The Dynamics and Differentiation of Latin American Metal Exports*

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Abstract

This paper investigates the propensity of exporters in certain primary commodity sectors to innovate, and attempts to measure the associated gains. First, the high degree of differentiation in metal products is documented, which gives rise to the potential for vertical upgrading for a substantial portion of Latin American export sales. Estimation of a demand system for U.S. imports shows that relatively high-priced new varieties tend to *gain* market share, which suggests a correspondingly large increase in the relative quality of those varieties. Breaking down the types of metal products by order of their value-added in production reveals a pattern of specialization away from low-value ores and toward high-value intermediate and finished products. Upgrading varieties and shifting specialization to downstream outputs account for the vast majority of Latin American market share growth in metals over the past 30 years.

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There has been extensive discourse on the role of primary commodity endowments as either a curse or blessing for economic growth. On one hand, richly endowed economies find themselves vulnerable to volatile and, in some cases deteriorating, terms of trade or else subject to stagnation in the production of low-value added outputs. The sudden onset of commodity wealth may result in Dutch disease, which radiates the curse into the industrial sector and beyond.[1] On the other hand, 'properly harnessed,' the benefits of commodities are potentially large, with gains in long-run output growth, mechanisms to smooth intertemporal consumption as demonstrated by the Norwegian model, and with the scarcity of resources itself acting as a stimulus for technological innovation economy-wide.[2] This paper adds an additional narrative to the blessing category: in differentiated commodity product categories, specialization gives rise to product upgrading and the capture of associated rents.

The framework with which to analyze and measure the benefits of upgrading is a class of models with an expanding number of new and higher quality product varieties on offer. The branch of the endogenous growth literature based on Schumpeter's observation that technological progress arises from fruitful investment in new products and processes, and formalized seminally by Aghion and Howitt (1992) and Grossman and Helpman (1991), has at its heart a distending set of traded varieties, each ascending an ever-reaching quality 'ladder.' Works in the resource curse strand of literature tend to treat commodity goods as homogeneous, and hence bereft of the benefits of Schumpeterian endogenous growth through expanding varieties. In this paper, it is argued that the framework of upgrading varieties and products extends beyond the realm of manufactured goods to commodities, which, in turn, are important components of developing countries' output. The objective herein is to search for evidence of upgrading within and across products in metals industries, representing a significant, less-explored component of commodity-driven growth.

As an empirical case study in the rents and externalities associated with new variety production, detailed trade data for a large and influential sector in a dynamic developing region, namely metal exports from Latin America and the Caribbean (LAC), are examined.

[1] Variations on these themes are developed in Prebisch (1950) and Singer (1950) and onwards, with later contributions on boom sectors and the resource curse by Corden (1984), Sachs and Warner (2001) and Collier and Goderis (2007), among others.

[2] Rosenberg (1973) argues that the U.S. reliance on wood in the 19th century drove an array of technological advances to make use of the abundant factor and subsequently to substitute away from it. Collier and Goderis (2007) illustrate that resource endowments interact with good governance to produce sustained output growth.

First it is contended that, contrary to conventional notions, commodities are often highly differentiated products and that the trade flows and prices in these industries share many characteristics in common with those of highly differentiated manufactures. In Section 2, four measures of product differentiation are constructed to evaluate this claim. Of note, the 'at-the-dock' transaction prices of U.S. metal imports within narrowly defined product groups (but across source countries and firms) are highly diffuse, suggesting a correspondingly high variance in quality characteristics across export sources. International trade in metals is also characterized by a high degree of intra-industry trade, an observation that implies exchange of distinct varieties. Further, recent studies using detailed trade price and quantity data have generated new measures of vertical and horizontal differentiation at the level of disaggregate goods. Applying these measures of product-level elasticity of substitution and quality scope, the implied distribution of characteristics across export varieties is far from uniform.

This high degree of heterogeneity in metals creates the potential for specialization in (and upgrading to) more desirable, higher-quality, higher-value varieties. However, due to data limitations on product characteristics, export quality levels and changes are not directly observable. The subsequent sections construct measures of upgrading for seven large metal sectors within product groups (for instance, from low grade copper coils to high grade) and across products (from copper ore to copper coils), making inference from trade prices and flows. There are two features of the quality ladder growth model that motivate these exercises. The first is the research arbitrage condition outlined in Aghion and Howitt (1992) in which producers face an inter-temporal trade-off between R&D expense today and monopoly rents from innovation tomorrow. This trade-off characterizes the incentive to invest. In the empirical trade literature, the recent focus on gains from trade due to augmented product variety has generated studies of their magnitude and relevance. For instance, employing Feenstra and Markusen's (1994) methodology for measuring productivity gains from new input varieties, Broda, Greenfield and Weinstein (2006) illustrate that gains from the proliferation of new goods and export source countries are indeed substantial, in particular for developing countries where new imported varieties can account for up to a quarter of TFP growth. The intuition for this result combines the observation that a large share of trade growth has occurred along the extensive (new variety) margin with a production technology that loves variety in intermediate imported inputs.[3] However, the focus of this approach on the benefits accruing to imported input *consumers* takes as given the mechanism of new variety production abroad and related rents. What if the creation of a new innovation hinged upon the size and number of potential foreign destination markets? In that case, trade expansion along the extensive margin and the innovation process would be simultaneously determined; markets increasing the number of imported input varieties would realize higher productivity growth and the expectation of higher productivity growth (and profits) would stimulate innovation in the export markets for those intermediate goods abroad. Carrying this logic a step further, the productivity gains due to new varieties can, at least in part, be interpreted as monopoly rents from innovation captured by foreign producers.

Given potentially large gains from innovation accruing to the producer, the within-product analysis in Section 3 estimates the extent to which increases in export market share can be ascribed to quality innovations. A novel data source on the relative price levels of newly traded U.S. import varieties is exploited to infer the sensitivity of market share to quality innovations relative to changes in the non-quality determinants of price. Market share is, in fact, positively and significantly correlated with new good price, an observation that implies large increases in the relative quality of those varieties; this 'upgrade elasticity' is about equal for metal goods and higher value-added manufacturing exports, and roughly half of LAC's market share increases over the past 30 years can be ascribed to upgrades of this sort.

The second feature of the quality ladder model to be explored is the existence of spill-overs across products and sectors. In particular, under certain assumptions the model of endogenous quality upgrades in varieties within a product group can be interpreted equivalently as one in which producers ascend a sequence of products, each with higher value-added than the last.[4] In Section 4, a special feature of the input-output structure of commodity production is exploited to search for trends in upgrading across products. Generally speaking, analyzing

[3] Although there appear to be significant benefits to the increase in imported inputs, Broda, Greenfield and Weinstein also find that there are only modest, transient gains to trade openness from the perspective of the importer's own ability to innovate in steady state. That is, exposure to new varieties of 'lab equipment' is quantitatively less important in explaining steady state growth.

[4] The spillover assumption is the multi-sector analogue to the industry quality ladder model. An innovation in one sector raises the frontier technology in the others (See Aghion and Howitt, 1996).

exporter capabilities in related products requires a detailed knowledge of the input-output structure of production and is complicated by the myriad combinations of production inputs. For example, relating changes in comparative advantage over time in digital cameras and small LCD screens is difficult since screens are but one of many inputs in digital cameras and digital cameras are but one of many uses for screens. In certain commodities, however, the input-output structure is fairly 'steep' with the inputs of each processing step largely, if not exclusively, composed of outputs from the previous step; copper cathodes are primarily composed of less refined copper anodes. The steps incrementally increase the product's value added without the addition of many other (if any) intermediate input goods. Defining inter-product upgrading as increased export success in a downstream output, and constructing a panel of revealed comparative advantage for the set of commodities with steep input-output structures, LAC metals product upgrading can be measured over time. Examining the trends in LAC revealed comparative advantage, there has been decreased specialization in upstream primary products such as ore and increased specialization in downstream manufactured products, a pattern which suggests an ascent of the value added chain over recent decades. Given the classification of products according to their locus on the value chain, about 75 percent of LAC metal share growth is due to growth in intermediate and high value products. While there have been studies documenting the changing composition of developing country exports in aggregate sectors (e.g., from commodities to manufactures and services in Martin, 2003), this is the first to make the analogous claim across disaggregate products within a commodity sector.

The remainder of the paper is organized as follows. Section 1 outlines the increasing importance of LAC metals exports to both the region and to global markets. In Section 2, the degree of product differentiation in metals industries is catalogued, which motivates the measurement of intra- and inter-product upgrading trends in Sections 3 and 4, respectively. Section 5 then decomposes LAC market share growth by applying these measures. Section 6 concludes.

1 Latin American Metal Exports

The LAC region is an intuitive choice for the study of metal exports vis-à-vis the resource curse. First, the region has a relatively long history of supplying the world with primary commodities, and metals figure prominently in LAC production[5] due to rich mineral endowments. Over the past 40 years, illustrated in Figure 1, metal export volume is characterized by steady growth at a compound annual rate of 9.4 percent, reaching a crescendo at the end of the sample in the most recent commodity boom.[6] This success story has occurred in spite of the pronounced boom and bust cycles in international metal markets. Highlighted in bold circles in Figure 1 are the peak years for the unit value price of copper, a proxy for high metal demand. To be sure, these periods coincided with relatively large gains in export sales, but what is remarkable is the minimal decrease in sales in periods of weak demand, as proxied by U.S. recession dates. Nominal sales have grown rapidly in the past decades, with limited downward swings during cyclical troughs.

Gains measured in sales corresponded to an increasing market share of global metal exports, as shown in Figure 2. The region's share rose steadily from approximately 4 percent in 1975 to over 12 percent in 2004. For the U.S., one of LAC's largest customers, approximately 19 percent of metal imports originated in LAC by the end of the sample period. Moreover, the increasing mutual dependence of LAC and the rest of the world is portrayed by the high metal share in total LAC exports, also plotted in Figure 2. Over the period 1975-2004, metals accounted for about 10 percent of total Latin American exports, reaching a peak of 16 percent in 1989 and troughs of about 7 percent in the late 1970's and early 2000's. In sum, against the backdrop of higher volatility in the overall composition of exports, the region has consolidated substantial gains in global share.

Delving deeper into the dependency of Latin American economies on commodities, the aggregate sales figures mask a high degree of heterogeneity in country-specific specialization patterns. Figure 3A shows the degree to which export sales hinge on metal markets in several large economies. At the high end, Chile and Peru derive approximately 40 percent of their respective export sales from metals, primarily copper. A second group of countries including

[5] Metals included in the analyses herein are: aluminum, copper, iron, lead, nickel, tin and zinc. See the Appendix for lists of included Latin American countries and metal products.

[6] Excluding 2004 as above trend, the annual growth rate from 1965-2003 is 8.5 percent.

Brazil, Venezuela and Argentina, has lower though more rapidly growing specialization in metals, owing largely to growth spurts in these industries in the mid- to late-1980's. A third set of countries including Mexico, Colombia and Uruguay has a small or decreasing metal export share. Though small in some countries in terms of their overall contribution to export sales, the dependence on the 7 metal sectors included above can be viewed more broadly as a floor for the overall dependence level of the region on commodities; expanding the analysis to other non-branded bulk goods, such as mineral products, stone, glass, wood products, foodstuffs and vegetables, would dramatically increase the commodity export share for LAC countries. Figure 3B puts the regional sales figures for metals in the context of other types of commodity products. After mineral products, which includes some metals at very low levels of processing, and vegetables, metal products are the third largest product group composing 14 percent of total commodity export sales. Since metals counted for about 8 percent of overall regional exports in 2000, the overall commodity share of exports is in the ballpark of 50 percent.

This paper purposefully chooses a case study that contravenes the canonical resource curse. Despite the pitfalls associated with significant dependence on a commodity sector, LAC metals have been a resounding success. The objective of the following sections will be to describe *how* the region has accomplished significant growth in these industries and the specific role of product upgrading.

2 Cataloguing the Differentiation of Metal Industries

The first assumption in a model of endogenous growth through upgraded varieties is the production of a differentiated good. At least since Krugman (1979), practitioners have viewed trade in manufactured goods through the lens of monopolistic competition, which takes as given the horizontal differentiation of products from different firms and source countries. Estimates of the product-level elasticity of substitution for U.S. imports by Broda and Weinstein (2006) find a median elasticity of 3.1, with homogeneous products having considerably higher levels of substitutability. In this section, both familiar and novel tools are employed to document the relative level of differentiation in metal industries compared to manufactures.

