs for these products using shares in personal consumption expenditures as weights and compare these indexes to corresponding aggregates of CPIs. CPIs are used as benchmarks for estimating sourcing bias because they usually capture the reductions in buyers' prices caused by sourcing substitution, but they may have some sourcing bias themselves.

After adjusting for effects of tariffs and CPI methods, the growth rate gaps between the wholesale purchasers' indexes and the CPI attributable to sourcing substitution bias is found to add 1 percentage point to the growth rate of the imports deflator per year for durable goods in 1997–2007, and 0.6 percentage points to the growth rate of the imports deflator for apparel and textile products.

The bias in the imports deflator is larger than the gap between the wholesale purchasers' indexes and the CPI under plausible assumptions about the gap between the PPIs and the CPIs caused by measurement problems. The effect of sourcing bias on the measure of multifactor productivity growth of the private business sector is estimated to be 0.13 percent per year.

The period of rapid sourcing change approximately corresponds with the multifactor productivity speedup period of 1996–2005. Mismeasurement of import prices related to sourcing change appears to be responsible for about a tenth of the speedup in measured productivity growth.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher’s website:

Appendix: Derivation Of Equation For The Bias In The Linked Index