4

Do Developed and Developing Countries Compete Head to Head?

In this chapter, we show that as an indicator of head-to-head competition in export markets, the data on high-technology products are insufficiently discriminating and thus seriously misleading. In fact, the United States remains a strong competitor in the most sophisticated (high unit value) high-technology products. By contrast, developing countries such as China generally export very different products, and where developing-country export products overlap with US exports, they are typically much cheaper and of lower quality. More generally, we demonstrate that even the most disaggregated data available—the 10-digit Harmonized Tariff Schedule (HTS) classification data—can be misleading because the products exported by developed and developing countries in these categories are fundamentally different. This is especially the case for products classified as high-technology because the scope for differentiating these products is much greater than for products in which technological inputs are less important.

We start by using disaggregated data to explore whether developed and developing countries export similar manufactured products. We calculate a similarity index that captures the degree to which exports share the same classification categories. This allows us to explore across-product specialization in exports. Fortunately, we can compile very fine-grained measures of similarity because the United States reports trade data in highly disaggregated 6- and 10-digit HTS categories. For example, the 10-digit HTS import category number 6103106030 contains values of "cotton waistcoats imported as parts of suits."

However, even at the 10-digit HTS level, the data still reflect an aggregation of products of different quality. For example, all cotton waistcoats that are parts of suits are not created equal. Indeed, some may be of much better quality and have different product attributes (e.g., silver versus gold buttons) than others. We therefore explore additional measures of within-product specialization. First, we compare price differences within detailed categories by examining average unit values at the most disaggregated level available (typically either the HTS 10- or 6-digit levels). Second, we report on additional tests in which we distinguish products according to both their technological intensity and whether they are finished products or intermediate inputs. And third, we report on the results of tests that reveal quality differences, even when goods have the same price. We also investigate the possibility that the classification system itself could bias the result.

Our tests all lead to a central conclusion. There are distinctive patterns of international specialization, and developed and developing countries export fundamentally different manufactured products. Judged by export shares, the United States and developing countries specialize in quite different product categories that for the most part do not overlap. Even when they do overlap and exports are classified in the same category, there are large systematic differences in unit values that suggest the products exported by developed and developing countries are not very close substitutes—developed-country products are far more sophisticated.

We find that per capita incomes are a powerful predictor of relative unit values—a result we draw on later in this study. It is generally possible, with a fairly high degree of accuracy, to rank relative export unit values from different countries and deduce their per capita income rankings. This finding is important because it suggests that developing economies will become serious head-to-head competitors with the United States in export markets only when their per capita incomes are much closer to US levels.

Nonetheless, these statements about prices do not hold to the same degree for all types of products. We find that the scope for price differentiation is far higher in what are called high-technology products than in primary-commodity-intensive products or manufactured products classified as "low-tech." Indeed, export prices for commodity-intensive products from developed and developing countries—think copper or steel—are typically not very different. Likewise, prices from developed and developing countries for low-tech products—think clothing—are often fairly close. (Although not all, of course—try comparing Italian and Brazilian shoes.) In these areas, therefore, head-to-head competition does exist. But when it comes to medium- and high-tech products, developing-country products are located much further down a much larger price spectrum. Moreover, there is little evidence of substantial price convergence over time. Especially in high-tech, therefore, developed and developing countries are not competing by exporting goods that are close substitutes.

To justify our conclusion that these goods are not substitutes we also consider and rule out two other interpretations of the results showing large price differences. The first is that the products reflect different stages of vertical integration because even these most disaggregated data do not distinguish sufficiently between finished goods and intermediate inputs. For example, exports from China and the United States might both fall in a category that is labeled as "audio parts," but the Chinese exports could be less finished parts (e.g., chips used in radio volume controls) while the US exports could be more finished products (e.g., completed volume control panels that contain chips). We carry out the analysis using only those end-use categories specifically identified as finished goods. While we do find the price differences are slightly smaller when we consider only high-tech finished goods, we again find that these differences are very large and persistent.

If products are homogeneous and of similar quality, the cheapest will capture the entire market, but if they are differentiated, price differences for similar products could coexist. A second concern, therefore, is that the lower prices of developing-country exports could simply indicate that they are selling fairly similar products at much lower prices rather than products that are fundamentally different from those sold by developed countries. We deal with this objection using a technique developed in the literature to distinguish quality differences. This approach uses the insight that if two similar but differentiated products have the same price, the one with higher quality will capture a larger market share. We report on a regression analysis that allows us to deduce product quality from the residuals of a regression that explains market shares controlling for price and variety. Our findings confirm that in terms of high-tech products, developing countries specialize in products that not only have lower prices but also, given these prices, lower quality.

These findings are particularly strong, as many of the goods imported by the United States from China and other developing countries actually contain high shares of value that was added in other countries that are more advanced than China. Global supply chains in which China adds assembly services to more sophisticated inputs bias the data toward suggesting China is more advanced than it actually is. Thus, the results show how seriously trade data in products classified as high-tech and advanced technology can mislead.

All told, our results point to the pitfalls of data aggregation in a world with a high degree of specialization within industries and narrow product categories. Developing countries have increasingly moved into the product categories in which developed countries also export. However, they have primarily moved into the low end of these categories, and there has not been a convergence in relative unit values over time.

Many years ago, Raymond Vernon (1966) wrote about a product cycle that is characteristic of trade in high-tech products. He argued that new products would initially be produced and exported by advanced countries, but later, as the new products became less novel and their production processes more standardized, production would eventually move to less developed countries. Our findings provide considerable confirmation for his view.[1] The anomalous findings that developing countries seem to be exporting technologically intensive products can be explained if it is recognized that the versions of these

1. See Zhu (2005) for a more recent application of product-cycle theory.

products that are made by these countries have become sufficiently standardized to no longer qualify as high-tech.

We are not the first researchers to argue that relative factor endowments provide poor explanations for specialization when aggregate industry data are used. We owe this insight to Peter Schott (2004), who concluded that the conventional Heckscher-Ohlin theory still explains trade patterns, but only when more disaggregated data are used to measure the factor intensity of products. However, the systematic relationships we find between the scope for differentiation and technological intensity could suggest that in addition to endowments, technologies are fundamentally different in developed and developing countries. Indeed, part of the reason developed countries are richer is that they have invested more in developing technologies that are more advanced. Support for this view is provided by the work of Daron Acemoglu (1998, 2003), who argues that skill-abundant countries are likely to develop skill-biased technologies.

In the chapters that follow we refer back to these results because they help us explain how the US manufacturing terms of trade have improved strongly, despite the apparent loss of comparative advantage in high-tech products, and how the effective (productivity-adjusted) prices of manufactured prices of goods produced in the United States have not reduced the relative wage of unskilled US workers.

Export Overlap

We first explore the overlap between US manufactured exports and foreign exports to the United States using the data on commodity shares for 1990, 2000, and 2006. We concentrate on US trade in manufactured goods (NAICS 331–333),[2] dropping refined petroleum products from the data. We use the US trade data provided by Robert Feenstra, John Romalis, and Peter Schott (2002) and the United States International Trade Commission. The data are highly disaggregated. There are about 9,000 export codes and approximately 12,000 import codes.

To exploit the US data we assume that the goods foreigners export to the United States are representative of the goods they generally export to the rest of the world. This allows us to base our comparison of trade flows using the most disaggregated trade data available—namely the 10-digit HTS level. Schott (2008) pursues a similar approach in his analysis of the sophistication of Chinese exports. Further, other research using much more aggregated 6-digit export data corroborates the findings presented in this chapter.[3]

2. NAICS is the North American Industry Classification System.

3. See the very detailed study by Lionel Fontagné, Guillaume Gaulier, and Soledad Zignago (2008), who find a high degree of international specialization within products, especially for trade between advanced and emerging-market economies. Andre Frauenknecht (2009) compares US and Chinese exports to 10 EU countries and six emerging Asian economies at the 6-digit level of the Harmo-

The overlap between US manufactured exports and foreign exports is calculated using an export similarity index. The similarity index involves (1) calculating shares of each commodity, (2) summing the absolute difference in these shares, (3) dividing the result by two, and (4) subtracting that result from unity.[4] If X_i is the share of commodity i in imports from country X and Y_i the share of commodity i in imports from country Y, then the absolute difference in the share of each commodity is first calculated.

$$|X_i - Y_i|. \tag{4.1}$$

The sum of these differences is then divided by two and subtracted from one to provide a similarity index SI_{XY} between X and Y that equals zero when the two series are completely different and one when they are completely similar.

$$SI_{XY} = 1 - \sum_i |X_i - Y_i|/2. \tag{4.2}$$

Consider, for example, if there were just two commodities and two countries. If each fully specialized in exporting one of the products, and both exported the same product, the second part of this expression would equal zero and thus subtracting zero from one would give us one, perfect overlap. If each exported a different product, the value of the second half would equal one, which subtracted from one would equal zero, indicating no overlap.

One weakness in the measure is that it is sensitive to the level of disaggregation. Accordingly, we have calculated these indices at the most disaggregated level possible, the 10-digit HTS level when comparing imports and the 6-digit level of the Harmonized System (HS) when analyzing US exports.[5]

Table 4.1 reports the various export similarity indices for a selection of developed and developing countries in 1990, 2000, and 2006. "Developing countries" here include all low- and middle-income economies defined according to the World Bank Income Classification System of 2007. Developed countries cover high-income economies.[6] The left side of the table compares

nized System (HS). He finds an increased overlap between Chinese and US exports to these regions, but also considerable overlap within product specialization. The mean unit value of US exports at the 6-digit level exceeds that of China's by a factor of 2–3 over the 1996 to 2006 period. Zhou Liu (2006) reaches similar conclusions.

4. An alternative approach developed by Michael Finger and Mordechai Kreinen (1979) sums the minimum share for each commodity and produces an index in which 100 implies complete similarity and zero no overlap. See also Sun and Ng (2000).

5. The HTS classification has been revised on numerous occasions to reflect the development of new products. To ensure comparability across time, we convert all the 10-digit HTS data to a time-consistent code using the concordance map developed by Justin Pierce and Peter Schott (2009). For similar reasons, the 6-digit HS code is converted to the 1988/92 revision.

6. Countries are divided among income groups according to 2006 gross national income per capita. The groups are low-income, \$905 or less; lower-middle-income, \$906–\$3,595; upper-middle-income, \$3,596–\$11,115; and high-income, \$11,116 or more. The high-income OECD category includes all OECD members prior to 2009, excluding Mexico, Poland, Slovakia, and Turkey.

Table 4.1 Export similarity indices for manufactured goods, ranked by similarity with high-income OECD countries in 2006

Country	Export similarity with high-income OECD country exports to the United States, 10-digit HTS level data				Export similarity with US exports, 6-digit HS level data			
	1990	2000	2006	Change, 1990–2006	1990	2000	2006	Change, 1990–2006
Vietnam	n.a.	0.03	0.08	n.a.	n.a.	0.04	0.07	n.a.
Hong Kong	0.22	0.19	0.18	–0.04	0.21	0.21	0.20	–0.01
India	0.08	0.13	0.18	0.10	0.09	0.15	0.21	0.12
Singapore	0.18	0.18	0.19	0.01	0.22	0.24	0.24	0.02
ASEAN 4	0.18	0.23	0.19	0.01	0.17	0.26	0.24	0.07
China	0.15	0.25	0.25	0.10	0.11	0.24	0.26	0.15
Taiwan	0.27	0.28	0.26	–0.01	0.27	0.33	0.31	0.04
Other developing	0.22	0.24	0.26	0.04	0.22	0.23	0.27	0.05
France	0.31	0.33	0.32	0.01	0.38	0.39	0.40	0.02
Mexico	0.33	0.41	0.39	0.06	0.30	0.37	0.37	0.07
United Kingdom	0.41	0.44	0.43	0.02	0.45	0.47	0.43	–0.02
Korea	0.28	0.34	0.44	0.16	0.23	0.30	0.34	0.11
Other developed	0.49	0.51	0.54	0.06	0.41	0.43	0.45	0.04
Japan	0.61	0.60	0.55	–0.06	0.42	0.46	0.40	–0.02
Germany	0.50	0.54	0.56	0.06	0.41	0.47	0.47	0.06
Canada	0.53	0.55	0.56	0.04	0.39	0.43	0.45	0.06

n.a. = not available

OECD = Organization for Economic Cooperation and Development; ASEAN = Association of Southeast Asian Nations

Note: Zero is completely different; higher numbers imply greater similarity. Processed petroleum products are excluded. The similarity indices based on high-income OECD countries use a time-consistent Harmonized Tariff Schedule (HTS) 10-digit code while the indices based on US exports use a time-consistent Harmonized System (HS) 6-digit code based on the 1988/92 revision of the HS. ASEAN 4 consists of Indonesia, Malaysia, the Philippines, and Thailand. The other developing countries category consists of the remaining low- and middle-income countries. The OECD category includes all OECD members prior to 2009 excluding Mexico, Poland, Slovakia, and Turkey.