The first observation that supports a high degree of product differentiation is that there is substantial price dispersion in metal exports within narrowly defined product categories. A simple arbitrage condition would constrain the 'at-the-dock' prices of homogeneous goods sold in the same market to be identical, so the distance from this benchmark can be interpreted as an index of product differentiation. To do so, a confidential data set of import transaction prices collected by the International Price Program (IPP) at the U.S. Bureau of Labor Statistics (BLS) is used to measure price dispersion directly. The BLS surveys import price information for a representative range of U.S. import product categories for use as an input in its published import/export price series. Each price observation is a survey response by a U.S. importer of the monthly import price for a precisely defined item. The data set contains approximately 20,000 monthly observations for a total of approximately 60,000 unique items over the period September 1993 to May 2007. These prices also have certain characteristics documented, such as the country origin of the import, the harmonized system 10-digit category it belongs to, the unit of sale, the invoice currency of the transaction, whether it is an intra-firm transfer price, etc. Taking as the unit of measure the unit of sale (e.g., pound, kilo, ton, container, etc.) within a harmonized system 10-digit category (e.g., HS 7208380030: "Flat rolled iron/steel coil; 3-4.75mm thick; untrimmed edge") in a given month, the dispersion of transaction prices is examined by computing their standard deviation.[7] Aggregating the computed standard deviations across unit-HS10-months within 14 broad sectors using import sales as weights, Figure 4 illustrates the weighted mean (hatch) and inter-quartile range (line) for each sector. Broadly consistent with our prior notions of differentiation, primary sectors such as mineral products (including metal ores), vegetables and foods have lower average price dispersion than products in transportation, machinery, computers and chemicals. Metal products have an intermediate level of price dispersion, with an average standard deviation of 69 percent. This rather large variance is more in line with footwear/headgear or plastics than with some of the other primary commodities.

Further, the degree of heterogeneity of price dispersion within products is highly correlated with the sector dispersion across products, as evidenced by the increasingly large inter-quartile range of product standard deviations moving from left to right. That is, metal products not only have high average price dispersion but also frequent incidence of both

[7] To be precise, the standard deviation of log item prices is computed, which can be interpreted as the precent deviation from the cell mean.

high and low dispersion products. Metal products are, indeed, quite heterogeneous across products with the sector's 25th percentile product having about the same dispersion as the mean mineral product and its 75th percentile product having the same dispersion as the mean transportation product. We shall return to the notion of inter-product heterogeneity below in the study of spill-overs, where the benefit of selling a more differentiated product less vulnerable to competition by close substitutes would factor into producers' optimal composition of outputs. As will be illustrated below, LAC exporters have taken advantage of this heterogeneity by specializing in higher-value, highly-differentiated products over time.

The second way to measure the relative product differentiation of metal industries employs structural estimates of demand and supply parameters from studies of detailed trade data; these parameters translate directly into indices of horizontal and vertical differentiation. On the demand side, estimates of the elasticity of substitution across varieties are produced by Broda and Weinstein (2006) for a large share of U.S. import products, where the degree to which varieties substitute one another in consumption is an index of their degree of horizontal differentiability. On the supply side, estimates that relate export prices to firm productivity are borrowed from Mandel (2009). That index of vertical quality differentiation is based on the assumption that there are costs associated with producing quality characteristics. As a result, more productive firms are better at undertaking quality upgrades and endogenously choose (higher priced) higher quality exports. The measure gauges the strength of the correlation between exporter productivity and output price, where a positive relationship denotes a higher scope for quality differentiation and a negative relationship denotes a narrower scope.

In employing the two sets of parameters, one must be careful to allow for ease of interpretation as well as the imprecision of the estimates for certain products. For example, taking an import sales weighted average of the measure of the elasticity of substitution potentially drastically over-weights imprecise estimates and, further, it is not obvious whether a difference of 1 unit of elasticity across products is an economically meaningful one. With these limitations in mind, the following transformation is applied to each classification. First, the median estimate of each set of parameters is taken across all products; since both the horizontal and vertical differentiation indexes are for a large set of products, the median is a good measure of the central tendency of each one. Then, the sales share above and below the overall median value is calculated within each of the 14 sectors defined in Figure 4.

This transformation stratifies the classifications into the less granular high/low categories, mitigating some of the error associated with specific product estimates.

Figure 5 illustrates the indexes of horizontal and vertical differentiation by sector, where the sectors are ordered from left to right by increasing horizontal differentiation. Similar to the measure of price dispersion, animal, mineral and food products tend to be relatively homogeneous both vertically and horizontally, while machinery, plastics and chemicals tend to be relatively differentiated. Again, metal products have an intermediate level of differentiation. The share of U.S. imports with low elasticity of substitution in metals products corresponds to the same level as mechanical and computer products. The share of U.S. imports with high scope for quality differentiation in metals products corresponds to the same level as textiles and transportation products. Thus while mineral ores tend to have relatively little horizontal and vertical differentiation, the bulk of metal export varieties (i.e., metal products at various levels of processing) are not close substitutes and have a large share of products with long quality ladders.

Finally, the level of differentiation within a sector can be inferred from the sector's degree of intra-industry trade, where a country's simultaneous import and export of like products implies distinctiveness across the products' component varieties. To measure the prevalence of intra-industry trade across sectors, a standard variant of the Grubel-Lloyd (1975) index is computed for each product i in country k as:

$$IIT_{ik} = 100 * \left(\frac{X_{ik} + M_{ik} - |X_{ik} - M_{ik}|}{X_{ik} + M_{ik}} \right) \tag{1}$$

where X and M are each country's export and import sales volumes, respectively. It is immediate that $IIT = 0$ if a country only imports or exports a given product and $IIT = 1$ if it imports and exports a product in equal values. Using the slightly more aggregate SITC 4-digit product categories makes it possible to expand our analysis of IIT beyond the confines of U.S. trade data, and the measure is computed for 766 products traded by 180 countries, using bilateral trade data for the year 2000 compiled by Feenstra et al. (2005). The result is 86,661 country-product measures of IIT, which are then aggregated using trade weights to the broader sector level. Sectoral summary values for the level of intra-industry trade are illustrated in Figure 6. What is apparent is an ordering of sectors strikingly similar to the previous measures of price dispersion and the elasticity of substitution/quality indexes. Minerals, food products and textiles tend to have a relatively low incidence of intra-industry trade, while machinery, plastics, chemicals and computers have a relatively high incidence of intra-industry trade. Again, metals have an intermediate degree of IIT, with levels comparable to transportation products as well as mechanical and computers.

Moreover, the preceding measures of differentiation are all dependent in one way or another on the classification schemes for disaggregate products. If an HS10 category is defined broadly or narrowly enough (e.g., 'Steel Coils' vs. 'Steel Coils of Length w, Circumference x, Conductivity y, Production Method z, etc.') then the measured differentiation of those products will be correspondingly high or low. To the extent that the breadth of product classifications differs systematically across broad sectors, this could be affecting their ranking of differentiation. However, the IIT measures in Figure 6 show that the ordering of sectors is not much affected when computed at the SITC 4-digit commodity level (as opposed to the HS10 level in Figures 4 and 5), and hence it is unlikely that product definitions alone could be determining the relative differentiation across sectors.

In summary, the preponderance of evidence suggests that metal industries are not very homogeneous. Part of this observation is driven simply by the disparity in what is dug out of the ground across source countries and, in part, by the extent and quality of subsequent processing. Peruvian copper has different composition across mines, no less when compared to similarly classified outputs from Indonesia. Brazilian processing of steel products is likely distinct from that of similar outputs in Mozambique. Regardless of its cause, though, the differentiation of metals is necessary for upgrades to occur. The next challenge is to measure trends in export upgrades without observing output characteristics or the production process directly. Inference is made as to the direction and magnitude of these trends in the following sections.

3 Climbing the Quality Ladder: Intra-Product Upgrades

Endogenous growth through upgraded varieties is not a static theory, and having documented the degree of product differentiation is not sufficient to claim that commodity producers continually ascend quality ladders. That is, despite the implication that products with a high scope for quality differentiation confer, in some sense, growth potential on those exporters producing them, simply exporting a differentiated commodity does not necessarily imply ease of upgrading varieties within that product. In order to gauge the upgrading trajectory of LAC metal exporters, a demand system for U.S. imports is estimated, relating changes in market share to changes in the relative price of exports as a means of inferring changes in export quality composition. Variations of this method are developed in Hallak and Schott (2008) and Khandelwal (2009) to infer quality levels from price and quantity data. The intuition for the identification of product quality is that an increase in share, conditional on price, is tantamount to an increase in quality; the only way for varieties to gain share without decreasing their price is an increase in their quality.

The principal difference in the application below is the use of a novel measure of price change for *newly* traded varieties. The set of quality characteristics for a given product type changes over time as specific varieties rotate in and out of the consumer's basket, thus it is precisely at the point of entry that compositional changes can be measured. This notion, that the point of item entry conflates price and quality changes, is at the heart of the IPP's mission to measure prices. In constructing an index of import prices, the distinction between existing and new goods is a natural one. In order to control for changes in quality composition from period to period, the IPP calculates a 'matched model' price index, holding the basket of individual items constant across periods. In a matched model index, usable prices must be observed in two consecutive periods, with the initial price of a new good ignored in that period. The resulting price index is quality-adjusted in the sense that it chains together the movements of incumbent prices only, with no change in the characteristics of the basket in each period. However, the relative price of the ignored new goods contains potentially valuable information about the quality of those goods and the trajectory of upgrading across source countries.[8] In this section, the relative price levels of new goods are used as a proxy for new good price changes, which allows for the identification of new good quality trends and the sensitivity of market share to those changes. The simple intuition is that share changes can be decomposed into quality-adjusted relative price changes and relative quality changes; controlling for changes in quality-adjusted price, increases in

[8] Nakamura and Steinsson (2009) use the IPP data to argue that fixed costs of changing price causes some firms to wait for a new product introduction to change both quality and price. As such, the quality-adjusted price index may itself be biased by ignoring new goods prices. This bias, which they measure conditional on exchange rate movements, is assumed here to cancel out at lower frequencies. It is also assumed that secular trends in product switching, such as those occurring due to outsourcing and discussed in Houseman, Kurz, Lengermann and Mandel (2009), are not affecting the relative quality of newly sampled IPP items.

share due to higher new variety prices must be due to quality improvements.

A Demand System for U.S. Imports

We commence with the notational distinction between quality-adjusted and quality-inclusive variables, where $p = qz$ defines observed prices as composites of quality-adjusted price q and quality z, and $x = d/z$ defines observed quantity likewise in terms of quality-adjusted quantity d normalized by quality. Equation (2) is the definition of country k's product j market share, which aggregates across all traded items i in that product group. The assumption of consumer utility with constant elasticity of substitution (CES) across varieties (with demand relation: $d_i = (q_i/Q)^{-\sigma}D$) allows us to re-express share in terms of country k's relative quality-adjusted price as follows:

$$share_{kj} = \frac{\sum\limits_i p_{ikj}x_{ikj}}{\sum\limits_k \sum\limits_i p_{ikj}x_{ikj}} = \frac{\sum\limits_i q_{ikj}d_{ikj}}{\sum\limits_k \sum\limits_i q_{ikj}d_{ikj}} = \frac{\sum\limits_i q_{ikj}^{1-\sigma}}{\sum\limits_k \sum\limits_i q_{ikj}^{1-\sigma}} \tag{2}$$

Using the definition of the CES price index $Q = \left(\sum_{(.)} q_{(.)}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$ and log differencing over time t yields:

$$\Delta \ln share_{kj} = (1-\sigma)\left[\Delta \ln Q_{kj} - \Delta \ln Q_j\right] \tag{3}$$

where the change in share is a negative function of the change in country k's quality-adjusted relative export price as well as product j's elasticity of substitution across varieties. The exact price index for CES preferences due to Sato (1976) and Vartia (1976) is a geometric mean of item price changes, $Q_{(.)t}/Q_{(.)t-1} = \prod_{(.)}(q_{(.)t}/q_{(.)t-1})^{w_{(.)}}$, with weights:

$$w_{(.)} = \frac{[(s_{(.)t} - s_{(.)t-1})/(\ln s_{(.)t} - \ln s_{(.)t-1})]}{\sum_i [(s_{(.)t} - s_{(.)t-1})/(\ln s_{(.)t} - \ln s_{(.)t-1})]}$$

Taking logs, the index is linear in its arguments, which allows for the convenient separation of existing (E) and new (N) varieties in (3), where $i \in \{1...I\}$, $E = \{1...n \leq I\}$, and

$N = \{n+1...I\}$:[9]

$$\Delta \ln share_{kj} = (1-\sigma)\left\{ \begin{array}{c} \left[\begin{array}{c} \sum_{i=1}^{n} w_{ikj} \ln(q_{ikjt}/q_{ikjt-1}) \\ -\sum_k \sum_{i=1}^{n} w_{ikj} \ln(q_{ikjt}/q_{ikjt-1}) \end{array} \right] \\ + \left[\begin{array}{c} \sum_{i=n+1}^{N} w_{ikj} \ln(q_{ikjt}/q_{ikjt-1}) - \\ \sum_k \sum_{i=n+1}^{N} w_{ikj} \ln(q_{ikjt}/q_{ikjt-1}) \end{array} \right] \end{array} \right\}$$

$$= (1-\sigma)\left\{ \left[\Delta \ln Q_{kj}^{E} - \Delta \ln Q_{j}^{E}\right] + \left[\Delta \ln Q_{kj}^{N} - \Delta \ln Q_{j}^{N}\right] \right\} \tag{4}$$

Given information on market share, quality adjusted price changes for incumbent varieties and a proxy for the relative price changes of new goods, equation (4) allows for inference of unobserved relative quality changes. Casting equation (4) in terms of price terms only and allowing for the price elasticities to be estimated yields:

$$\frac{1}{(\sigma_j - 1)} \Delta \ln share_{kj} = \alpha_0 + \alpha_1 \Delta \ln \left(\frac{Q_{kj}}{Q_j}\right)^{E} + \alpha_2 \Delta \ln \left(\frac{P_{kj}}{P_j}\right)^{N} + \varepsilon_{kj} \tag{5}$$

where

$$\alpha_2 \Delta \ln \left(\frac{P_{kj}}{P_j}\right)^{N} = \alpha_3 \Delta \ln \left(\frac{Z_{kj}}{Z_j}\right)^{N} + \alpha_4 \Delta \ln \left(\frac{Q_{kj}}{Q_j}\right)^{N}$$

and ε_{kj} is a mean zero disturbance. The relative price changes of new goods conflate quality and quality-adjusted price changes since at the point of a new variety's entry both are presumably reset. The identifying assumption for the effect of quality change on share is that existing and new goods have identical quality-adjusted price elasticities: $\alpha_4 = \alpha_1$, which implies a quality elasticity of: $\alpha_3 = \alpha_2 - \alpha_1$. For example, the quality-adjusted price elasticity in the CES model in (4) is -1. A percent increase in quality-adjusted price leads to a percent decrease in market share. If a new item has a one percent price increase, but share decreases by less than one percent or even increases, it must be that the new good is of higher quality. If share increases by, say, half of a percent the implied quality elasticity is 1.5.

[9] The index number results for the exact CES price index are based on a constant basket of varieties and constant item quality/consumer taste across time periods. Feenstra and Reinsdorf (2007) generalize the Sato-Vartia price index for the case with constant basket and stochastic taste parameters. Here the distinction between existing and new items can be understood as an approximation to the case with constant basket and stochastic quality, where in t-1 a subset of goods ($n+1...I$) have quality levels (and hence share) very close to zero. The resulting indexes for new and existing items are not themselves exact price indexes, since their weights do not add up to one.

The main challenge in taking (5) to the data is finding a measure of the changing relative price of new goods; to calculate this price change, each item's Hicksian reservation price in the period prior to entry (i.e., the price at which demand is zero) is needed. Recall that the matched model price index avoids this problem by ignoring new goods prices in their inaugural period altogether. In this case, though, only needing the *relative* reservation price of new goods simplifies matters. Consider a newly entering variety in an industry characterized by the utility function above. Since all firms in that industry face a downward sloping demand curve, item demand only falls to zero when the reservation price is infinite. It is immediate that the ratio of reservation prices with this demand structure is unity, and that the relative price change of new goods is equal to the relative price level of new goods each period. As such, (5) is implemented as:

$$\frac{1}{(\sigma_j - 1)}\Delta \ln share_{kj} \approxeq \alpha_0 + \alpha_1 \Delta \ln \left(\frac{Q_{kj}}{Q_j}\right)^E + \alpha_2 \ln \left(\frac{P_{kjt}}{P_{jt}}\right)^N + \varepsilon_{kj} \tag{6}$$

Data & Results

The left-hand side variable in (6) is the long difference of country market share for HS4 product j between the years $t-1 = 1997$ and $t = 2006$ provided by Feenstra et al. (2002), adjusted at the HS10 level by elasticities estimated by Broda and Weinstein (2006). Given the long-term nature of innovation and the associated time lag in the market penetration of new products, the regression is run in long differences over a 10 year period.[10] The first term on the right-hand side is the change in the quality-adjusted country-product relative price, which is measured using IPP matched model locality of origin (LOO) and harmonized system price indices. The LOO indexes cover manufactured and non-manufactured goods for a selection of large exporting countries and regions. Exporters are broken down into the following localities, for which the IPP manufactured goods price index is applied: LAC, Canada, Japan, industrialized countries, Asian newly industrialized countries and other countries.[11] The inauguration of several of these LOO indexes in 1997 motivates that year as a starting point. To construct a relative price change, the LOO indexes are divided by

[10] The use long differences also mitigates the problem of varieties sparsely traded at the quarterly frequency.

[11] In December 2003 several other LOO indexes were launched by the IPP, including China, Mexico, UK, Pacific Rim, ASEAN, France and Germany. However, these provided too narrow of a window to be included in the construction of the quality-adjusted relative price change.

IPP HS4 product indexes.[12]

The second term on the right-hand side is the country-product aggregate of new good relative prices in the IPP sample. This relative price is computed by taking the ratio of newly appearing individual item prices in the sample to a geometric mean of all prices within the same HS10 category. This relative for each country-HS10 pair is:[13]

$$\ln\left(\frac{P_{kjt}}{P_{jt}}\right)^{N,HS10} = \frac{1}{N-n}\sum_{i=n+1}^{N}\frac{\ln(p_{ijkt})}{\sum_{i=1}^{N} w_{ikj}\ln(p_{ijkt})} \tag{7}$$

which is then aggregated across HS10 products and months to the country-HS4 level using BLS item-, firm- and HS10 product weights. While strictly speaking the new good price term in (6) is a ratio of (country) new goods prices to all new goods prices in that period, the relative sparsity of new goods in the IPP sample makes it difficult to construct a meaningful measure of the average new good price level for every month. As such, the denominator takes the average across all items including the incumbents.

The demand structure of the previous section guides our expectations of the coefficient signs and magnitudes. For quality-adjusted prices, it suggests that the elasticity of share to quality-adjusted price changes is one (i.e., $\alpha_1 = -1$). If, hypothetically, the quality of new goods equaled that of incumbents, then new good relative prices would represent quality-adjusted price changes and α_2 would equal -1 as well. But, to the extent that new goods have higher quality and price, the new good price change would not come at the expense of as much loss in share and the elasticity would be less than unity or even positive. Since new goods can be expected to generate the same correlation between their quality-adjusted price and share changes as incumbents, the implied quality change in units of share elasticity is simply the difference between α_2 and α_1. Moreover, since quality is a demand shifter in utility, quality and share are expected to always be positively correlated; the notion of downgrading to capture share does not exist in the underlying theoretical framework. As such, the model predicts that all of the implied quality elasticities are positive.

[12] Granted, dividing total country (or regional) price changes by specific product price changes is less desirable than using product-country-specific price changes in the numerator. In principle it is possible to construct these from the IPP transaction prices, however averaged over a broad enough set of products the aggregate region measure is a decent approximation and remains totally consistent with BLS practices for producing quality-adjusted price series.

[13] Additionally, the unit of sale (e.g., ton versus kg) within the HS10 group is controlled for.

Table 1 shows the result of running OLS on (6) for five of the largest U.S. import sectors, where the coefficient on the relative price of new goods is parsed out for LAC, OECD and East Asian Exporters. In the top row, the estimated share elasticity to quality-adjusted price changes is always significantly negative. Given that those price changes are matched across incumbent items, a negative effect on shares is to be expected. What is surprising is how close the estimates are to the prediction of the CES framework, with most coefficients indistinguishable from unity. Across sectors, chemicals and plastics shares are the most sensitive to quality-adjusted price changes and metals the least, though all sectors are well characterized by an elasticity of -1 or -2.

For the relative price of new goods, the price measure (7) is interacted with dummies for LAC, OECD and East Asian exporters to distinguish quality upgrades by region. Overall, the sign of the coefficients is mixed, with some new prices positively correlated with share and others negatively correlated. High priced new varieties from LAC tended to increase market share in metals, textiles and apparel, and chemicals and plastics, implying large associated quality increases. The implied quality elasticity of LAC metals is 1.83, and for both textiles and chemicals is above 3. High-priced new electric and machinery goods from OECD countries tended to decrease share, as did chemicals and metals from East Asia. Importantly, those decreases were not as great as the share decreases due to quality-adjusted price changes, implying a smaller but positive change in their relative quality. The implied quality elasticity is shown in the bottom panel. The quality elasticity is positive and large for LAC exporters and, with the exception of electric machinery, is in the range of 2-4. OECD exporter share was particularly sensitive to quality in textiles and chemicals, though less so in comparison to LAC. East Asian countries exhibited the strongest upgrade sensitivity in electric and machinery goods over the course of the sample with an elasticity of 1.61.

The prediction of the model that quality elasticity is positive is supported across sectors and exporting regions. Of note, though, is a policy shift within the sample period which highlights a failure of this prediction. In 2005, the Multifibre Arrangement system of quotas expired, giving rise to a deluge of lower unit value varieties of textiles exported from China. Prior studies have found that binding quantitative export restrictions cause exporters to select higher value, higher quality products. The estimates in Table 1 appear to capture the effect of this large trade policy shift that substantially altered the composition of trade in textiles and apparel. The new product price elasticity of East Asian textiles exports of

-2.91, less than the quality-adjusted elasticity of -1.62, suggests that increased share was achieved by the introduction of low quality varieties. Indeed, the only sector-region with a large negative implied quality change is East Asian textiles and apparel. It is plausible that the positive quality elasticities across Asian sectors are mitigated by the emergence of low priced varieties from China. The model is not equipped to handle trend changes in export participation, but for large enough exporters such as China this could present a relevant alternative story for the changing composition of varieties.

4 Ascending the Value Chain: Inter-Product Upgrades

Having established the relatively high differentiation of metal goods and the propensity of metal exporters to upgrade within product categories, we now return to the observation of a high degree of inter-product heterogeneity in the level of differentiation in metals industries. Given that ores have relatively low scope for horizontal and vertical differentiation compared to products further downstream (with additional processing) such as semi-finished and finished goods, metal exporters would seem to have four distinct incentives to ascend the value chain of production. First, downstream products are larger, higher value markets. Second, downstream products have lower degrees of substitutability amongst competing varieties due to increased differentiation, with associated higher markups. Third, more sophisticated outputs often require higher levels of technical expertise to produce, and thus the level of value added in production can be a reflection of technical ability. Finally, high value-added products per se may be desirable insofar as they reflect the ends of development. In the same way that the transition from agriculture to manufacturing and services accompanies growth, intra-sectoral development can be gauged analogously. Thus, while it is always beneficial to be an infra-marginal producer (i.e., higher sales are desirable at any stage in product processing), there are incremental benefits to specializing downstream.