Source: Authors' calculations based on US trade data obtained from Feenstra, Romalis, and Schott (2002).

US imports from these countries with US imports from high-income OECD countries. The right side compares the similarity of US imports with aggregate US exports.

The two different comparisons yield remarkably similar results in terms of both the level and trend of the indices. Focusing first on 2006, it is clear that among the sample of countries Vietnamese exports are the most different from those of the United States and high-income OECD countries. Next most different are those from Hong Kong and then India. China and the category of other developing countries occupy intermediate positions, while developed countries such as Germany, Japan, and the category of other developed countries have the most similar structure to US exports.

The ordering of export similarity is broadly consistent with GDP per capita. Exports from low-income countries display the least overlap with OECD exports and aggregate US exports, but exceptions are evident.[7] Surprisingly, perhaps, Hong Kong's export similarity with the OECD countries and the United States was very low in 2006 despite its high-income per capita status. This is consistent with Hong Kong specializing in the more sophisticated parts of global supply chains that produce labor-intensive products, e.g., contributing services like design and marketing to clothing and electronics produced in China. The composition of Korea's and Mexico's exports to the United States was more similar to aggregate OECD exports than France's export bundle (and the United Kingdom in the case of Korea) in 2006, but this ordering is reversed in the comparison with aggregate US exports.

The change in similarity over time is also interesting. The export similarity of China, India, and Korea with the OECD countries and the United States rose from 1990 to 2006. China, for example, rose from a low similarity position in 1990 to an intermediate position in 2006, but remains more similar to other developing economies than to developed countries, including the United States. A further observation is that almost the entire increase in China's export similarity took place between 1990 and 2000, with very little change in similarity from 2000 to 2006, a period when US imports from China rose dramatically.[8] Exports from Korea and India, in contrast, showed a steady increase in similarity with OECD and aggregate US exports in both periods.

Overall, the indices reveal a rising export similarity between many developing countries and the OECD and the United States, but the overlap remains low. The rising similarity is broadly consistent with improvements in per capita growth in these countries and does not necessarily reflect exceptional increases in competition with US exports in recent years. Further, developing-country export similarity with the United States continues to be far lower than for developed countries. Even developed countries show a high degree of dissimilarity with US exports (typically around 0.5).

A comparison of cumulative export shares to the United States in table 4.2 corroborates this finding. China has been the focus of considerable attention in the debate on the effect of emerging-market economies on US welfare. We have therefore ranked manufactured products according to their share in Chi-

7. Econometric estimates by Schott (2008) reveal a statistically significant association between GDP per capita and export similarity with the OECD. In Schott's simple regressions, China's export similarity to the OECD is greater than what would be predicted on the basis of its income per capita. However, China is no longer found to be an outlier after jointly controlling for size and level of development.

8. This is consistent with the findings in Amiti and Freund (2010) that most of China's export growth has taken place along the intensive margin.

Table 4.2 Cumulative shares of manufactured exports to the United States relative to China, 2006 (percent)

	Developing-country exports to the United States					High-income Asian country exports to the United States				Other high-income exporters	
China	ASEAN 4	Mexico	India	Vietnam	Other	Korea	Hong Kong	Singapore	Taiwan	OECD exports to the United States	US exports
5	10	0	0	0	0	0	0	1	1	0	0
10	13	2	0	0	1	13	1	4	5	2	1
15	21	3	0	3	1	19	2	20	14	3	2
20	24	12	1	3	1	21	3	20	19	4	2
25	25	15	1	11	2	21	3	21	19	4	3
30	32	15	1	12	2	22	5	39	20	4	4
35	38	17	3	19	3	22	10	40	22	5	4
40	40	18	3	22	3	23	11	42	25	6	5
45	50	20	4	30	4	31	14	55	37	7	9
50	52	23	6	37	9	33	27	56	44	8	11
55	56	27	21	45	14	36	48	56	47	11	13
60	64	29	22	47	15	37	53	58	50	12	14
65	67	33	26	53	17	41	56	59	54	14	16
70	69	36	33	57	21	42	63	59	59	15	17
75	73	41	39	63	24	43	66	60	62	17	18
80	76	48	42	70	29	47	74	62	67	21	23
85	79	52	46	77	35	50	77	63	71	24	28
90	84	56	68	84	43	56	85	65	79	31	35
95	89	64	77	93	52	62	92	73	86	40	43
100	100	100	100	100	100	100	100	100	100	100	100

OECD = Organization for Economic Cooperation and Development; ASEAN = Association of Southeast Asian Nations

Note: Calculated using US trade data at the Harmonized System 6-digit level (1988/92 revision). ASEAN 4 consists of Indonesia, Malaysia, the Philippines, and Thailand. The OECD category includes all OECD members prior to 2009 excluding Mexico, Poland, Slovakia, and Turkey.

Source: Authors' calculations based on US trade data obtained from Feenstra, Romalis, and Schott (2002).

nese exports to the United States in 2006 and then sorted the other countries' trade data by these rankings. We then cumulate the shares of foreign exports according to each percentile of Chinese rankings. Table 4.2 compares China's manufacturing exports to the United States with those of other countries according to these cumulative shares.

The data reveal the weak overlap in the export bundles of developing countries with the United States and other developed countries. Products that accounted for 50 percent of US imports from China in 2006 made up just 8 percent of US imports from high-income OECD countries and 11 percent of US exports. In contrast, these products accounted for 52 percent of US imports from the ASEAN 4 (Indonesia, Malaysia, the Philippines, and Thailand), 37 percent from Vietnam, but less than 10 percent from India and the category for other developing countries. Interestingly, these products made up 27 percent (Hong Kong) to 56 percent (Singapore) of US imports from selected high-income Asian economies, suggesting that the head-to-head competition is taking place between China and other countries within the Asian region rather than with other high-income economies, including the United States.

A similar story is evident if we look at products accounting for 80 percent of Chinese imports. These constituted just 21 percent of US imports from high-income OECD countries and 23 percent of US exports in 2006, but up to 76 percent of US imports from the ASEAN 4 and over 47 percent from the selected high-income Asian economies. It is clear that by and large the goods the United States imports from China are very different from those that it exports or that are exported to the United States by high-income countries outside of Asia. Most Chinese exports are not competing with the bulk of US or other developed-country exports, but they are competing with the rest of Asia. Support for this view is provided by Barry Eichengreen, Yeongseop Rhee, and Hui Tong (2007), who find that Chinese exports displaced those from less developed Asian economies in consumer goods (see also Blecker and Razmi 2009).

Unit Values

There has been some convergence in the composition of developed- and developing-country exports, but are the developing countries producing the same products in the categories in which exports overlap? To answer that question we turn to unit value data, which are obtained by dividing trade values in a particular category by a measure of quantity such as dozens or kilograms.[9] If

9. There are a number of data quality issues that arise in using this data. Errors in measurement can result in highly volatile unit value measures. The units of measurement are also not applied consistently over all periods and across countries. In what follows, we deal with outliers in unit values by eliminating the top and bottom 1 percent of data ranked according to price level. In constructing relative unit values, we also ensure that we only compare products measured using the same units.

US exports or imports from developed countries are similar to exports from developing countries in quality, composition, and price we would expect them to have similar unit values. But as we show, the unit values of US imports from developing countries are actually substantially lower than those of equivalent products imported from high-income OECD countries and products exported by the United States. Further, unlike the export similarity indices that indicate rising across-product similarity in developing-country exports with US exports, the unit value ratios reveal no such convergence. All told, these results suggest that although developing countries are increasingly exporting in categories in which developed countries also specialize, they are selling different and cheaper types of products.[10]

Our analysis is again based on annual data from 1990 to 2006. Unit values of imports from foreign countries are compared with import unit values from high-income OECD countries as well as unit values of aggregate US exports. In the comparison with the OECD countries, we first calculate the ratios of unit values using 10-digit data. We then weight the 10-digit unit value ratios by the annual share of each product in total US imports from high-income OECD countries.[11] For the comparison with US export unit values, only 6-digit HS data are available and we aggregate these using annual US export values as weights. The advantage of using OECD import unit values as the reference price is that we are able to present a much finer resolution of the relative price relationship.

Even at the 10-digit level, however, unit values are imprecise measures. In particular, relatively high values could indicate higher prices for similar products, higher quality, or within any product category a larger quantity of products with higher unit values. We try to condition for these effects later, but the simple relative unit value comparisons reported in table 4.3 are nonetheless quite remarkable and correlate very strongly with levels of development.

Our selected countries clearly group into two categories, particularly when import unit values are compared with US export unit values. The import unit values of high-income countries such as the United Kingdom, France, the category for other developed countries, Canada, Japan, and Germany on average equal or exceed US export unit values by up to 60 percent (figure 4.1). There is some movement in their relative price ratios over time, but in most cases the price relative to US exports is not too dissimilar in 2006 from 1990. US import unit values from Singapore are a striking excep-

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10. A similar conclusion is reached by Fontagné, Gaulier, and Zignago (2008) in their cross-country comparison of unit values at the product level.

11. This measure therefore also captures the effect of changes in the US import bundle over time. The use of trade weights for a fixed period leads to the elimination of all products not exported in all years, but this does not alter the results much. The reason is that most of the growth in the value of imports from developing countries, including China, has been along the intensive margin since the early 1990s (Amiti and Freund 2010).

Table 4.3 Average unit values relative to OECD exports to the United States and aggregate US exports, ranked by price relative to the OECD countries in 2006

	Unit values relative to OECD exports			Unit values relative to US exports		
Country	**1990**	**2000**	**2006**	**1990**	**2000**	**2006**
United Kingdom	1.66	1.20	1.30	1.28	1.16	1.30
Singapore	1.04	0.96	1.19	0.64	0.93	1.19
Germany	1.38	1.02	1.07	1.20	0.97	1.06
Japan	1.13	1.11	1.05	1.02	1.06	1.08
Other developed	1.38	1.19	1.25	1.36	1.28	1.32
Other developing	0.74	0.89	1.00	0.97	0.95	1.08
Canada	1.06	0.94	0.84	0.94	0.99	1.00
France	1.50	1.03	0.83	1.53	1.19	1.29
ASEAN 4	0.53	0.63	0.65	0.44	0.42	0.40
Korea	0.59	0.62	0.59	0.46	0.52	0.61
Mexico	0.64	0.68	0.59	0.50	0.50	0.44
Taiwan	0.47	0.43	0.52	0.38	0.34	0.39
India	0.58	0.34	0.48	0.50	0.34	0.50
China	0.46	0.39	0.43	0.25	0.25	0.34
Vietnam	n.a.	0.17	0.37	n.a.	0.19	0.31
Hong Kong	0.65	0.41	0.32	0.46	0.42	0.35

n.a. = not available

OECD = Organization for Economic Cooperation and Development; ASEAN = Association of Southeast Asian Nations

Note: Unit values relative to OECD exports are based on Harmonized Tariff Schedule 10-digit-level data. Unit values relative to US exports are based on Harmonized System 6-digit-level data. The OECD category includes all OECD members prior to 2009 excluding Mexico, Poland, Slovakia, and Turkey. ASEAN 4 consists of Indonesia, Malaysia, the Philippines, and Thailand. The other developing countries category consists of the remaining low- and middle-income countries.