However, in the case of most manufactured goods, quantifying upgrading across related products requires a detailed knowledge of the production inputs and technology of those products. The special nature of metals processing suggests a short-cut. In many metals industries, the input-output structure is fairly 'steep' with the inputs of each processing step largely composed of outputs from the previous step. For instance, Figure 7 illustrates the pyrometallurgical processing steps of copper, starting from the mine and increasing in purity and processing to semi-finished and finished goods; the steps incrementally increase the value added of production without the addition of many other (if any) intermediate input goods. Inputs in the production of the highly refined cathode are composed essentially of three things: lesser refined anodes, labor and machines for refining. This implies that country or regional strengths in penetrating cathode markets are closely related to those in anode markets, and suggests that spill-overs may exist between lower and higher value added outputs. This observation makes it possible to sidestep the complicated task of disentangling complicated networks of intermediate inputs, and as such, largely ignores the body of literature on value chains and global production. I will attempt to address the associated limitations in turn.

Figure 7 also illuminates the empirical approach to quantifying inter-product specialization patterns, namely the breakdown of trade data classifications by value-added. Several of the largest metal types have a production process analogous to that of copper, with a primary stage of agglomeration, followed by refinement and purification, and ultimately semi-finished/finished product formation. I break the chain into three parts to reflect these stages and concord each to a product category defined by the SITC (Revision 2) system. For instance, "copper ore and concentrates" (SITC 2871) consists of all products from the mine to low levels of agglomerate purity, with 45-60 percent pure copper matte at the high end of that category. "Unwrought copper and copper alloys" (6821) groups together the outputs of all production steps leading up to the 99.99 percent pure copper cathode, while "worked copper and alloys" (6822) traces the shaping of cathodes into a diversity of functionally useful products. This 3-stage concordance of ore, unwrought and worked SITC categories exists for some of the largest metals industries, including: aluminum, copper, lead, nickel, tin and zinc.

Clearly the interpretation of the three stages will vary across products depending on the nature of the production process. For iron, in addition to continued purification of downstream products, the process of chemical reduction and the subsequent mixture of alloying agents actually alters product composition; the nature of products emerging at the end of the process is significantly different than at its beginning. But production still consists of essentially three stages, shown in Figure 8: agglomeration of iron, alternate processes for the generation of carbon steel and alloy steel, and the formation of semi-finished and finished goods from those raw materials. The iron and steel SITC products are allocated to the three sections of the value chain accordingly.

This concordance of trade data to the metal value chain is exploited to measure global and regional trends in product specialization and inter-product upgrades, where an upgrade is defined as increased relative market share in a 'downstream' product. Specialization and export performance over time, in turn, are measured by a variant of Balassa's (1965) revealed comparative advantage (RCA). For SITC 4-digit product $i = \{\text{ore, unwrought, worked}\}$, in sector $s = \{\text{aluminum, copper, iron, lead, nickel, tin, zinc}\}$, exported from country k in year t:

$$RCA_{iks} = \frac{\frac{X_{iks}}{X_{is}}}{\frac{X_{ks}}{X_s}} \tag{8}$$

where X denotes export sales and the t subscripts are dropped for convenience here. The measure is each country's product market share divided by its sector market share, a normalization of product hare that takes into account factors affecting each country's sector participation. For instance, a change in the bilateral exchange rate that affects all products within a sector proportionately would not affect the country's RCA. The measure seems particularly appropriate for metal exports, where a country's participation in a sector typically involves export of multiple products within the sector. This measure is computed using country-product export sales data described in Feenstra et al. (2005) for approximately 200 countries that exported in at least one metal sector over the period 1965-2004.

Figure 9 illustrates the evolution of RCA for a selection of four large LAC copper exporters. In panel (a), the regional heavyweight in copper exporting, Chile, has a pattern of specialization dominated by unwrought copper products, with steadily growing RCA in ore and an appreciably smaller presence in worked products. In panel (b), Peru has much the same composition of export products within the sector, however in that case, ore and products trade as the dominant export product. At the beginning of the sample heavy specialization in ore is supplanted by unwrought products, only to reverse in the most recent years.

Of greater interest for the study of inter-product specialization changes are the regional players whose mix of products is better diversified. That is, while in Chile and Peru large percentage increases in worked product sales are dwarfed by annual ore and unwrought copper exports in the billions of dollars, exporters with less skewed product composition present a better picture of inter-product trade-offs. Countries of this sort are represented by Mexico and Brazil in panels (c) and (d) of Figure 9, respectively. In Mexico, a clear evolution takes place over the course of the sample, from the dominance of ore in the 1970's and 80's, to the rise of unwrought products in the 1990's, and most recently to the rise of worked products. Remarkably, the upper envelope of panel (c) traces a clear progression up the value added chain illustrated in Figure 7. Just as pronounced in panel (d) is the rise of worked products to supplant unwrought copper as the dominant export; again, the upper envelope progresses along the value chain. Classifying the evolution of export specialization as either progress or regress depending on its direction in the value chain provides an intuitive measure of the exporters' upgrading success.

In order to gauge the direction and magnitude of trends in product specialization, the following regression is run for each of the three stages in the value chain:

$$\ln(RCA_{ikst}) = \alpha_0 + \alpha_i t + \sum_s \alpha_s[d_s] + \sum_k \alpha_k[d_k] + \varepsilon_{ikst} \tag{9}$$

where d_s and d_k are sector and country fixed effects, respectively. We can interpret the coefficient α_i as the annual percentage rate of specialization deepening within each stage in the value chain, where negative values denote de-specialization.

Sample selection for estimating (9) poses a subtle complication. Since RCA is a relative measure, within a sector each exporter's log changes in RCA add to zero *if* the time trend is being estimated over common products. If RCA trends are not a zero sum game, then it becomes difficult to interpret them as changes in specialization. Consider a country that exports ore and unwrought products in period $t-1$, and enters the worked product market in period t. Ceteris paribus, the non-zero RCA for worked products causes the ore and unwrought RCA measures to decrease; this decrease will be captured by (9), however, the fixed effects specification does not capture the increase in worked RCA from zero. In order to mitigate this problem of entry into export markets, the sample is constrained in two alternative ways. First, we consider only 'diversified' countries that export all three value stages in a given period. Second, we allow for countries to produce any number of products within each sector, but constrain the sample to only relatively frequently traded, 'balanced' products which are those that are traded at least 15 times over the 40 year sample.

Table 2 illustrates the resulting α_i coefficients for the diversified and balanced samples, pooling across all seven metal sectors. For the set of all countries in the diversified sample, there has been a marked decline in ore specialization over time at a rate of 2.2 percent per annum. To get a better understanding of the magnitudes of the declines in absolute terms, a decline of 0.022 per year over 40 years in ore products would move an economy from perfect symmetry across products (i.e., RCA=1) to roughly zero specialization in ore. The decline in ore is complemented by lesser increases in specialization in each of unwrought and worked products. Thus the overall trend is toward higher value added outputs, as in the pattern illustrated for Mexico and Brazil in Figure 9(c)-(d). Breaking this down be region, the same pattern is repeated for LAC, Africa and Asia, with significant declines in ore and varying degrees of increasing specialization in unwrought and worked products.[14] Overall, OECD countries showed a more tempered decline in ore specialization as well as a reversal of the global trend with a decline in unwrought specialization. Since the OECD lumps together many smaller and disparate participants in metal markets, the final row shows the trend for three of the largest OECD metal exporters: Australia, Canada and USA (herein ACU). Remarkably, the global trend is completely reversed with a 1.2 percent annual increase in ore RCA and 0.7 percent annual decreases in each of unwrought and worked products. One possible interpretation is that increasing specialization in downstream outputs by developing regions has come at the expense of the market share of incumbent North producers. The de-specializaton of LAC in ore together with an overall increase in LAC market share in Figure 2 supports this narrative. Alternatively, the increasing specialization in upstream outputs by North producers may have come at the expense of developing region ore share.

Since the concordance between trade data and the value chain is more complicated for iron and steel products,[15] Table 3 presents the analogous trend estimates for the other 6 metal sectors only. The global and regional patterns are preserved, with LAC, Africa, and Asia exhibiting downstream specialization and OECD countries exhibiting more moderate, upstream specialization. Of note is the heterogeneity in RCA trends across developing re-

[14] The imprecision of the LAC estimates for unwrought and worked may reflect either the small sample size due to the selection constraints or the use of the natural log as an approximation for percentage changes. For large changes in RCA, the log difference will be an underestimate of the percentage change; as such, the trend coefficients would be overestimates of the ore RCA decreases and underestimates of the unwrought/worked increases.

[15] The concordance is difficult due to the diversity of products and alloys in iron and steel production. The distinction between the second and third stages is blurred by the fact that scrap steel from the third stage is used as an input in the second stage. Moreover, the prevalence of copper, silicon, manganese and chromium as alloying agents complicates the inter-sector interaction in specialization patterns.

gions; there is a pronounced de-specialization in ore in LAC and a pronounced specialization in products in Africa.

Interpreting Downstream Specialization as Spill-overs

We now return to the question of the desirability of downstream specialization, and it is argued that for developing countries it is indeed advantageous. In several respects, the sequential upgrades to high value added products can be seen as an alternative characterization of growth. To be sure, several primary product categories have relatively high value and value-added, and export growth in those categories is not necessarily a bad thing. But, from an accounting perspective, access to relatively large, downstream markets is propitious. Categorizing world metal exports according to the scheme above, ores and concentrates represent the smallest category by value accounting for only 15.7 percent of the global market in 2004, compared to 21.2 percent for unwrought products and 63.0 for worked products. In terms of relative growth, the distribution of sales has stayed more or less constant since 1975 when ores accounted for 8.3 percent, unwrought products 20.1 percent and worked products 71.6 percent.

All else equal, producers should also prefer a more differentiated output due to their ability to charge consumers higher markups. In this dimension downstream products are also better. Using the U.S. import micro-data to compute transaction price variability within HS10 groups (as in Figure 4) and then aggregating within metal product categories, ores and concentrates have an average price dispersion of 39.8 percent compared to 78.1 percent for worked products.[16] This difference suggests that the variety characteristics within HS10 groups for semi-finished products are correspondingly diffuse. Moreover, the sheer number of HS10 groups for worked products relative to ores and unwrought is an indication of the broader product space at that level of processing.

The final claim regarding the desirability of downstream specialization is that higher value-added is a reflection of higher underlying technical capability. The results in Tables 2 and 3 paint a more complex picture of this claim since the 'advance' in developing country specialization patterns is juxtaposed on the 'regress' of rich metal exporters. A narrative

[16] The unwrought products have average price dispersion of 33.1 percent, comparable to ores.

consistent with that interpretation has to do with the nature and quality of the other production inputs. In a dynamic context, primary production can benefit from a high rate of technical change, discussed for the case of agriculture in the U.S. and Japan by Hayami and Ruttan (1970), among others. However, realization of those benefits may hinge on factors such as the R&D environment, the local stock of human capital in engineering, or strong international linkages to foreign know-how. As a result, increased specialization in low value ore in OECD countries may reflect the quality of ancillary inputs in mining and extraction. Factors such as these may also be driving the re-specialization in ore in Chile and Peru in Figures 9(a)-(b). Alternatively, countries with lower skill endowments may reach a certain threshold proficiency of output and can grow only by upgrading to downstream outputs. The results are suggestive that the nature of inter-product spill-overs is a function of both material and skill endowments.

Concentration Along the Value Chain

In addition to trend changes in specialization, the data on revealed comparative advantage by value chain segment allow us to analyze the mix of export product types by source country. Thus far we have had a particular model implication in mind, namely that spill-overs from the production of less sophisticated outputs stimulate increased specialization in more sophisticated outputs. However, both growth and trade models are either silent or highly stylized with respect to the optimal mix of products along the value chain; for instance, if it were possible, would it be desirable to divest entirely of production in ore? If not, to what extent would producers favor high value versus low value products in the long-run? These questions can be addressed empirically by examining the concentration of specialization for countries at different stages in development.