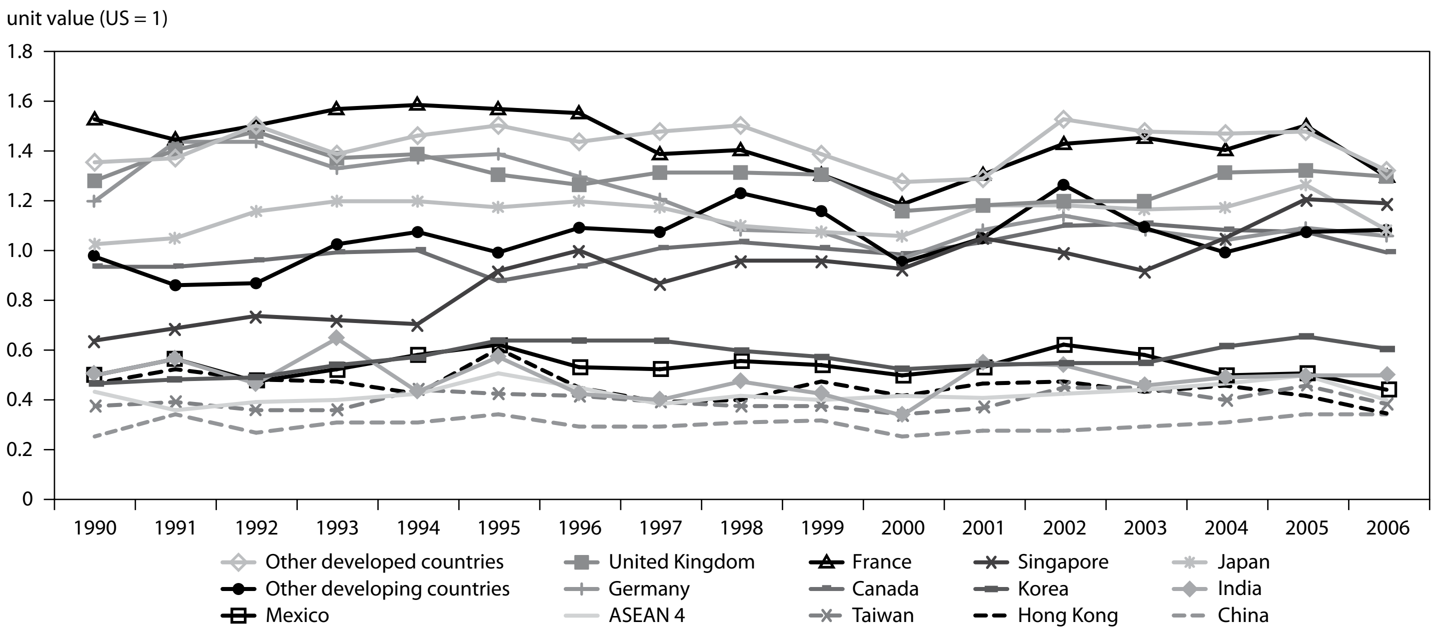
Source: Authors' calculations based on US trade data obtained from Feenstra, Romalis, and Schott (2002).

tion, rising from 64 percent of US export unit values in 1990 to 119 percent in 2006.

A second grouping covers the developing countries as well as some of the higher-income Asian economies such as Korea, Taiwan, and Hong Kong. Looking first at China, it is striking that Chinese import unit values at the product level have hardly changed relative to OECD imports and aggregate US exports over the entire period. On average, Chinese import unit values were 43 percent of OECD import values and 34 percent of US export unit values in 2006, insignificantly different from the relative unit values in the early 1990s.

Unit values of imports from India, Mexico, and the ASEAN 4 countries are also relatively low and stable, ranging from 40 to 60 percent of the price of US exports. The relative unit values of imports from Taiwan, Korea, and especially Hong Kong are surprisingly low, despite their relatively high per capita incomes. This has potentially important implications for the effect of

Figure 4.1 Weighted-average import unit values relative to US export unit values, 1990–2006



ASEAN = Association of Southeast Asian Nations

Notes: Calculated using 6-digit Harmonized System (1988/92 Revision) classification data and annual US exports as weights. ASEAN 4 consists of Indonesia, Malaysia, the Philippines, and Thailand. Foreign-country export unit values are calculated using US import data.

Source: Authors' calculations based on 6-digit Harmonized System classification data obtained from Feenstra, Romalis, and Schott (2002).

production fragmentation and outsourcing within the Asian region. According to our unit value data, widespread relocation of production from industrialized Europe or North America to Asia would be expected to raise within-product relative unit values in these countries. In contrast, production fragmentation driven by the relocation of production from newly industrialized Asian economies to their developing neighbors would have a much smaller impact on within-product unit values in the developing countries.

The one anomaly in these results is the category for other developing countries. These import unit values are very similar to US export unit values in all periods and show a slight increase relative to high-income OECD imports. This reflects a product composition effect: additional disaggregated analysis reveals that imports of nonpetroleum manufactures from other developing countries are concentrated in textiles and clothing (27 percent) and base metals (23 percent). As we show later in this chapter, these products show relatively small differences in prices across countries, including relative to US exports. The primary source of price differences across countries is in the machinery, transport, and specialized equipment sectors. Again, we explore this further in the disaggregated analysis presented later.

As reported in a working paper version of this chapter (Edwards and Lawrence 2010b), we have formally tested for the relationship between exporter income and within-product price variation using regression analysis. Our results confirm that relative unit values are explained well by per capita incomes.[12] However, we find that Chinese products trade at a substantial discount (29 log points) even after controlling for the country's GDP per capita, population, and other characteristics. This result is similar to that reported by Schott (2008), except that unlike his regressions, we find a significant discount even when population is included to capture greater production scale. Additional regressions also reveal no change in the Chinese discount over the period, a result that is consistent with the stable trends in unit values shown in figure 4.1. This suggests that Dani Rodrik's (2006) finding that Chinese exports are unusually sophisticated for their level of development needs to be qualified. The product categories in which Chinese exports fall may be unusually sophisticated, but judged by their unit values, the actual products they sell in these categories are not.

Technological Sophistication

The concern about emerging-market exports to the United States is not simply that they are becoming more similar to US exports in general but that the rising similarity has been driven by rapid increases in exports of "sophisticated" products from the United States. If production and export of sophisticated products stimulates an acceleration in overall growth of the economy and

12. See also Schott (2008) and Fontagné, Gaulier, and Zignago (2008).

supply of these very products, as is argued by Sanjaya Lall (2000) and Ricardo Hausmann, Jason Hwang, and Dani Rodrik (2007), then the sophistication of the current structure of exports is a foreshadow of competitiveness pressures that are to come.

What is meant by "sophistication" varies and can cover the use of sophisticated production processes to produce a standardized good or the export of goods that are themselves technologically advanced. Even the highly disaggregated product classification used by the US International Trade Commission cannot isolate the production process from product composition (Ferrantino et al. 2007). We are cognizant of this limitation. Nevertheless we use a product technology classification developed by Lall (2000) and refer the reader to the working paper version of this chapter (Edwards and Lawrence 2010b), where we find support for our argument using other product-level technology classifications: the advanced technology products classification developed by the US Census Bureau and an export measure developed by Hausmann and Rodrik (2003) that distinguishes products on the basis of the incomes of countries that export them.[13]

Lall (2000) classifies products at the 3-digit level of the SITC (Rev. 2) into primary products and resource-based, low-technology, medium-technology and high-technology manufactures.[14] Detailed descriptions and product examples for each of these categories are provided in table 4.4. In general, the skill requirements rise with the degree of technological complexity, although there are exceptions in all categories (e.g., among resource-based products, the synthesis of fuel from coal requires skill-intensive technologies).

Table 4.5 outlines the 1990 and 2006 share structure of US manufacturing imports for China, other developing countries, and high-income OECD countries according to Lall's (2000) technology classification. The table reveals the diverse patterns of specialization across regions as well as the remarkable shift in the composition of US imports from low- and middle-income countries toward medium- and high-technology products. High-income country exports to the United States are concentrated in medium- and high-technology manufactures and there has been little change in this structure over the full period.

Contrast this with Chinese exports to the United States. In 1990, 74 percent of US imports of manufactured goods from China were made up of low-technology products (mainly clothing) and only 7 percent of high-technology products. By 2006, high-technology products accounted for 35 percent of US imports of manufactured goods from China, with all of the increase attributable to electronics and electrical products. The share of high-technology

13. Sanjaya Lall, John Weiss, and Jinkang Zhang (2005) develop an alternative sophistication measure based on the income level of the exporting country. Conceptually, the approach is similar to that of Hausmann and Rodrik (2003) and therefore is not included in the analysis.

14. SITC is the Standard International Trade Classification.

Table 4.4 Lall (2000) technology classification of exports

Category	Product examples	Description
Primary products	Fresh fruit, meat, rice, cocoa, tea, coffee, wood, coal, crude petroleum, gas, and metals	
Manufactured products		
Resource-based manufactures (RB)		
RB1: Agro/forest-based products	Prepared meats/fruits, beverages, wood products, and vegetable oils	Manufactures tend to be simple and labor intensive or intensive in use of natural resources.
RB2: Minerals-based products	Ores and concentrates, petroleum/rubber products, cement, cut gems, and glass	
Low-technology manufactures (LT)		
LT1: "Fashion cluster"	Textile fabrics, clothing, headgear, footwear, leather manufactures, and travel goods	Manufactures tend to be undifferentiated products that compete on price (hence labor costs are important) and are produced using stable, well-diffused technologies.
LT2: Other low technology	Pottery, simple metal parts/structures, furniture, jewelry, toys, and plastic products	
Medium-technology manufactures (MT)		
MT1: Automotive products	Passenger vehicles and parts, commercial vehicles, motorcycles and parts	Products comprise the bulk of skill- and scale-intensive technologies in capital goods and intermediate products and tend to have complex technologies, with moderately high levels of R&D, advanced skill needs, and lengthy learning periods.
MT2: Process industries	Synthetic fibers, chemicals and paints, fertilizers, plastics, iron, and pipes/tubes	
MT3: Engineering industries	Engines, motors, industrial machinery, pumps, switchgears, ships, and watches	
High-technology manufactures (HT)		
HT1: Electronics and electrical products	Office/data processing/telecommunication equipment, TVs, transistors, turbines, and power-generating equipment	Products have advanced and fast-changing technologies, with high R&D investments, and require sophisticated technology infrastructures and high levels of specialized technical skills.
HT2: Other high technology	Pharmaceuticals, aerospace, optical/measuring instruments, and cameras	
"Special" transactions	Electricity, cinema film, printed matter, art, coins, pets, and nonmonetary gold	

Source: Lall (2000).

Table 4.5 Share structure of US manufacturing imports by technology classification, 1990 and 2006 (percent)

	1990			2006		
Category	**China**	**Other developing countries**	**High-income OECD countries**	**China**	**Other developing countries**	**High-income OECD countries**
Primary product manufactures	1	10	5	1	8	5
Resource-based manufactures (RB)	3	20	17	5	13	18
RB1: Agro/forest-based products	1	13	12	3	8	11
RB2: Other resource-based products	2	7	6	2	5	7
Low-technology manufactures (LT)	74	36	14	38	29	9
LT1: "Fashion cluster"	56	29	7	23	22	3
LT2: Other low technology	18	7	7	15	7	7
Medium-technology manufactures (MT)	17	26	53	22	33	56
MT1: Automotive products	0	7	30	2	14	34
MT2: Process industries	2	5	6	3	7	8
MT3: Engineering industries	14	13	17	17	13	15
High-technology manufactures (HT)	7	18	15	35	25	17
HT1: Electronics and electrical products	6	17	14	34	23	9
HT2: Other high technology	1	1	2	1	1	9
"Special" transactions	0	1	1	1	1	1

OECD = Organization for Economic Cooperation and Development

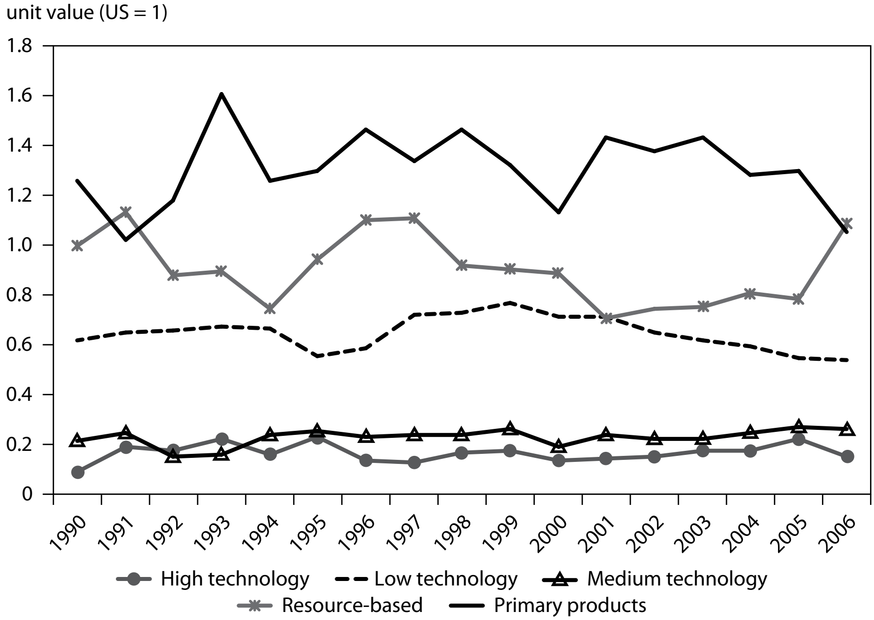
Note: Some products classified by Lall (2000) as primary products fall under North American Industry Classification System (NAICS) 331-333 and are hence included as primary product manufactures in the table. The OECD category includes all OECD members prior to 2009 excluding Mexico, Poland, Slovakia, and Turkey.