Concentration is measured as the standard deviation of RCA by country and sector. For example, in a given year copper exports from Brazil are divided among ore, unwrought and worked products. The standard deviation of RCA across these products types can be interpreted as the average percent deviation of a given RCA from the Brazil-copper-year mean, with higher dispersion indicating heavy concentration on some segment of the value chain and low concentration on others. In Figure 10, the variance measures are aggregated across countries and sectors within each region, weighted by annual export sales. In terms of the levels of dispersion/concentration, the benchmark group of developed, resource-rich countries composed of Australia, Canada and the U.S. has the lowest, followed by the broader OECD group, LAC, Asia and Africa. Notably, developing regions have dispersion of roughly twice that of the OECD countries, indicating that richer countries, particularly resource abundant ones, tend to balance their production across value-added categories to a greater extent. The time series of this measure reveals that much of the action in terms of changes in concentration over the value chain is taking place in developing regions. Africa and Asia exhibit sustained, moderate decreases in concentration (i.e., decreases in dispersion) since 1975, while LAC had a precipitous decrease in concentration in the 1980's dropping and remaining near the level of OECD countries thereafter. The OECD group had little change over the period. Overall, these patterns are suggestive that there exists some stable optimal distribution of production across product categories that is relatively balanced. Over the past 30 years developing regions have moved progressively away from high concentration, presumably in ores and concentrates, and towards the allocation of richer countries.

5 Decomposing LAC Market Share Growth

In this section, estimates of intra-product upgrades and the breakdown of the metal value chain are applied to distinguish upgrading from other sources of market share growth. Figure 11 illustrates the overall growth of LAC share in global metal exports between 1975 and 2004. LAC market share increased by 175% over these years at an annual compound growth rate of 1.9 percent.[17] Decomposing this increase in share by the stages of the metal production process shows that the overwhelming majority of share growth occurred in the intermediate and high value-added categories. The share of both ore and unwrought products to overall share roughly doubled over the 30 year period while worked product share increased by 8-fold. The contribution of these growth rates to overall share growth is likewise skewed toward the high end of the value chain; ore represented 25 percent of share growth, unwrought products represented 33 percent and worked products represented 41 percent. Consistent with the

[17] Figure 2 illustrates overall share growth of 212% between 1975 and 2004, an annual growth rate of 2.5 percent over the past 30 years. SITC codes 2815 and 2816 for iron ore and concentrates were first introduced in 1984. In order to make a more balanced comparison of market share over time these products are excluded. Given this modification to the data, LAC metal exports rose 175% to 10.8 percent over the period 1975-2004.

RCA estimates of the previous section, 75 percent of LAC share growth took place on the intermediate and advanced segments of the value chain. Those segments accounted for 5.1 percent in overall share growth, equivalent to 20 billion dollars in additional export sales.

Given the estimates of the price and quality elasticities of market share above, LAC metal share growth can be broken down further by the amount attributable to upgraded new varieties within products. In Table 1, the estimated sensitivity of market share to new product quality was positive and significant, with an elasticity of $\widehat{\alpha}_3 = 1.83$. Together with the observed substantial increase in LAC metal share over the past 30 years, this suggests a large increase in the relative quality of new varieties exported from LAC. A prediction of the fraction of share growth due to increased relative quality is formulated as follows:

$$\Delta \ln \widehat{share}_{kj} = \widehat{\alpha}_3(\sigma_j - 1) \ln \left(\frac{Z_{kjt}}{Z_{jt}}\right)^N \tag{10}$$

$$\frac{\Delta \ln \widehat{share}_{kj}}{\Delta \ln share_{kj}} = \frac{\widehat{\alpha}_3(\sigma_j - 1) \ln \left(\frac{P_{kjt}}{P_{jt}}\right)^N}{\Delta \ln share_{kj} * \Delta \ln \left(\frac{Q_{kj}}{Q_j}\right)^E} \tag{11}$$

where $\Delta \ln \widehat{share}_{kj}$ is the percentage change in LAC metal share (in US imports) due to export quality relative to the actual total share increase $\Delta \ln share_{kj}$, and where (11) employs the definition of quality-adjusted price to cast quality in terms of observed price changes. The predicted share increase is computed for approximately 200 HS4-country pairs. The mean value for these predictions is 0.47, implying that about one half of share growth is attributable to upgrades. Applying the value chain classifications, the fraction of ore growth due to upgrades is 0.5, and that of unwrought and worked products is 0.64 and 0.43, respectively. As an illustration of the scale of these share increases, Figure 10 divides growth within the each stage of the value chain into intra-product quality changes, marked with hatched shading, and other changes. Since 1975, the quality changes have cumulated to approximately 3.5 percent of global share, equivalent to \$14 billion dollars (one third) of LAC metal exports.

It would be desirable to conflate the measures of intra- and inter-product upgrading into a single estimate of share growth due to quality change. However, without some prior belief about the nature of each type of upgrading it is not possible to separately identify their contributions to growth. Nor is the distinction as clear cut as that of the extensive margin (i.e., expansion in the number of products) versus the intensive margin (i.e., intra-product growth); after the initial period of extensive margin growth it is difficult to discern market penetration in existing varieties from the development of new ones. With some additional information about the other inputs in production, such a distinction may indeed be feasible. For example, if the development of a new variety uses R&D inputs intensively and the development of a new product uses physical capital inputs intensively, then input usage and endowments could potentially provide valuable clues to that end. However, absent clear priors a more robust decomposition method remains dubious.

6 Conclusions

The overall objective of this paper is take an empirical view of the question: Have resource-rich countries captured the rents associated with new and better traded varieties? If so, it would present a significant mitigating factor to common arguments citing the existence of a resource curse. To explore this question, I have focussed on metal exports from LAC and use very disaggregate international trade data to measure the degree of differentiation and upgrading in that sector.

First, the significant potential for upgrading in certain non-branded bulk goods is established by documenting that large metal industries often consist of highly differentiated varieties. In many cases, metals have differentiation profiles similar to what we would observe for industrial or technology products. We then turn our attention to the important question of whether this fact has been exploited to further export growth. That is, in addition to being the benign beneficiaries of foreign innovations, have LAC exporters captured the rents associated with being the progenitors of new and better varieties? Operating in the background is a model like that presented in Aghion and Howitt (1992, 1996) in which output has an array of quality levels and R&D successes spill over into other sectors; I search for evidence of upgrading along the quality ladder at the product level and for linkages of export success across related downstream products.

The findings are encouraging. Within export products, relatively high export prices for new varieties correlate positively with increases in market share, which suggests an increase in the relative quality of those varieties. The estimated elasticity of market share with respect to export quality is found to be twice as large as the quality-adjusted price elasticity and, given that estimate for U.S. imports, changes in variety quality accounted for roughly half of the market share growth of LAC exports. Across products, exploiting a novel concordance of trade data to the value chain in metals, the long term trends for LAC exporters are away from low-value ores and concentrates and towards intermediate and finished levels of processing. Three quarters of LAC market share growth over the past 30 years has been in downstream output markets. One could interpret these trends as a significant decline in the average exporter's reliance on ore and low-value products, and as offsetting to some extent the diminishing specialization of richer countries along higher segments of the value chain.

Given the large share of non-metal commodities in the region's trade, and to the extent that non-metal commodities are also differentiated products, the results suggest potentially even larger benefits accruing to developing countries due to upgrading. Although the differentiation of other commodities is smaller in relative terms (e.g., mineral products, dominated by oil, is by all accounts the most homogeneous sector and accounts for 40 percent of LAC exports), other products such as foodstuffs, wood, stone and glass have both significant relative measures of differentiation and sizable export shares.

Finally, the empirical findings above are left wanting of a uniform framework to describe the dynamics of commodity-driven growth. Extensions of the quality ladder model are capable enough of describing the rise in share of LAC and other regions due to upgrading and the incentives to produce downstream products. However, in that light the re-specialization of wealthy, resource-rich countries in upstream products is puzzling. Anecdotal evidence of high-skill service providers emerging in the North to serve mining and extraction industries adds texture to the story of countries' march up the quality ladder by incorporating the quality of inputs as determinants of specialization patterns. A richer framework of that sort would not only provide a rationale for sustained growth due to primary goods, but would describe a rewarding legacy for an economy's set of depleting assets.

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	Industry				
	Metals	Electric & Machinery	Textiles & Apparel	Chemicals & Plastics	Foods, Animals & Wood
Quality-Adjusted Price	-0.87 **	-1.21 **	-1.62 **	-1.86 ***	-1.12 **
	(0.40)	(0.50)	(0.69)	(0.50)	(0.55)
New Good Relative Price					
LAC	0.97 **	-0.21	2.53 ***	1.53 ***	0.72
	(0.51)	(0.44)	(0.69)	(0.41)	(0.57)
OECD	0.02	-0.73 ***	-0.16	0.29 **	0.10
	(0.25)	(0.16)	(0.25)	(0.14)	(0.40)
East Asia	-0.55 *	0.40	-2.91 ***	-1.54 ***	0.05
	(0.35)	(0.32)	(0.75)	(0.32)	(0.82)
Implied Quality Elasticity					
LAC	1.83 ***	1.00	4.15 ***	3.39 ***	1.83 **
	(0.65)	(0.64)	(0.92)	(0.62)	(0.79)
OECD	0.89 *	0.48	1.46 **	2.15 ***	1.21 *
	(0.49)	(0.54)	(0.76)	(0.53)	(0.67)
East Asia	0.32	1.61 **	-1.29	0.32	1.17
	(0.53)	(0.64)	(1.02)	(0.62)	(1.05)
Observations	1,673	4,520	2,026	2,908	1,369

Table 1: The elasticity of market share to price and quality

Notes: Shown are OLS coefficients for the regression of country-HS4 market share long-differences on quality-adjusted and new good relative price changes. The quality-adjusted series are based on IPP locality of origin price indexes, and the new good relative prices are the relative price levels of items entering into the IPP sample. The implied quality elasticity is the linear combination of the new good relative price and the (negative) quality-adjusted price elasticity. Stars denote: * p<.1, ** p<.05, *** p<.01.

	Diversified Exports			Balanced Exports		
	Ore	Unwrought	Worked	Ore	Unwrought	Worked
All Countries	-0.022 ***	0.002 *	0.008 ***	-0.016 ***	0.004 ***	-0.002 **
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
R^2	0.30	0.27	0.46	0.42	0.2	0.32
Obs	8,997	8,997	8,997	10,014	14,202	16,168
LAC	-0.02 ***	0.000	0.005	-0.007 *	0.006 *	-0.011 ***
	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)
R^2	0.3	0.3	0.45	0.31	0.13	0.28
Obs	916	916	916	1,475	1,590	2,315
Africa	-0.023 ***	0.004	0.027 ***	-0.01 ***	0.009 ***	0.007 **
	(0.007)	(0.005)	(0.006)	(0.004)	(0.003)	(0.003)
R^2	0.45	0.48	0.45	0.49	0.28	0.35
Obs	590	590	590	1,237	1,505	1,859
Asia	-0.049 ***	0.028 ***	0.019 ***	-0.049 ***	0.019 ***	-0.004
	(0.005)	(0.005)	(0.004)	(0.005)	(0.003)	(0.003)
R^2	0.35	0.14	0.35	0.36	0.18	0.24
Obs	1,284	1,284	1,284	1,339	2,262	2,581
OECD	-0.011 ***	-0.005 ***	0.001	-0.007 ***	-0.006 ***	-0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
R^2	0.31	0.29	0.41	0.34	0.23	0.37
Obs	4,910	4,910	4,910	4,805	6,516	6,603
AU/CA/US	0.012 ***	-0.007 ***	-0.007 ***	0.012 ***	-0.007 ***	-0.006 **
	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)	(0.003)
R^2	0.29	0.25	0.63	0.29	0.24	0.6
Obs	821	821	821	824	840	837