Source: Authors' calculations based on US trade data obtained from Feenstra, Romalis, and Schott (2002) and the technology classification developed by Lall (2000).

products in US imports from the category other low- and middle-income countries also rose, but at a slower pace, from 18 to 25 percent.[15]

15. A comparable picture emerges when analyzing the United States according to the alternative technology classifications. Rodrik (2006), for example, finds that China's export profile to the world in the early 1990s was associated with an income level more than six times higher than its per capita GDP at the time. When we replicate his study for manufacturing products (Edwards and Lawrence 2010b), we find that US imports from other developing countries including Thailand,

Figure 4.2 China's export unit values relative to US export unit values, 1990–2006



Note: For each country, relative unit values are aggregated up using annual US exports are weights. The group "Primary products" reflects manufactures (North American Industry Classification System [NAICS] 331–333) classified as primary products by Lall (2000).

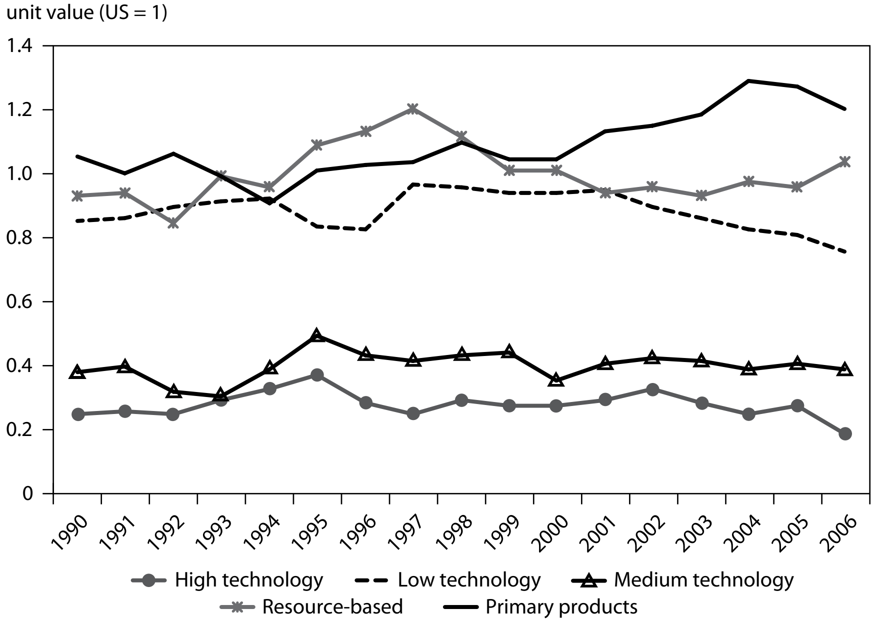
Source: Authors' calculations based on 6-digit Harmonized System classification data obtained from Feenstra, Romalis, and Schott (2002).

Again the rising technology intensity of developing-country exports (especially China) to the United States appears to confirm concerns about head-to-head competition with the United States in those products where America has a comparative advantage. However, as discussed earlier, import values obscure a high degree of within-product specialization. We therefore reevaluate the apparent rise in sophistication of developing-country exports to the United States using unit value data.

Figures 4.2 to 4.4 present the weighted-average unit value of US imports relative to US exports of manufactured goods for the period from 1990 to 2006. Figure 4.2 focuses on US imports from China, figure 4.3 focuses on import unit values from developing countries as a group, and figure 4.4 looks at import unit values from high-income OECD countries. In all cases, relative prices are first calculated at the 6-digit HS level and then aggregated up using annual US ex-

Mexico, Malaysia, Korea, India, and Indonesia are also more sophisticated than what is predicted on the basis of their per capita incomes.

Figure 4.3 Developing-country export unit values relative to US export unit values, 1990–2006



Note: For each country, relative unit values are aggregated up using annual US exports as weights. Weighted averages for regions are calculated by aggregating the country-level average using total bilateral import values as weights. The group "Primary products" reflects manufactures (North American Industry Classification System [NAICS] 331–333) classified as primary products by Lall (2000).

Source: Authors' calculations based on 6-digit Harmonized System classification data obtained from Feenstra, Romalis, and Schott (2002).

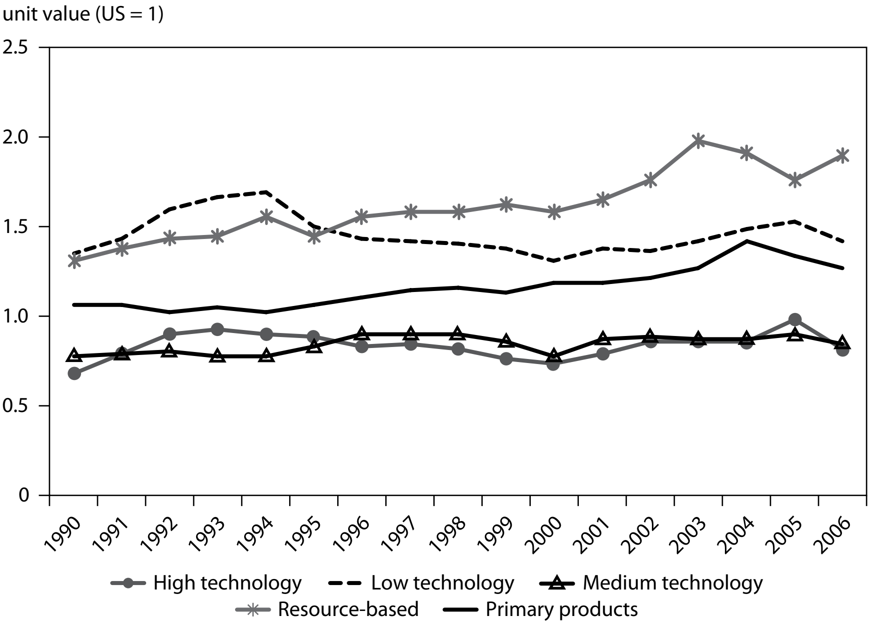
port values as weights. We are therefore comparing average within-product price differences assuming that the structure of trade reflects that of US exports.[16]

We first look at unit values of US imports from China and other developing countries relative to the price of US exports. The relative price measures group neatly into two categories. The relative prices of resource-based, low-technology, and primary manufactures range between 0.5 and 1.4 for China and 0.8 and 1.3 for all developing economies. This is to be expected, as these products, particularly resource-based ones, tend to be relatively undifferentiated.

Medium- and high-technology products are different. The unit values of US imports from China of these products lie between 15 and 30 percent of the equivalent products exported by the United States. Further, remarkably, there has been no significant movement in these relative prices over the en-

16. Note that the relative unit-value measures do not account for across-product specialization that was captured in our similarity index measures and therefore underrepresent the overall degree of specialization.

Figure 4.4 High-income OECD export unit values relative to US export unit values, 1990–2006



OECD = Organization for Economic Cooperation and Development

Note: For each country, relative unit values are aggregated up using annual US exports as weights. Weighted averages for regions are calculated by aggregating the country-level average using total bilateral import values as weights. The group "Primary products" reflects manufactures (North American Industry Classification System [NAICS] 331-333) classified as primary products by Lall (2000).

Source: Authors' calculations based on 10-digit Harmonized Tariff Schedule classification data obtained from Feenstra, Romalis, and Schott (2002).

tire 16 years covered in the sample. Looking at the average for all developing countries, the level of relative prices is slightly higher than for China alone, but there is also no change in the trend over time.

Contrast these figures with figure 4.4 comparing the unit values of US imports from high-income OECD countries with aggregate US exports. US imports of medium- and high-technology manufactures from high-income OECD countries are on average 80 percent of the unit value of the equivalent product exported by the United States. Import unit values of resource-based, low-technology, and primary manufactures are 30 to 90 percent higher (and increasing over time for resource-based products) than the equivalent aggregate US export price.

We have undertaken numerous exercises to confirm that these findings are not a particular outcome of our choice of technology classification, reference price, or weights. For example, we replicate these findings if we focus on China's top 30 export industries (box 4.1) and if we use import unit values from high-income OECD countries at the 10-digit level as the reference price and log mean shares as weights (table 4.6).[17] We see that high-technology products imported by the United States from developing countries are on average a third of the price of those imported from OECD members. Relative unit values of imports of resource-based products from developing countries are higher at 0.6–0.7, but remain less than one.[18]

We have also undertaken regressions that explain unit values for the various technology categories reported in our background working paper (Edwards and Lawrence 2010b). Unit values are positively associated with per capita incomes in each category for most countries, but the relationship is stronger for the sophisticated products relative to the primary-commodity-based manufactures. This is revealed by the stronger coefficients on the square of the log of GDP per capita for the relatively sophisticated product categories. In other words, the gap in unit values between wealthy and poor countries rises according to the sophistication of the product.[19]

Vertical Specialization

Our results for imports from China, both with respect to the small overlap with US exports and especially with respect to the low relative unit values of its high-tech products, are particularly striking because vertical specialization has been so prominent a feature of its trade.[20] This has predominantly taken the form of processing trade, where Chinese firms process or assemble imported intermedi-

17. We calculate the geometric average price inclusive of transport costs and tariffs relative to high-income OECD countries, where the OECD price is an import-weighted average price of OECD countries and weights on the relative price, wj_{ki}, are the logarithmic means of the import shares, normalized to sum to unity. Following Feenstra, Yang, and Hamilton (1999) the formula for the weights is:

$$w_{jki}(I_i) = \left(\frac{s_{ji}(I_i) - s_{ki}(I_i)}{\ln s_{ji}(I_i) - \ln s_{ki}(I_i)} \right) \Big/ \sum_{k \in I_j} \left(\frac{s_{ji}(I_i) - s_{ki}(I_i)}{\ln s_{ji}(I_i) - \ln s_{ki}(I_i)} \right),$$

where $s_{ji}(I_i)$ is the import share of product i in total US imports from country j or the OECD.

18. Classifying products according to the sophistication measure of Hausmann and Rodrik (2003) and the advanced technology products classification developed by the US Census Bureau leads to the same conclusion (Edwards and Lawrence 2010b): The more sophisticated the product is, the more the unit values of imports from developing countries decline relative to developed countries. We also independently replicate these findings using 6-digit HS level export data obtained from the UN Comtrade database. For example, we find that over the period 1996–2011, the unit values of Chinese exports were on average 90 percent of the unit values of US exports in primary products, 81 percent in resource-based products, 40 percent in low-technology products, 36 percent in medium-technology products, and 18 percent in high-technology products.

19. There is no significant price discount on imports of primary-product-based manufactures from China, but imports of high- and medium-technology products from China sell at 33 and 36 percent of the expected price, respectively.

20. Vertical specialization refers to the use of imported intermediate parts to create goods that are later exported. International trade arising from vertical specialization has become an increasingly important source of the growth in world exports since the 1970s (Hummels, Ishii, and Yi 2001).

Box 4.1 The United States and China: A disaggregated analysis

It is illuminating to take a closer look at the US-China data and see what they reveal about particular products. Table B4.1.1 presents a comparison of unit values, relative unit values, and cumulative trade shares for China's top 30 exports to the United States at the 6-digit level of the North American Industry Classification System (NAICS) in 2006. These products accounted for about 49 percent of all US manufactured imports from China.