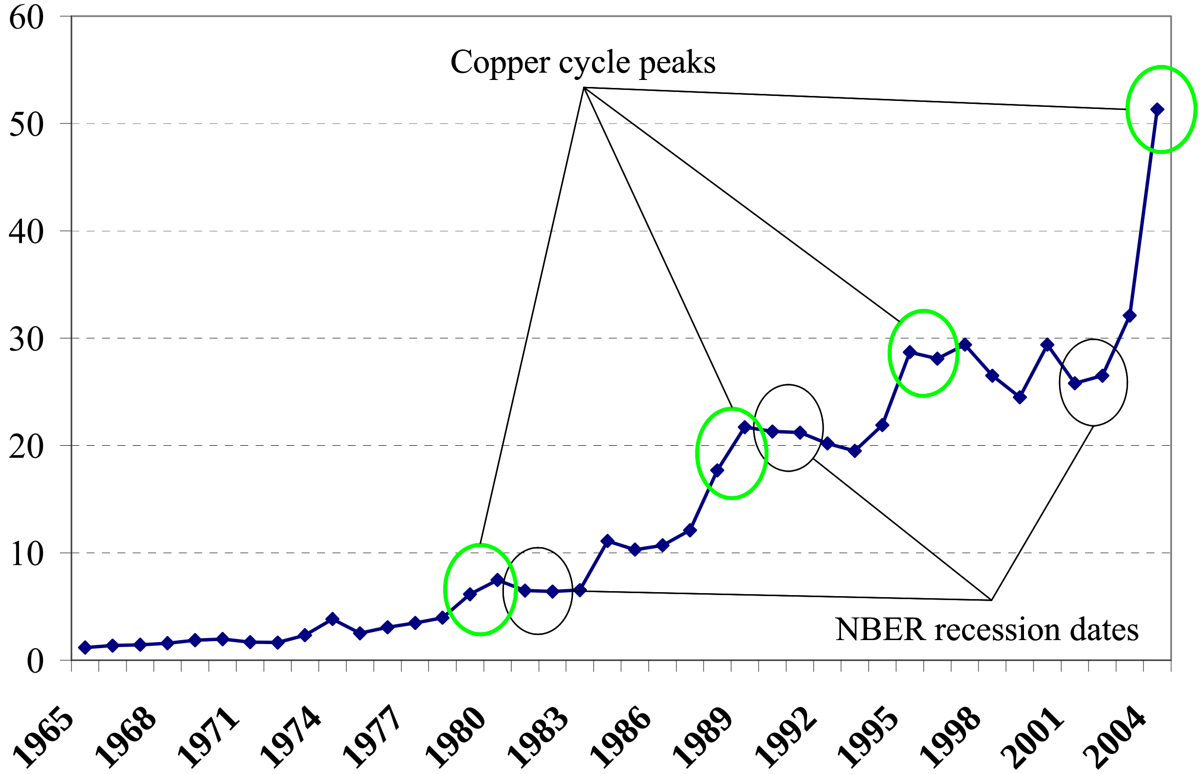
Table 2: Global and regional trends in revealed comparative advantage.

Notes: Shown are time trend coefficients for revealed comparative advantage measures in 7 metal sectors over the period 1965-2004. Regional trend measures and those at different stages along the value added chain are estimated separately. The estimation pools across seven metal sectors: aluminum, copper, iron, lead, nickel, tin and zinc. Included but not shown are sector and country fixed effects. Stars denote: * p<.1, ** p<.05, *** p<.01.

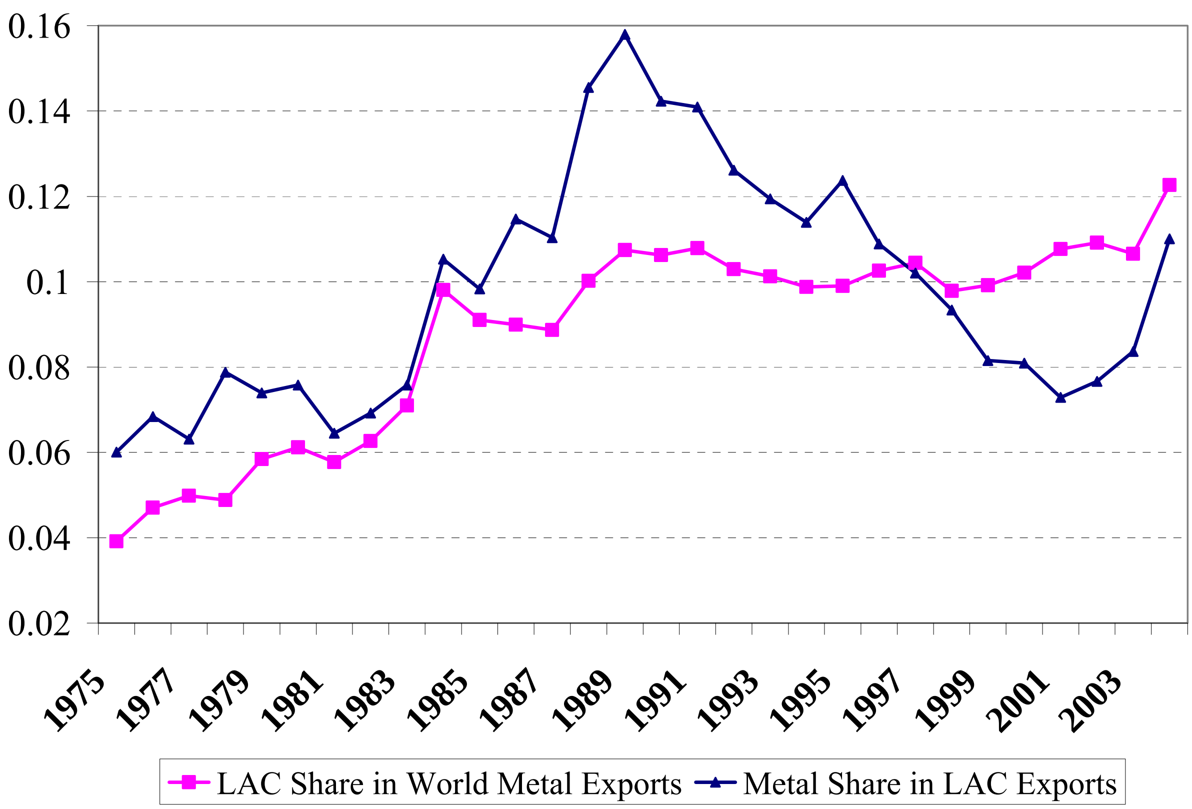
	Diversified Exports			Balanced Exports		
	Ore	Unwrought	Worked	Ore	Unwrought	Worked
All Countries	-0.011 ***	0.008 ***	0.008 ***	-0.002	0.007 ***	0.005 ***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
R^2	0.33	0.30	0.52	0.44	0.25	0.46
Obs	6,711	6,711	6,711	5,535	9,250	8,836
LAC	-0.020 ***	0.006	0.007	0.001	0.008 *	-0.004
	(0.006)	(0.005)	(0.005)	(0.003)	(0.004)	(0.005)
R^2	0.25	0.34	0.42	0.36	0.14	0.5
Obs	660	660	660	758	833	785
Africa	0.001	0.009	0.029 ***	0.008 *	0.007 **	0.032 ***
	(0.007)	(0.005)	(0.007)	(0.004)	(0.003)	(0.006)
R^2	0.56	0.46	0.41	0.62	0.27	0.52
Obs	446	446	446	738	883	559
Asia	-0.051 ***	0.038 ***	0.022 ***	-0.046 ***	0.026 ***	-0.007 **
	(0.006)	(0.005)	(0.005)	(0.006)	(0.003)	(0.004)
R^2	0.29	0.21	0.42	0.36	0.24	0.37
Obs	908	908	908	666	1,592	1,734
OECD	0.001	0.001	0.000	0.009 ***	-0.002	-0.002 *
	(0.003)	(0.001)	(0.002)	(0.003)	(0.001)	(0.001)
R^2	0.34	0.35	0.46	0.42	0.29	0.43
Obs	3,907	3,907	3,907	3,464	5,199	5,117
AU/CA/US	0.013 ***	-0.004	-0.006 **	0.013 ***	-0.004	-0.005 *
	(0.004)	(0.002)	(0.003)	(0.004)	(0.002)	(0.003)
R^2	0.24	0.27	0.68	0.24	0.25	0.65
Obs	701	701	701	704	720	717

Table 3: Global and regional trends in revealed comparative advantage (excl. iron).

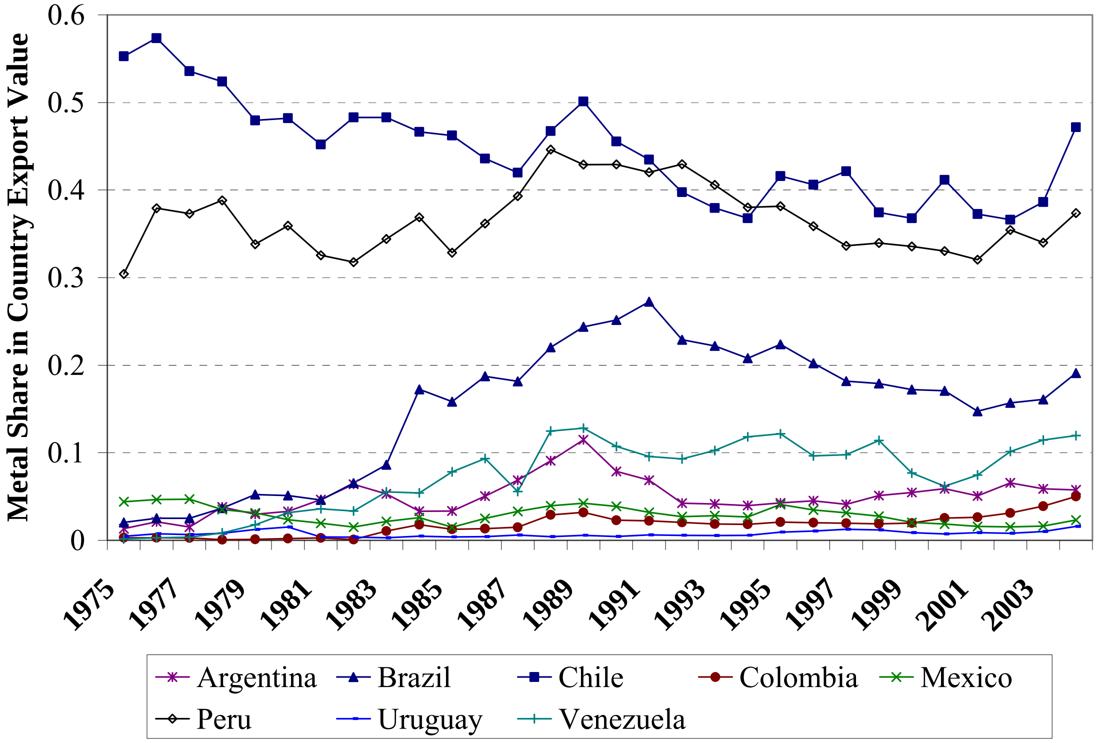
Notes: Shown are time trend coefficients for revealed comparative advantage measures in 6 metal sectors over the period 1965-2004. Regional trend measures and those at different stages along the value added chain are estimated separately. The estimation pools across seven metal sectors: aluminum, copper, lead, nickel, tin and zinc. Included but not shown are sector and country fixed effects. Stars denote: * p<.1, ** p<.05, *** p<.01.



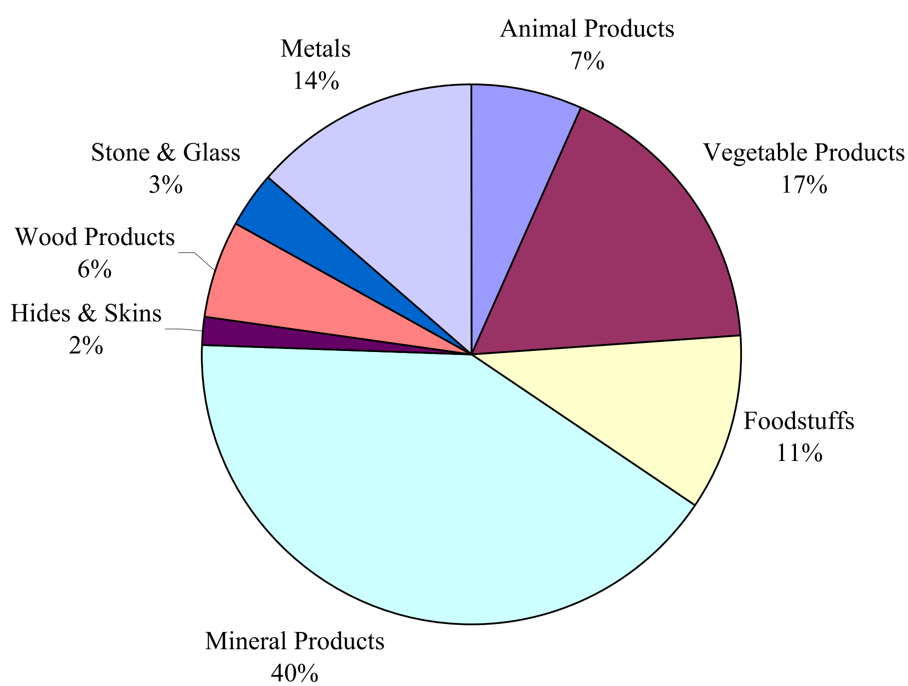
<u>Figure 1</u>: LAC metal export sales volume (1965-2004)



<u>Figure 2</u>: LAC metal share of world metal exports and LAC total exports (1975-2004)



<u>Figure 3A</u>: Metal share of total exports, by country (1975-2004)



<u>Figure 3B</u>: Metal share of total LAC commodity exports (2000)

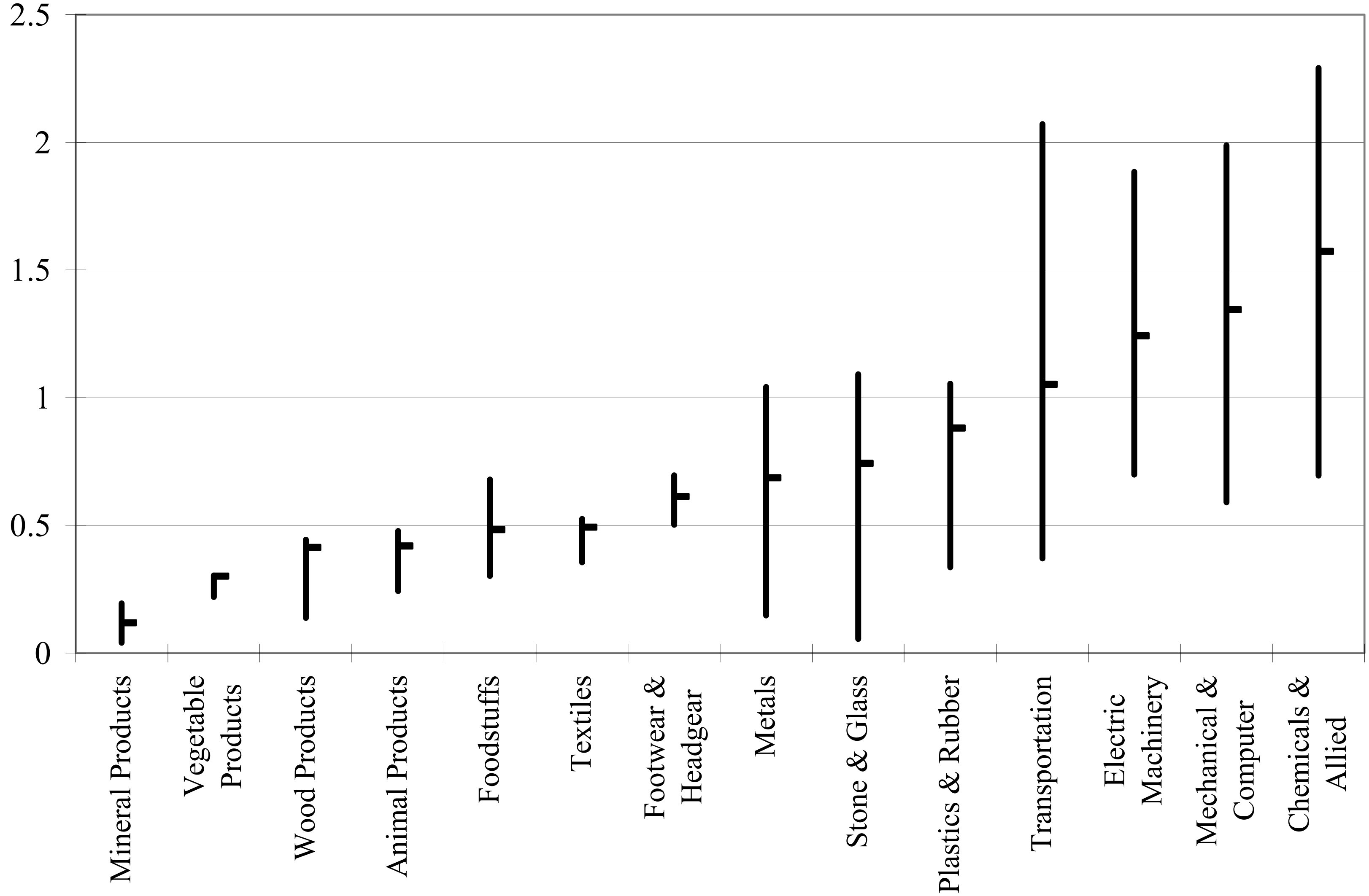


Figure 4: Intra-product price dispersion in U.S. imports[16]

[16] Shown by sector are the sales-weighted mean (hatch) and interquartile range (line) of the standard deviation of log price levels within HS10 products.

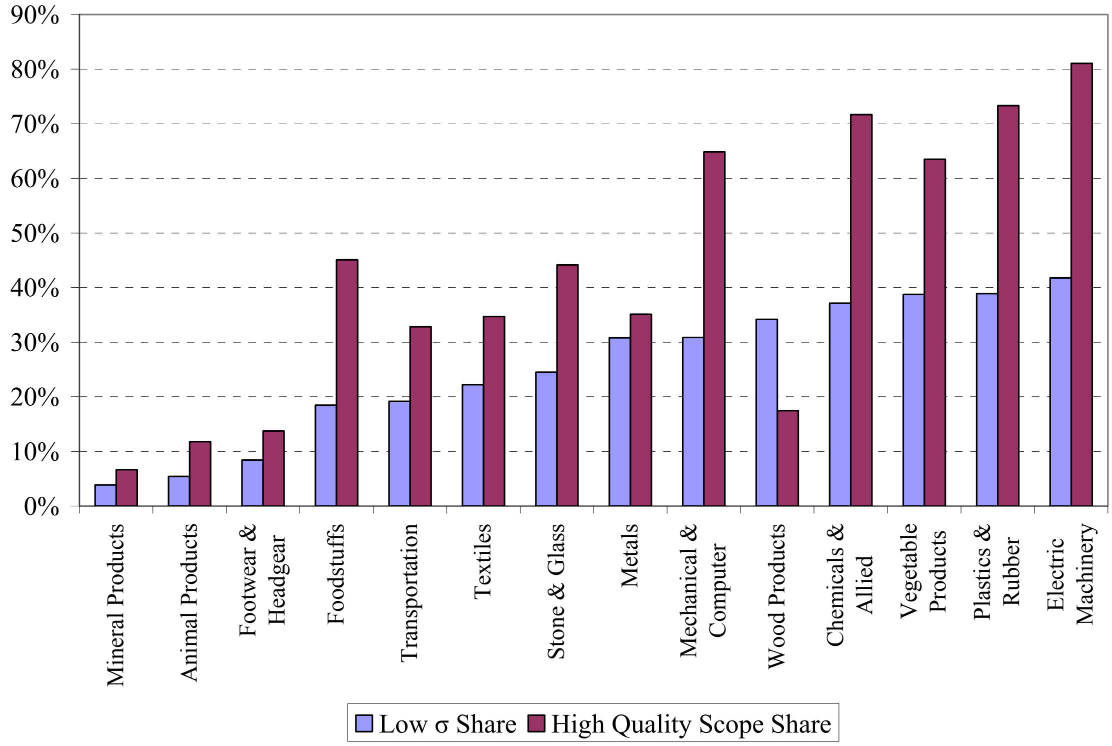


Figure 5: Measures of product differentiation in U.S. imports[17]