Four of the top five Chinese industries and nine of the top 30 industries come from NAICS category 334, which covers computer and electronic products.[1] Apparel, textiles, and footwear products are also important, accounting for nine of the top 30 industries and 11 percent of the value of Chinese exports to the United States in 2006. The remaining categories are diverse. Computer and electronic products (334) constitute a sizable share of total US manufacturing exports (16.5 percent in 2006). Yet few of the large US export industries in the electronics sector are also prominent export industries for China. The strongest US performance in electronics was in semiconductors (334413), which constituted 4.3 percent of US exports in 2006, but only 0.6 percent of Chinese exports to the United States in 2007. Altogether, these top 30 Chinese export industries, which accounted for half of Chinese exports, accounted for only 13.6 percent of US manufac-

Table B4.1.1 Prices, relative prices, and cumulative trade shares of top 30 Chinese export industries in 2006

			Price per unit (US dollars)			Cumulative export share (percent)		
NAICS code	Description	Units	China	High-income OECD	US exports	China	High-income OECD	US exports
334310	Audio and video equipment	Number	89	424	198	7	1	0
334111	Electronic computers	Number	652	1,901	2,490	13	1	1
334119	Other computer peripheral equipment	Number	113	508	907	18	2	2
334220	Radio, TV broadcasting and wireless equipment	Number	96	164	493	22	3	3
316214	Women's footwear (except athletic)	Pairs	8	52	19	24	3	3
333313	Office machinery	Number	84	1,939	757	26	3	3
335211	Electric housewares and household fans	Number	12	86	77	28	4	3
315239	Women's & girls' cut and sew outerwear	Dozen	82	247	73	30	4	3
316219	Other footwear	Pairs	8	37	15	31	4	3
331111	Iron and steel mills	Kilograms	1	1	2	32	6	4
315232	Women's & girls' cut and sew blouses and shirts	Dozen	84	143	29	33	6	4

(box continues next page)

Box 4.1 The United States and China: A disaggregated analysis *(continued)*

Table B4.1.1 Prices, relative prices, and cumulative trade shares of top 30 Chinese export industries in 2006 *(continued)*

			Price per unit (US dollars)			Cumulative export share (percent)		
NAICS code	Description	Units	China	High-income OECD	US exports	China	High-income OECD	US exports
314129	Other household textile product mills	Number	5	11	7	34	6	4
316991	Luggage	Number	3	53	8	36	6	4
316213	Men's footwear (except athletic)	Pairs	14	53	35	37	6	4
334112	Computer storage devices	Number	35	211	1,495	38	6	5
332999	Other miscellaneous fabricated metal products	Kilograms	3	8	7	39	7	5
337127	Institutional furniture	Number	37	105	103	40	7	5
315234	Women's and girls' cut and sew suits, coats, skirts	Dozen	100	804	95	40	7	5
334418	Printed circuit assembly (electronic)	Number	30	58	28	41	7	5
335129	Other lighting equipment	Number	3	76	36	42	8	5
334419	Other electronic components	Number	9	52	126	43	8	6
336399	All other motor vehicle parts	Number	12	7	49	44	10	6
335121	Residential electric lighting fixtures	Number	10	100	46	44	10	6
326211	Tires (except retreading)	Number	39	78	89	45	10	6
335221	Household cooking appliances	Number	73	293	344	46	10	6
334210	Telephone apparatus	Number	39	365	963	46	10	6
325199	All other basic organic chemicals	Kilograms	7	31	4	47	12	9
334413	Semiconductor and related devices	Number	2	4	3	47	14	14
337121	Upholstered household furniture	Number	85	206	114	48	14	14
316992	Women's handbags and purses	Number	7	145	24	49	14	14

NAICS = North American Industry Classification System; OECD = Organization for Economic Cooperation and Development

Note: Products are classified according to multiple units, even within the NAICS 6-digit classification. The values in the table correspond to the unit associated with the largest Chinese trade flow within each product category. Price levels at the 6-digit NAICS level are constructed by weighting up unit values at the 10-digit HTS level (OECD and China) and 6-digit HTS level (United States) using trade values as weights.

Source: Authors' calculations based on 10-digit US Harmonized Tariff Schedule classification data obtained from Feenstra, Romalis, and Schott (2002).

(box continues next page)

Box 4.1 The United States and China: A disaggregated analysis *(continued)*

turing exports in 2006 and 13.8 percent of exports from high-income countries of the Organization for Economic Cooperation and Development (OECD) to the United States.

Further, where there is an overlap, the unit values of the Chinese products are considerably lower than the equivalent US or OECD exports. For example, the average price per unit of audio and video equipment (334310), the top import industry from China in 2006, was $89. The comparable price of US exports in this industry was $198 and $424 for high-income OECD imports. There are very few instances (five) where the Chinese price exceeds that of the United States or the OECD (one). If we weight up the relative price data using Chinese import values as weights, all of these top products are on average 32 percent of the price of equivalent high-income OECD imports and 44 percent of the price of equivalent US exports.

1. They include audio and video equipment (334310), 6.6 percent of 2006 exports; electronic computers (334111), 6 percent; other computer equipment (334119), 5.1 percent; and wireless communications equipment (334220), 4.4 percent.

ate inputs and then export the finished product to the international market. Processing exports have accounted for more than 50 percent of Chinese exports since at least 1996 (Koopman, Wang, and Wei 2008) and have been an important driver of export growth over the past decade (Wang and Wei 2010).

Vertical specialization has important implications for our analysis of head-to-head competition between developed and developing countries in international trade. The production of exports involves multiple stages located in multiple countries. The source country is not necessarily the country where most of the value is added. For example, in the Chinese processing trade close to 60 percent of the inputs are sourced from other Asian economies, including Japan, Hong Kong, Taiwan, Korea, and Singapore (Dean, Fung, and Wang 2007). These economies form an "Asian supply network for China's global production sharing" (Dean, Fung, and Wang 2007, 10). The United States is also an important input supplier, including the supply of innovation, product design, software development, and many other inputs.

Take, for example, the iPod that Taiwanese firms located in China assemble for export to the United States. In a detailed breakdown of production costs, Greg Linden, Kenneth Kraemer, and Jason Dedrick (2009) find that the value added attributable to producers in China of the 30GB video model in 2005 was just under $4 of the $150 factory cost. The remaining factory costs are made up of the various intermediate inputs that are sourced from Japan, Taiwan, Korea, and the United States. In terms of value capture, the United States dominates, capturing $87 (or $162 if the product is sold in the

Table 4.6 Comparison of average relative import unit values by technology classification using log mean share weights, 1990–2006 (US = 1)

	High technology		Medium technology		Low technology		Resource-based		Primary products	
Country/grouping	**1990–95**	**2001–06**	**1990–95**	**2001–06**	**1990–95**	**2001–06**	**1990–95**	**2001–06**	**1990–95**	**2001–06**
Price relative to the United States										
China	0.101	0.155	0.149	0.152	0.633	0.572	0.682	0.582	0.885	1.063
Low- and middle-income countries	0.287	0.261	0.382	0.366	0.836	0.794	0.959	0.964	1.005	1.207
High-income countries	0.672	0.853	0.787	0.85	1.259	1.301	1.506	1.897	1.074	1.301
Price relative to OECD countries										
China	0.184	0.192	0.247	0.24	0.374	0.351	0.574	0.414	0.659	0.769
Low- and middle-income countries	0.317	0.292	0.517	0.526	0.428	0.392	0.702	0.597	0.789	0.842

Notes: The average is calculated as the exponent of the average log relative price. Country- level averages are constructed using log mean share weights. The averages for low- and middle-income countries are the import-weighted average of the country values.

Source: Authors' calculations based on US trade data obtained from Feenstra, Romalis, and Schott (2002) and the technology classification developed by Lall (2000).

United States) of the $190 gross profit associated with the sale of the iPod. The retail price of the iPod was $299.

In high-technology products, vertical specialization is especially prominent (Amador and Cabral 2009; Dean, Fung, and Wang 2007).[21] For example, processing exports make up 90 percent of Chinese exports of advanced technology products to the United States, with almost all of this produced by foreign-invested enterprises (Ferrantino et al. 2007). Indeed, the share of domestic value added in Chinese exports declines the more sophisticated the product becomes.[22] At the extreme are Chinese exports of computers and accessories, where the domestic value added is only 4.6 percent, but domestic value added is also low in other high-tech products including telecommunications equipment (14.9 percent); cultural, office, and other computer peripheral equipment (19.1 to 19.7 percent); electronic elements and devices (22.2 percent); and radio, television, and communications equipment (35.5 percent).

It is the Chinese exports of these products to the United States that have increased rapidly and raised concerns about head-to-head competition. Yet our price analysis indicates that despite the fact that these products contain a high share of value added that comes from more developed countries, they have much lower prices than products in the same categories that are imported from developed countries.

Price Dispersion by Technology Classification

High-tech products are those evolving the most rapidly, and we might expect a systematic relationship between the scope for product differentiation and the technological intensity of the product. To explore this further, we compare the cross-country dispersion of US import unit values across Lall's technological categories. Using 2006 US import data for manufactured goods at the 10-digit HTS level, we first divide US import unit values of each product from each country by the mean US import unit value of that product from all countries. We then take the natural logarithm of these demeaned import unit values such that, within each 10-digit product, average priced imports have a value of zero, more expensive imported products have a positive value, and lower-priced imports have a negative value.[23] The data are then used to construct the box plot diagrams presented in figure 4.5.

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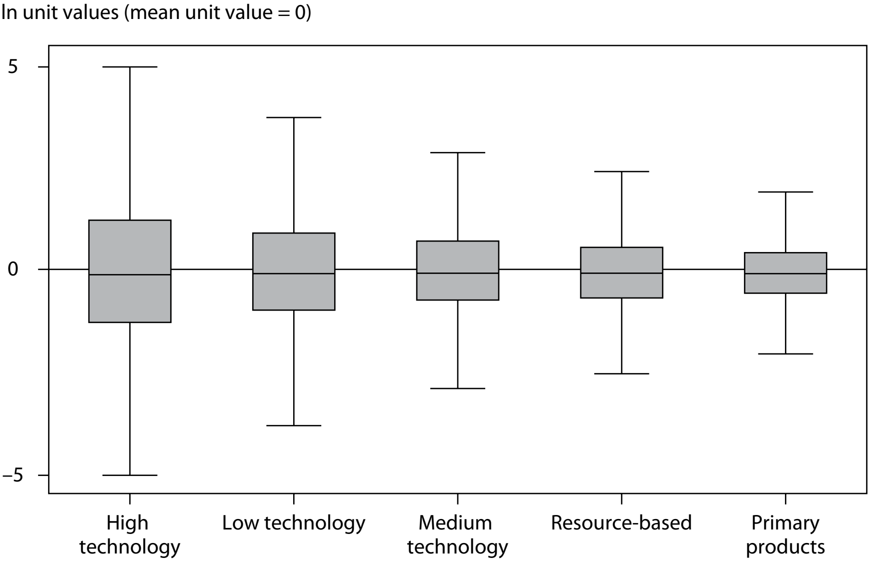
21. One reason for the dramatic increase in processing trade in high-tech products is the multilateral reduction in tariffs on information technology products from 1997 to 2000 as a result of the Information Technology Agreement enforced by the WTO. This led to an increase in varieties of information technology products imported (sourced from new countries) as well as a magnified reduction in prices (Feenstra, Yang, and Hamilton 2009).

22. Robert Koopman, Zhi Wang, and Shang-Jin Wei (2008) estimate that the foreign content of China's total exports is about 50 percent, but is 80 percent or more for sophisticated products where processing trade is high.

23. Relative unit values (RUV) are calculated as $RUV_{i,c,t} = \ln(UV_{i,c,t} / \frac{1}{N}\sum_{c=1}^{N} UV_{i,c,t})$, where i denotes HTS 10-digit product, c denotes country, and t denotes time.

Figure 4.5 Cross-country dispersion of US import unit values by technology classification, 2006



Note: The box plot is based on 2006 US import data with relative unit values calculated at the 10-digit level of the Harmonized Tariff Schedule. The box is bounded by the first and third quartile value. The upper adjacent limit is the largest data value that is less than or equal to the third quartile plus 1.5 x the interquartile range. The lower adjacent limit is the smallest data value that is greater than or equal to the first quartile minus 1.5 x the interquartile range. The adjacent limits are denoted by the horizontal bars at the top and bottom of each plot.

Source: Authors' calculations based on 10-digit Harmonized Tariff Schedule classification data obtained from Feenstra, Romalis, and Schott (2002).

These box plot diagrams conveniently illustrate the relationship between import price dispersion and the technology intensity of the product. The shaded box in each box plot depicts the interquartile range between the 25th and 75th percentiles of the demeaned import unit values. Also shown are the upper and lower adjacent limits denoted by the horizontal bars at the top and bottom of each plot. The upper adjacent limit is the largest data value that is less than or equal to the third quartile plus 1.5 times the interquartile range. The lower adjacent limit is the smallest data value that is greater than or equal to the first quartile minus 1.5 times the interquartile range. The box plots therefore reveal the extent to which unit values of US imports at the 10-digit level are dispersed across countries.

What is immediately evident is that the cross-country dispersion of US import unit values rises according to the technological intensity of the product. Focusing on the shaded box in each diagram, there is a decline in the interquartile range as one moves from the high-technology category to the primary-product-classified manufactures. This is also true of the range between the upper and lower adjacent limits. As shown in Edwards and Lawrence (2010b), equivalent relationships are found when using alternative technology classifications, including the advanced technology product classifications of the US Census Bureau and a NAICS 6-digit industry-level classification based on the share of nonproduction workers. Sophisticated products in all cases are characterized by a greater scope for price differentiation.

Although we do not measure characteristics of products directly, the price variation suggests that imports from different countries differ enormously in terms of their characteristics, and that the scope to differentiate a product increases the more sophisticated the product.[24] Take, for example, motor vehicles that differ vastly according to characteristics such as motor size, number of doors, type of gearbox, styling, quality of components, etc. Contrast this with resource-based products such as steel bars where the scope to differentiate the product is more restrictive.

This association provides additional insights into the nature of the apparent head-to-head competition between developed and developing countries. The restructuring of developing-country imports that has raised concerns about increased competition with US exports has been concentrated in those sophisticated product categories where the scope to differentiate products according to price is higher. US firms are more able to insulate themselves from this competition if they can differentiate their products.

To conclude, there are vast and sustained differences in unit values between developed- and developing-country exports. This is suggestive of a high degree of within-product specialization with China and other developing countries producing relatively low-priced products and varieties. Changes in the composition of trade flows give the impression of rising head-to-head competition with the United States in high-technology sectors, but this is not corroborated by an increased similarity in prices. The difference in unit values between US exports and developing-country imports actually rises the more

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24. The figures are consistent with an alternative explanation, namely that the classification systems are not sufficiently refined to distinguish between different products. This is likely to be particularly pronounced for high-technology products where rapid innovation leads to repeated introductions of new and different products. There is some evidence from the trade data to support this. Lall's high-technology category covered 1,302 HTS 10-digit product lines with an average of $247 million of imports per product line in 2006. In contrast, the low-technology category covered 5,202 product lines with an average of $41 million of imports per product. Low-technology products are therefore more precisely defined, which may explain their relatively low degree of price dispersion at the product level across countries. In effect, the relationship between the scope for product differentiation and technological sophistication that we identify may merely be a product of the classification system. Simple regressions, however, suggest that this is not entirely the case. In regressions explaining the standard deviation of relative import unit values, the coefficient on the skill intensity of industries remains significant and positive (i.e., the variation of relative import unit values rises according to the skill intensity of the industry) even after controlling for the number of HTS 10-digit product lines and the average value of imports by product line within each industry. Similar results are found when using an HS 6-digit version of the Hausmann and Rodrik (2003) export productivity measure.

sophisticated the product. What sustains this is a systematic relationship between the scope for price differentiation and the sophistication of the product. Developing countries are able to enter into the export market for technology-intensive products, but do so at the lower end of the price spectrum.

Intermediate Inputs versus Finished Products

Our analysis thus far rests on the assumption that prices are a good proxy for differences in product quality and characteristics and that the large price differences we find reflect specialization in distinct products.[25] Yet there are objections that we need to consider. The first is that the data are not sufficiently disaggregated and are biased because the price differences we find reflect the effects of vertical specialization.

Growth in world trade over the past few decades has far exceeded growth in global production. One reason is the rapid growth of trade in intermediate inputs driven by multinational firms as they outsource input processing to their foreign affiliates (Hanson, Mataloni, and Slaughter 2005). An outcome is global production networks in which the various stages of the production process are located in different countries across the globe.

This has implications for how we measure and compare unit values of products. Unit values reflect the price of the traded good and hence the various components and value-added services embodied in the product. Intermediate inputs will therefore have a lower price per unit than the price of the product that embodies these inputs. It may well be that the vast price differences we find between developed and developing countries simply reflect specialization by developing countries in the intermediate input stage of the vertical supply chain.

Our earlier analysis draws on highly disaggregated 10-digit HTS level trade data, and we are careful to ensure that we only compare unit values across countries of the same 10-digit product. Nevertheless, even these highly disaggregated categories may include both intermediate and final goods. For example, say that developed and developing countries produce identical rotors and motors that are classified as "parts for washing machines." Since rotors are used in making motors, we would expect them to be cheaper. But if the developing countries make more rotors and the developed countries make more motors, their average import unit values would be different only because of mix effects. Unfortunately, we are unable to disaggregate the 10-digit data any further and hence cannot isolate this bias from our analysis.

However, we can compare relative prices of intermediate and final goods within our technology categories. Our technology categories aggregate the 10-digit relative unit values *across* intermediate and final goods and this may also distort the extent to which prices differ. To account for this concern, we separate out intermediate inputs from final goods (capital goods and consumer

25. See also Schott (2004, 2008) and Fontagné, Gaulier, and Zignago (2008).

Table 4.7 Weighted-average unit values of developing-country exports relative to OECD exports, 1990–2006

Category	Capital goods	Consumption goods	Intermediate goods	Passenger vehicles	Total
High technology	0.29	0.25	0.36		0.30
Medium technology	0.37	0.32	0.60	0.81	0.51
Low technology	0.35	0.38	0.55		0.40
Resource-based		0.65	0.66		0.65
Primary products		0.73	0.82		0.80
Total	0.31	0.38	0.58	0.81	0.44

Notes: The data are aggregated up to the end-use groups using a Harmonized System (HS) 6-digit map obtained from the United Nations Statistical Division (2007). Relative prices for each end-use group within the Lall (2000) categories are calculated for each country using relative prices at the HS 10-digit level and log mean expenditure shares as weights. The average relative prices for all developing countries presented in the table are calculated using country-level import values as weights. Cells are left blank when the end-use and technology categories do not overlap (e.g., capital goods include no resource-based products).

Source: Authors' calculations based on US trade data obtained from Feenstra, Romalis, and Schott (2002), Lall's (2000) technology classification, and end-use categories obtained from United Nations Statistical Division (2007).

goods) within each of the Lall technology categories and explore whether the differences are still present when looking only at finished goods.[26] Passenger vehicles are presented separately as they are both a capital and consumer good.

Table 4.7 presents the weighted-average unit values of US imports from developing countries relative to US imports from high-income OECD countries for each of the end-use groups within the Lall technology categories. The data cover the period 1990–2006. We compare unit values against OECD countries because we want to use the most disaggregated trade data possible, i.e., the 10-digit HTS level data. Comparisons of import unit values against US export unit values yield comparable results.

In general, the unit values of developing-country and OECD imports are indeed more similar for intermediate goods than for capital or consumer goods, but the gap still remains considerable, particularly in high-technology products. Imports of all high-technology capital goods from developing countries are on average 29 percent of the price of the good imported from the OECD countries. For high-technology intermediate inputs, the relative price ranges from 30 to 45 percent. Other than high-technology consumer goods

26. The classification of final and intermediate goods is based on the United Nations Classification by Broad Economic Categories (BEC), which closely resembles the US International Trade Commission's End-Use Classification. The various subcategories are aggregated into categories that approximate the three classes of goods in the System of National Accounts: capital goods, intermediate goods, and consumer goods (United Nations Statistical Division 2007).

that make up less than 10 percent of high-technology imports, there is also no sustained trend in relative prices over time.

These results are broadly replicated for medium- and low-technology products. The largest differences in unit values between developing-country and OECD-country imports are in final consumer and capital goods and, in contrast to high-tech products, the price gap appears to be rising. As found earlier, the price difference is smaller the less sophisticated the product: import unit values of final and intermediate goods are more similar for resource-based and primary-product manufactures (0.6–0.9) than for high- and medium-technology products (0.2–0.6).

Our conclusion of substantial price differences between developed- and developing-country exports that rise according to the sophistication of the product is therefore robust to the further subdivision of these products into final and intermediate goods. Nevertheless, it may still be the case that the trade data are too aggregated to adequately separate out intermediate from final goods within each product line. However, further disaggregation is unlikely to alter our conclusion that developed and developing countries have specialized in different products. Further disaggregation may reveal evidence of greater similarity of import unit values for particular products, but at the same time, it will most likely reveal evidence of greater across-product specialization. As we saw earlier, the overlap between the top Chinese imports and OECD or US exports at the 6-digit to 10-digit level is already low. Further disaggregation would reduce the overlap even more.

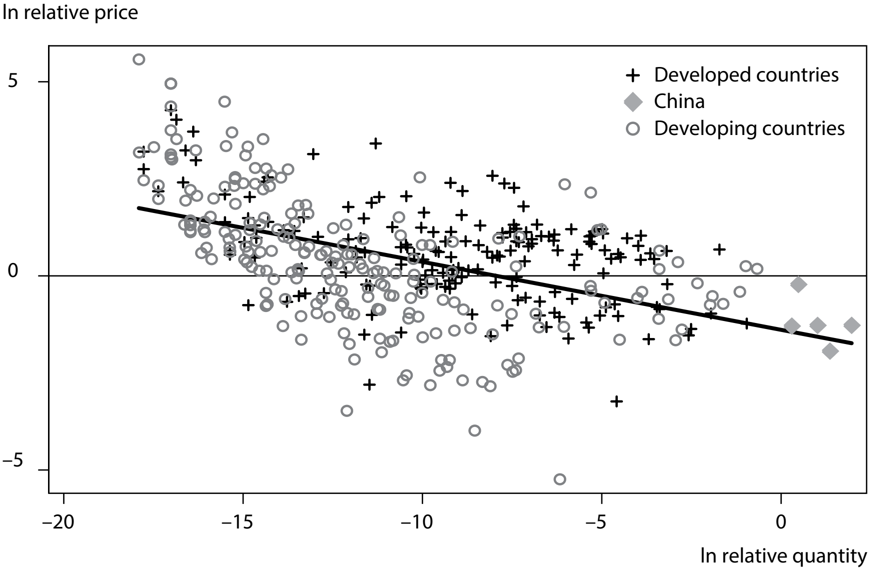
The Question of Quality

Thus far we have used product-level price differences to identify whether imports from developing countries are distinct from those from developed countries. This approach implicitly assumes that if products are equivalent, arbitrage would ensure that their prices would converge. When products are homogeneous this seems reasonable. However, if products are differentiated and consumers value variety, market equilibrium can sustain price differences for different varieties of the same product. The implication for our price analysis is that the cross-country differences in product prices we find could reflect differences in production costs of very similar products and not necessarily differences in the type or quality of the product (Hallak and Schott 2008, Khandelwal 2010, Mandel 2010).[27] Chinese goods might not actually be less sophisticated or different but simply cheaper versions of very similar products.

The association between relative market shares and relative prices can help us sort out whether price differences actually reflect products that differ in quality or just in price. We would expect that if higher prices reflect more costly

27. Benjamin Mandel (2010) uses transaction-level data and finds that the high unit values in wealthier countries belie specialization in low-priced varieties in less-quality-differentiated sectors and specialization in high-price varieties in more quality-differentiated sectors.

Figure 4.6 Identifying relative quality from relative prices and relative quantity, data processing machines, 2006



Source: Authors' calculations based on 10-digit Harmonized Tariff Schedule classification data obtained from Feenstra, Romalis, and Schott (2002).

products of a similar quality, market shares would fall, but where higher prices reflect higher quality, market shares should rise. Our approach to identifying whether price differences reflect quality differences or cheaper products, therefore, is to consider the market shares that are associated with given prices.

Our identification of quality is depicted in figure 4.6, a cross-country scatter plot of the (log) relative quantity and (log) relative price for data processing machines in 2006 (made up of HS 847120 and the subdivisions of HS 847190). There is clearly a negative relationship between relative price and relative quantity, the slope of which we can interpret as reflecting the price elasticity of substitution across the varieties in our sample. But the price-relative quantity combinations do not all fall on the regression line, and it is this variation—i.e., the deviations from the line—that we attribute to quality differences. For example, relatively high-quality varieties are situated to the right of (and above) the regression line, as the relative volume of imports exceeds what we would predict on the basis of relative price. Note also that in this example, it is the varieties from developed countries (indicated by +) that are mostly found in the high-quality domain. The Chinese products in the sample are cheap and have large market shares, but their close location to the line does not suggest that given their prices, their quality is unusual.

Based on this insight, as reported in greater detail in appendix 4A, we run regressions that detect unusual quality taking account of relative product prices, market shares, and a proxy for the number of varieties. This allows us to estimate where developing countries are located in the quality spectrum and whether this has changed over time. Figure 4.7 plots the unweighted mean (log) relative quality of (low- and middle-income) developing countries and (high-income) developed countries according to the various categories of Lall's classification system.

The average quality of all imports (solid line) from developed countries exceeds that of all imports (including developed and developing) by around 6 log points, and the premium has not changed significantly over the entire period. In contrast, the mean quality discount of imports from developing countries is around 11 log points, and apart from 1991 and 1992, there is also no discernible trend in the ratio. Thus developing countries, on average, not only export relatively low-priced varieties, but the quality of the varieties is relatively low, controlling for these relatively low prices.[28] This reinforces the conclusion that developed and developing countries specialize in different products.

There is also substantial quality heterogeneity across measures of product sophistication. In general, the relative quality of developing-country exports is lower in more sophisticated products. This holds for Lall's classification (resource-based products are an exception) as well as other measures of product-sophistication-based classifications presented in Edwards and Lawrence (2010b).

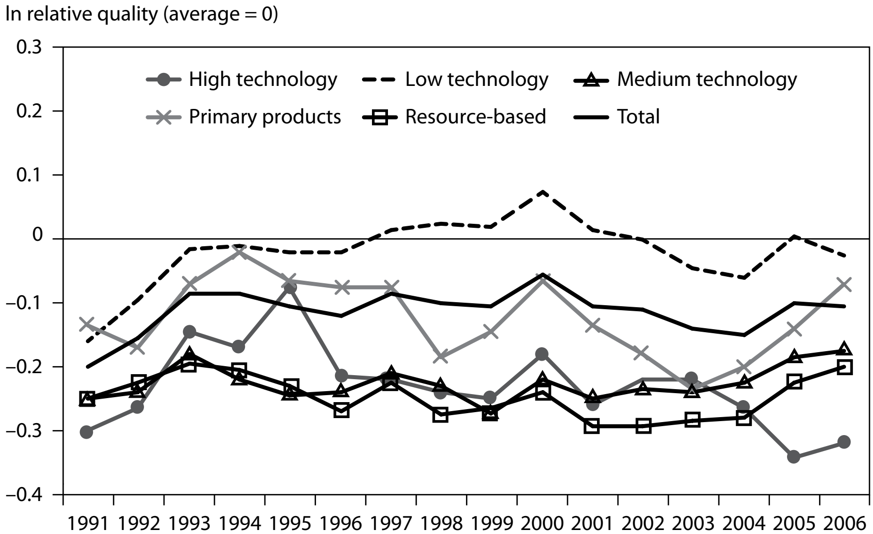
Conclusions

Using highly disaggregated trade data, we find that aside from natural-resource-intensive products such as steel, manufactured goods produced and exported by the United States and other developed countries are very different from those exported by developing countries in general and China in particular. Our analysis of unit values and relative quality reveals that even when they share similar product categories, these goods have a high degree of within-product specialization. Specialization is particularly high in sophisticated products in which developing countries have experienced considerable growth in exports. These exports are low-priced and low-quality varieties that differ

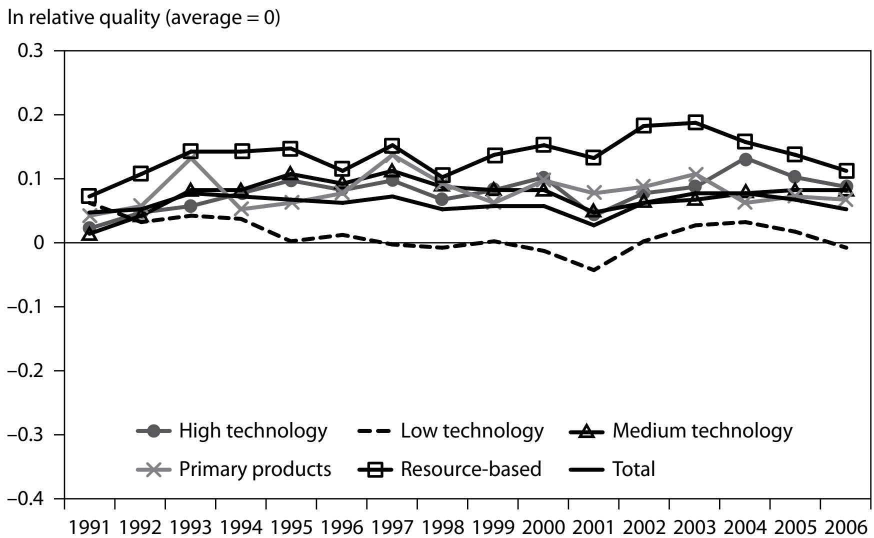
28. The degree of product specialization across developed and developing countries is actually greater than is implied by the relative quality results. The denominator in each relative quality observation covers all other countries, developed and developing. Similar quality levels among developing countries will therefore bias the log relative quality estimates toward zero. Further, the indicators only measure quality differences along the intensive margin (i.e., for products that overlap). The specialization by developed and developing countries in different products shown earlier is therefore not taken into account. Nevertheless, what is remarkable about the relative quality trend is that it has remained stable despite the increase in the range of products imported from developing countries over this period. The implication is that when developing countries export new products, they enter the market at the lower end of the quality spectrum.

Figure 4.7 Average relative product quality by technology classification for developed and developing countries, 1991–2006

a. Mean relative quality: Developed countries



b. Mean relative quality: Developing countries



Note: Values reflect the cross-country simple average relative quality measure obtained from the 10-digit level of the Harmonized Tariff Schedule estimates for each of the Lall (2000) technology categories. A positive value indicates above-average levels of quality.

Source: Authors' calculations based on residuals from relative quality regression estimates.

substantially from those exported by high-income OECD countries and the United States. The scope for quality differentiation within these products is also higher than in less sophisticated products, but we find no evidence of within-product quality upgrading by developing countries on average in these technology-intensive products. Growth in exports from developing countries to the United States appears, therefore, to have come through increases in the supply of existing or very similar varieties, rather than through within-product upgrading of quality.

Our findings have important implications for the work that follows. The concerns raised by Paul Samuelson (2004) that developing-country growth reduces US welfare are based partly on the assumption that these countries have become competitors with the United States in export markets. But we have shown here that developing countries by and large do not compete with their developed-country counterparts in the same export markets. Indeed, great caution is required in using measures of "advanced technology" trade that are routinely produced by the US Department of Commerce in its monthly trade release to track performance. When imports from developing countries are important, trade balances, particularly in terms of high-tech products, are likely to involve comparing apples and oranges. This is especially the case for information technology products.

We point out in later chapters that the theory motivating Paul Krugman's[29] concern that trade with developing countries hurts unskilled workers assumes they export products that are perfect substitutes for those made in the United States. Empirical tests of the theory use US industry data to classify the skill intensity of US imports from developing countries. But the evidence we have produced indicates that developing-country exports are quite different products, and the products imported into industries that are classified as high-tech or skill-intensive may actually be quite standardized and unskilled-labor-intensive.

In concluding, we should acknowledge that while the evidence here casts doubt on the conventional (Stolper-Samuelson) theory that assumes domestic and imported products are perfect substitutes, it does not rule out the possibility that trade could cause wage inequality through other mechanisms. For example, this evidence *is* compatible with theories we discuss later (in chapter 8) that use the framework developed by Rudiger Dornbusch, Stanley Fischer, and Paul Samuelson (1980) to consider how factor returns are affected when specialization changes in countries that are fully specialized (Feenstra and Hanson 1996, Zhu and Trefler 2005).[30] This evidence is also compatible with forces that operate by influencing demand (Whalley and Abrego 2000).

29. Paul R. Krugman, "The Trouble with Trade; Keep Our Markets Open but Protect Those Who Get Hurt," *Pittsburgh Post-Gazette*, December 29, 2007, B-7.

30. Typically in these theories, two sets of countries are assumed: the North and the South. Initially, there is a cutoff point such that the more skilled-labor-intensive products are produced in the North and the more unskilled-labor-intensive in the South. They then consider a shock

Appendix 4A
Quality Measurement

Our approach to detecting quality considers the market shares that are associated with given prices. Where higher prices reflect more costly products of a similar quality, market shares should fall, but where higher prices reflect higher quality, market shares should rise. Based on this insight, our measure of relative quality is captured by the following relationship representing the consumption of goods (in category *i*) by US consumers from country *j* relative to any other country *k*:[31]

$$\ln(N_j x_j / N_k x_k) = -\sigma \ln(p_j / p_k) + \ln(N_j / N_k) + \sigma \ln(Q_j / Q_k),$$

where $N_j x_j / N_k x_k$ is the quantity of imports from country *j* relative to country *k* and is made up of symmetric varieties relative to *k* (N_j / N_k) (think different brands of similar products from each country relative to each other), and relative quantities of each variety (x_j / x_k). The variable p_j / p_k denotes relative prices, Q_j / Q_k denotes relative quality, and σ is the elasticity of substitution.

This relationship neatly captures three distinctive drivers of market share—price, variety, and quality—and demonstrates the problem of assuming that relative prices indicate relative quality. Price plays a role and consumers adjust to changes in the relative price of imports of equivalent quality by altering their relative consumption according to the elasticity of substitution (σ). Relative consumption differences could therefore sustain differences in prices, even though the quality of the products is equivalent. In addition, the number of varieties will also drive market share. And finally, consumer demand will be affected by relative quality.[32] Improvements in the relative quality of country *j* would raise demand for its products, even if prices and the number of varieties do not change. Quality in this model acts as a demand shifter.

The relationship also gives us insight into how firms may respond to competitive pressures. We do not develop the firm supply relationship (Hum-

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(increased productivity in the South or capital inflows) such that the cutoff shifts, and production of the most unskilled-labor-intensive goods in the North shifts to the South, where they become the most skilled-labor-intensive products the South produces. Consequently, the relative demand for skilled labor goes up in both sets of countries.

31. This relationship is drawn from Hummels and Klenow (2005). Consumers maximize a Dixit-Stiglitz utility function:

$$U_m = \left[\sum_{j=1}^{J} \sum_{i=1}^{I} Q_{jmi} N_{jmi} x_{jmi}^{1-1/\sigma} \right]^{\sigma/(\sigma-1)} \quad \text{subject to} \sum_{j=1}^{J} \sum_{i=1}^{I} N_{jmi} p_{jmi} x_{jmi} \le Y_m,$$

where N_{jmi} is the number of symmetric varieties exported by country *j* to country *m* within category *I*, x_{jmi} is the quantity of each variety exported, Q_{jmi} is the quality of varieties exported, Y_m is country *m*'s income, and p_{jmi} is the price of each unit. The first-order conditions give the optimal consumption relationship.

32. Note that relative demand is negatively related to quality-adjusted prices, $(p_j/Q_j)/(p_k/Q_k)$.

mels and Klenow 2005), but it is apparent from the relationship that there is a tradeoff between price and quality in supplying consumers with products. For example, firms in country *j* can offset a decline in relative demand associated with lower prices from country *k* by improving the quality of their products. The effect of import competition on output and employment of a firm is therefore influenced by the product market's scope for quality differentiation (Khandelwal 2010).

The consumer demand relationship forms the basis of our relative quality estimates using US import data. In the trade data, we observe total quantities *Nx* and prices, but not the number of varieties and quality. To identify relative quality, we use regression analysis. In particular, we estimate the following equation using data for the period 1990–2006:

$$\ln(RX_{jit}) = \beta_1 \ln(RP_{jit}) + \beta_2 \ln(rlabf_{jt}) + \beta_3 \ln(R\lambda_{jt}) + \mu_{it} + \varepsilon_{it},$$

where RP_{jit} is the geometric average of the cost, insurance, and freight (c.i.f.) price of product *i* (defined at the HTS 10-digit level) in country *j* relative to all other countries exporting that product to the United States.[33] RX_{jit} is the implicit relative quantity index calculated from the ratio of import values,[34] while $rlabf_{jt}$ is the geometric average of relative labor force which is used as a proxy for relative varieties.[35] The residual from the estimate, ε_{jit}, is interpreted as the measure of relative quality. In other words, we attribute relative import values in excess of what is predicted on the basis of prices and the labor force to the higher quality of the product.

The regression also includes a control for new product varieties, $R\lambda_{jt}$, defined at the 4-digit level of the SITC. Based on Feenstra, Yang, and Hamilton (1999) and Hummels and Klenow (2005), $R\lambda_{jt}$ measures the proportion of imports (at the SITC 4-digit level) from the rest of the world over which country

33. $RP_{ji} = \prod_{k \in K_{-j}} \left(\frac{p_{ji}}{p_{ki}} \right)^{w_{jki}},$

where K_{-j} is the set of all countries, excluding *j*, and the weights w_{jki} are the logarithmic means of the import shares, normalized to sum to unity. The formula for the weights is:

$$w_{jki}(I_i) = \left(\frac{s_{ji}(I_i) - s_{ki}(I_i)}{\ln s_{ji}(I_i) - \ln s_{ki}(I_i)} \right) \Big/ \sum_{k \in I_j} \left(\frac{s_{ji}(I_i) - s_{ki}(I_i)}{\ln s_{ji}(I_i) - \ln s_{ki}(I_i)} \right),$$

where $s_{ji}(I_i)$ is a constant fraction equal to one over the number of countries for which positive import data for product *i* are available ($s_{ji}(I_i) \equiv 1/N_{K_{-j}}$) and $s_{ki}(I_j)$ is the import share of product *i* from country *k* in total US imports from the sample of countries K_{-j} ($s_{ki}(I_i) \equiv p_{ki}N_k x_{ki} / \sum_{k \in I_i} p_{ki}N_k x_{ki}$).

34. $RIM_{ji} = RP_{ji}RX_{ji}$, where RIM_{ji} equals the value of US imports of product *i* from country *j* relative to its imports of *i* from all other countries.

35. This variable is suggested by a model in which each worker is a firm. Other studies such as Khandelwal (2010) and Hummels and Klenow (2005) use population as their proxy for variety. However, the relative labor force is a closer indicator of employment levels in each country. In practice, relative labor force and relative population are highly correlated.

j has an overlap.[36] This ratio rises with the importation of new products from country j (i.e., growth along the extensive margin). Intuitively, the introduction of new varieties by a country can be thought of as a reduction in the average price of imports from that country and hence is expected to have a positive impact on US demand for its products (Feenstra 1994).

Finally, 10-digit HTS product-by-year fixed effects, μ_{it}, are included to account for product-by-year specific trends in quality common to all countries. The inclusion of the fixed effect means that the regression explains within-product differences in relative output across countries.[37]

The regression equation is estimated for 648 categories of products defined at the 4-digit level of the SITC (Rev. 2). We use lagged relative prices as instruments for relative prices. This is necessary as optimizing firms simultaneously choose prices and quality (Hummels and Klenow 2005), implying a correlation between relative prices and the residual (relative quality). An alternative instrument is unit transport costs, but as argued by Armen Alchian and William Allen (1964) and estimated by David Hummels and Alexandre Skiba (2004), these are likely to be correlated with quality in our estimates, rendering them inappropriate for use as an instrument in our estimates.[38]

Summary statistics of the quality regressions are presented in table 4A.1. Overall the estimates are reasonably good. The average R-squared is 0.42 with a maximum of 0.9, and the first-stage F-statistic p-value is on average very low, indicating a generally significant association between the instrument (lagged relative price) and the relative price. The mean estimated elasticity of substitution is –1.75 and ranges from 3.58 to –16.39.[39] The relationships for the other variables are also consistent with expectations: relative import quantities from each country are positively associated with its relative labor force and increases in the range of products imported.

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36. To be explicit, $R\lambda_{jt} = \lambda_{kt}/\lambda_{jt}$, where k denotes the rest of the world and, ignoring the number of symmetric varieties, $N\,\lambda_{kt} = \sum_{i\in I} p_{ki}x_{ki} / \sum_{i\in I_k} p_{ki}x_{ki}$ and $\lambda_{jt} = \sum_{i\in I} p_{ji}x_{ji} / \sum_{i\in I_j} p_{ji}x_{ji}$. The variable I is the set of products exported by both country j and k, while I_j and I_k are the set of products imported by the United States from country j and the rest of the world, respectively. In almost all cases, I_j is a subset of I_k with the result that $\lambda_{jt} = 1$.

37. The elasticity of substitution, β_1, is often interpreted as an indicator of horizontal differentiation (Broda and Weinstein 2006). In our estimates, we use the residual as an indicator of vertical differentiation across the quality spectrum.

38. Amit Khandelwal (2010) uses unit transportation costs, but exploits the within-product time variation of the variable, which he argues is less problematic than in estimates, such as ours, that exploit the cross-country variation within each product. An alternative instrument, ad valorem tariff rates, is also inappropriate as tariff levels interact with unit transportation costs to influence relative demand for high-quality goods (Hummels and Skiba 2004, Krishna 1987).

39. As in Khandelwal (2010), the (relative) quality of a country's exports is positively correlated with its GDP per capita. We find that the relationship with GDP per capita is stronger for high-technology products whether classified according to Lall (2000) or the US Census Bureau's advanced technology product classification. Unlike Khandelwal (2010), the estimated elasticities of substitution are significantly correlated with those estimated by Christian Broda and David Weinstein (2006), although the correlation coefficient is low.

Table 4A.1 Summary statistics of relative quality regression estimated at the SITC 4-digit level

	Mean value	Median value	1st quartile value	3rd quartile value	Maximum value	Minimum value
Relative *P* coefficient	–1.75	–1.70	–2.09	–1.26	3.58	–16.39
Relative *L* force coefficient	0.10	0.09	0.01	0.19	1.74	–1.68
Lambda ratio coefficient	2.52	2.17	0.71	3.76	85.07	–45.38
1st stage *F*-statistic *p*-value	0.01	0	0	0	0.98	0
Adjusted *R*-squared	0.42	0.44	0.32	0.54	0.90	–0.01
Observations per estimation	2,870	1,385	412	3,270	58,848	21
Fraction of estimations with statistical significance relative *P* coefficients	0.91	1	1	1		
Total estimations	647					
Total observations	2,602,020					

Notes: Summary statistics based on estimates using lagged relative price as instrument for current relative price.

Source: Authors' calculations based on relative quality regression estimated at the Standard International Trade Classification (SITC) 4-digit level.

We can also use our estimates to provide insight into product markets' scope for quality differentiation—or "quality ladders"—and hence the ability of US firms to respond to international competition by shifting into a differentiated product. Amit Khandelwal (2010), for example, finds that the decline in employment and output in US industries resulting from low-wage competition is substantially lower in industries characterized by long quality ladders.

Table 4A.2 presents various indicators of the scope for product differentiation according to technology classification. These indicators include the difference between the maximum and minimum relative quality, the 10th–90th percentile range of relative quality, and the standard deviations of relative quality and log unit values across countries, each calculated at the HTS 10-digit level. The table presents the mean of these product-level indicators across all countries and all periods.

We find that the scope for quality differentiation is greater in high-technology product categories, but only marginally more so than in the other technology categories that do not differ substantially from one another. For example, the mean ladder length of relative quality for high-technology products using the 10th–90th percentile range is 568 log points versus 494 to 519 log points for the other categories. The mean standard deviations in relative quality also do not differ widely across technology categories, although the deviation in relative quality is highest for high-technology products.

Contrast this with the much stronger positive relationship between price variation and sophistication shown in chapter 4 and in the mean standard deviations of relative unit values presented in the final column of table 4A.2.

Table 4A.2 Indicators of quality differentiation by technology classification, manufacturing sectors only

Technology classification	Mean log ladder length	Mean log ladder length (10th to 90th percentile range)	Mean standard deviation relative quality	Mean standard deviation ln(unit value)
High-technology	7.24	5.68	2.35	1.76
Medium-technology	6.08	5.10	2.26	1.32
Low-technology	6.74	5.19	2.20	1.06
Resource-based	5.98	5.15	2.30	1.16
Primary product manufactures	5.66	4.94	2.29	0.97

Source: Authors' calculations based on residuals from relative quality regression estimates.

The relationship between the scope to differentiate products of equivalent quality horizontally and product sophistication is therefore stronger than the relationship between the scope for quality differentiation (vertical differentiation) and product sophistication.

Further, note that the variation in relative quality of US imports across countries far exceeds the variation in relative unit values. What this indicates is that the scope for quality differentiation far exceeds the scope to differentiate the product horizontally.

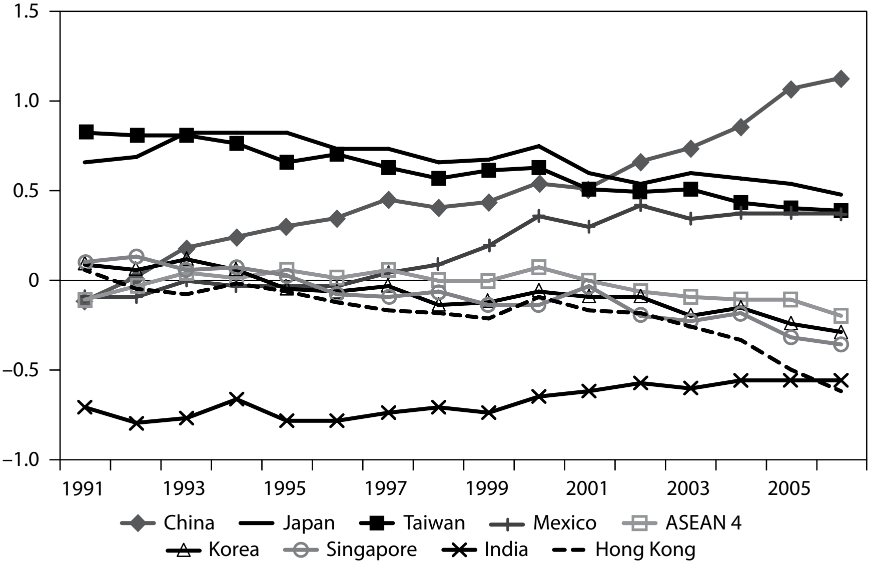
We are also interested in where individual countries are located in the quality spectrum and whether their position has changed over time.

The indicators of average quality in figure 4.7 mask large trends in relative quality at the country level. These trends are evident in figure 4A.1, which presents the average relative quality of all products for selected countries over the full period. The trends for sophisticated products are very similar (they are slightly more pronounced) (Edwards and Lawrence 2010b), so we focus on the average for all products.

What is noticeable is that there are contrary trends in relative quality across the sample of countries. Most obvious is the rapid increase in relative quality from China, followed by Mexico. Over the period 1991–2006, the estimated quality of Chinese imports rose by an astounding 124 log points and imports from Mexico by 47 log points. In contrast, estimates of relative quality declined for many of the Asian economies including Japan, Taiwan, the ASEAN 4, Korea, Singapore, and Hong Kong.

These dramatic changes in relative quality reflect far greater changes in relative import quantities than could be predicted from changes in relative prices. This is very apparent for imports of technology-intensive products from China. For example, consistent with our earlier analysis, the simple average price of high-technology products imported from China is 16 to 19 percent of other countries, and the average did not change much between

Figure 4A.1 Average product-level relative quality for selected countries, 1991–2006



ASEAN = Association of Southeast Asian Nations

Notes: Values reflect the simple averages of the 10-digit Harmonized Tariff Schedule–level estimates of relative quality. All products are included. ASEAN 4 consists of Indonesia, Malaysia, the Philippines, and Thailand.

Source: Authors' calculations based on residuals from relative quality regression estimates.

1990 and 2006. The average quantity of imports at the HTS 10-digit level, however, increased dramatically from 7 times the quantity of imports from other countries in 1991 to 126 times the amount in 2006. The implication is that our estimates predict an exceptionally strong rise in the relative quality of the goods imported from China. This outcome is not unique to our estimates. Mary Amiti and Amit Khandelwal (2009) find that China was the quality leader in 44 percent of the total number of products it exported to the United States in 2005.

We identify two possible explanations for these trends, both of which suggest that caution should be exercised when analyzing relative quality at the country level using residual-based approaches such as ours and that of Khandelwal (2010).[40] The first explanation is that the constant elasticity of

40. Another problem is that the model imposes a constant elasticity of substitution over the entire period and assumes that the income and other price elasticities of demand for the products are equal. Reestimating the equations over shorter periods and at the HTS 10-digit level in an attempt to deal with these concerns does not alter our finding.

substitution function requires that products be sufficiently similar such that the reaction to demand for each product to other economic variables is identical, but also dissimilar enough for consumers to purchase both (Leamer and Stern 1970, 58). The degree of within-product variation of prices (and estimated quality) suggests that this assumption may not hold. In effect, the results may be picking up evidence of specialization by countries in different products, even within the narrowly defined HS 10-digit product categories.

A second and more plausible explanation is that these estimates of relative quality are distorted by processing trade.[41] The fragmentation of the production process leads to a change in the geographical sourcing of imports without commensurate changes in relative prices. Treating the residual in the estimates as a measure of quality therefore erroneously attributes these changes to changes in relative quality. This is particularly problematic if we are interested in analyzing changes in relative quality on a country-by-country basis. However, looking at the average effect for the full sample of countries is less problematic, as the outsourcing effects on relative quality offset each other. For example, we would measure a decline in Taiwan's relative quality and a rise in China's relative quality as Taiwan shifts production to the mainland. The average relative quality of both countries pooled together, however, should not change.

41. Processing trade also distorts the measure of quality upgrading developed by Randi Boorstein and Robert Feenstra (1991). In this approach, shifts in imports toward more expensive goods within a product category, as measured by an increase in the unit value index relative to the exact price index, are interpreted as quality upgrading. For example, final goods should be more expensive per unit than the price per unit of the components used in the production process. Hence, outsourcing of the assembly stage of the production of final goods from developed to developing countries will raise the average unit value relative to the exact price index and erroneously be interpreted as quality upgrading. This would also explain the relatively high unit values of China's processing trade found by Zhi Wang and Shang-Jin Wei (2010).