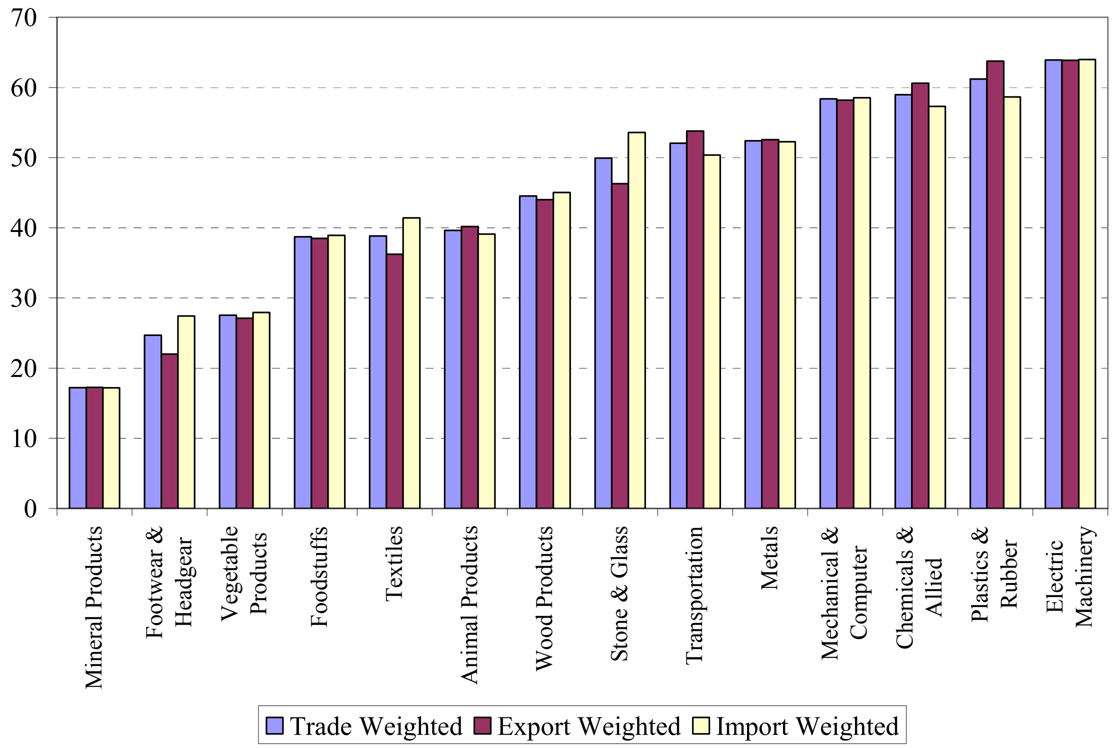
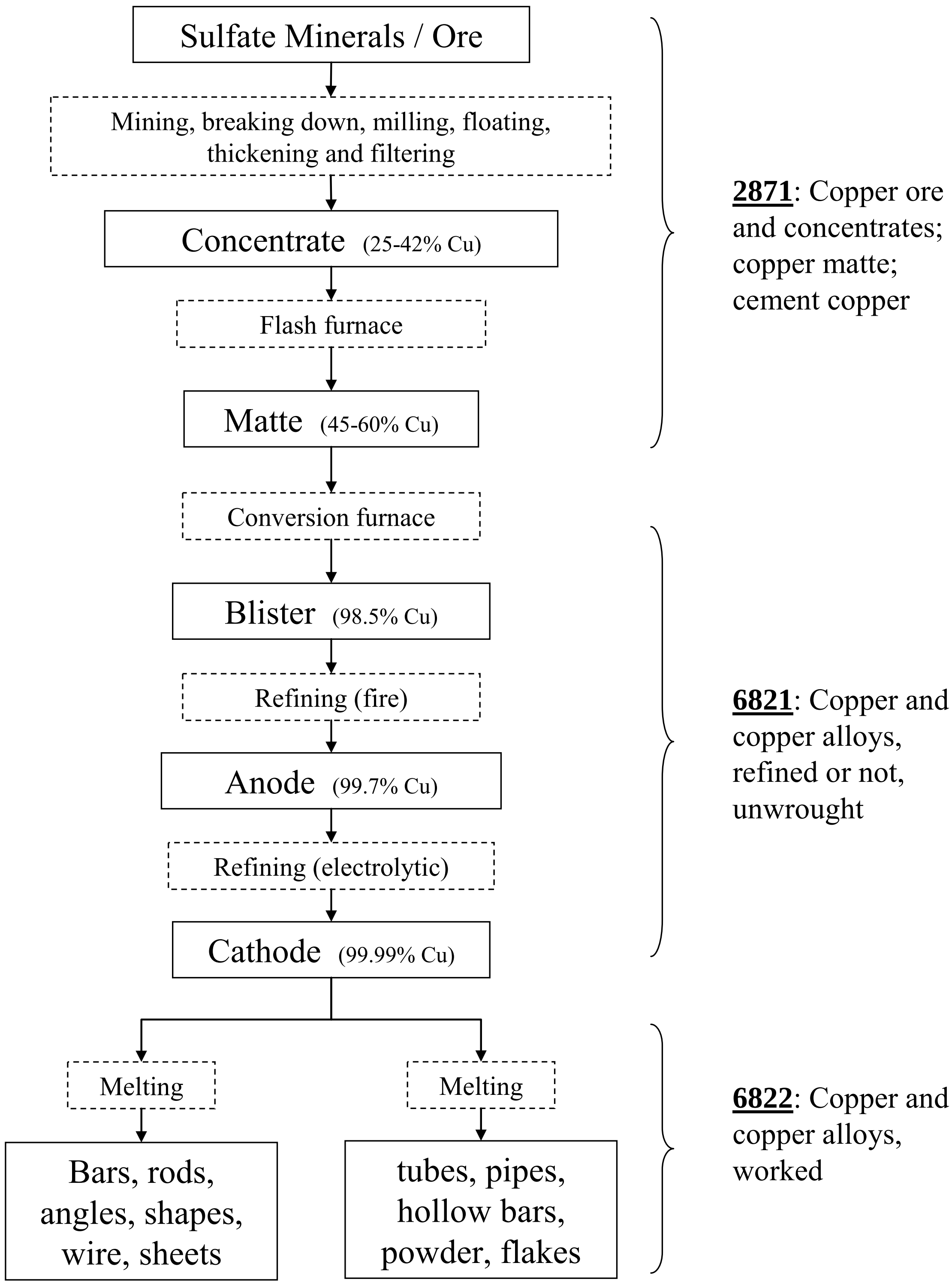
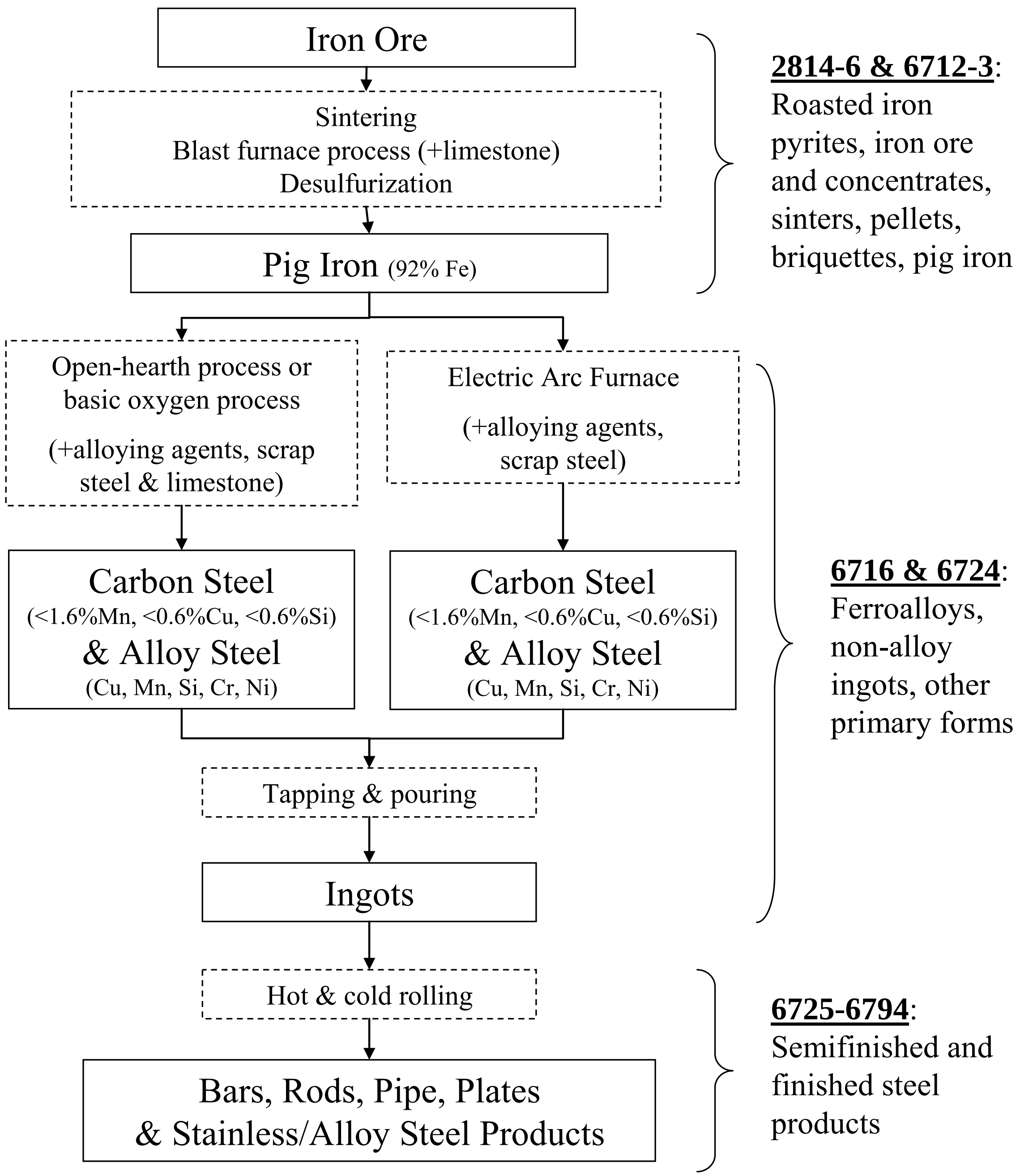


Figure 6: An index of intra-industry trade by sector[18]

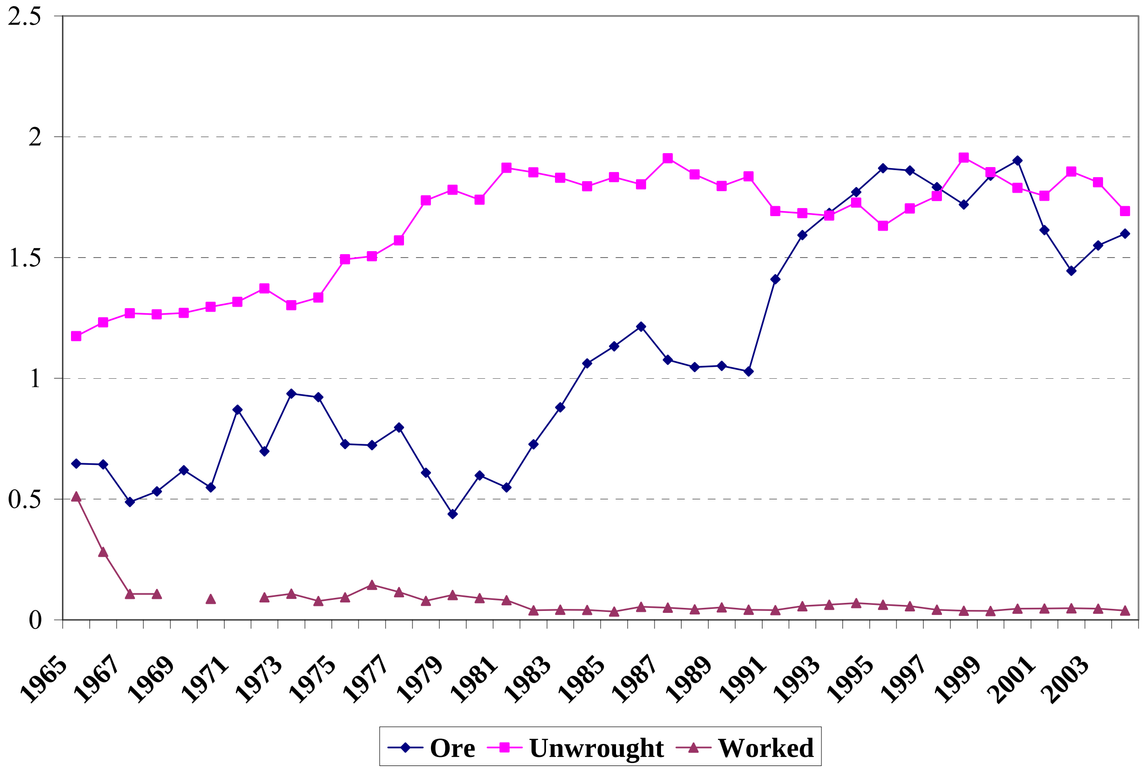
[17] Shown for each sector is the 2005 sales share of imports with either low elasticity of substitution (σ) or high scope for quality differentiation, where low and high are discerned by the median overall parameter value.
[18] Shown is the value of IIT in 2000, aggregated across SITC 4-digit codes and 180 countries.



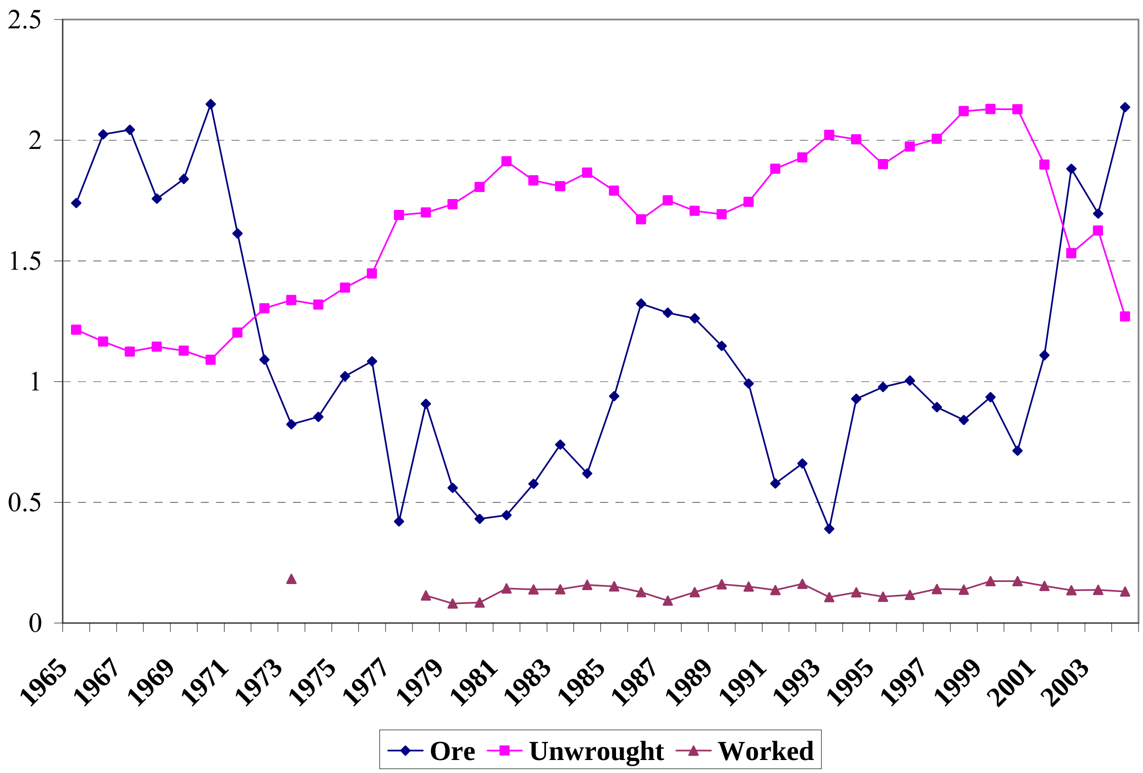
<u>Figure 7</u>: The sequential stages of pyrometallurgical copper processing and corresponding SITC commodity codes and descriptions



<u>Figure 8</u>: The sequential stages of iron and steel production with corresponding SITC commodity codes and descriptions

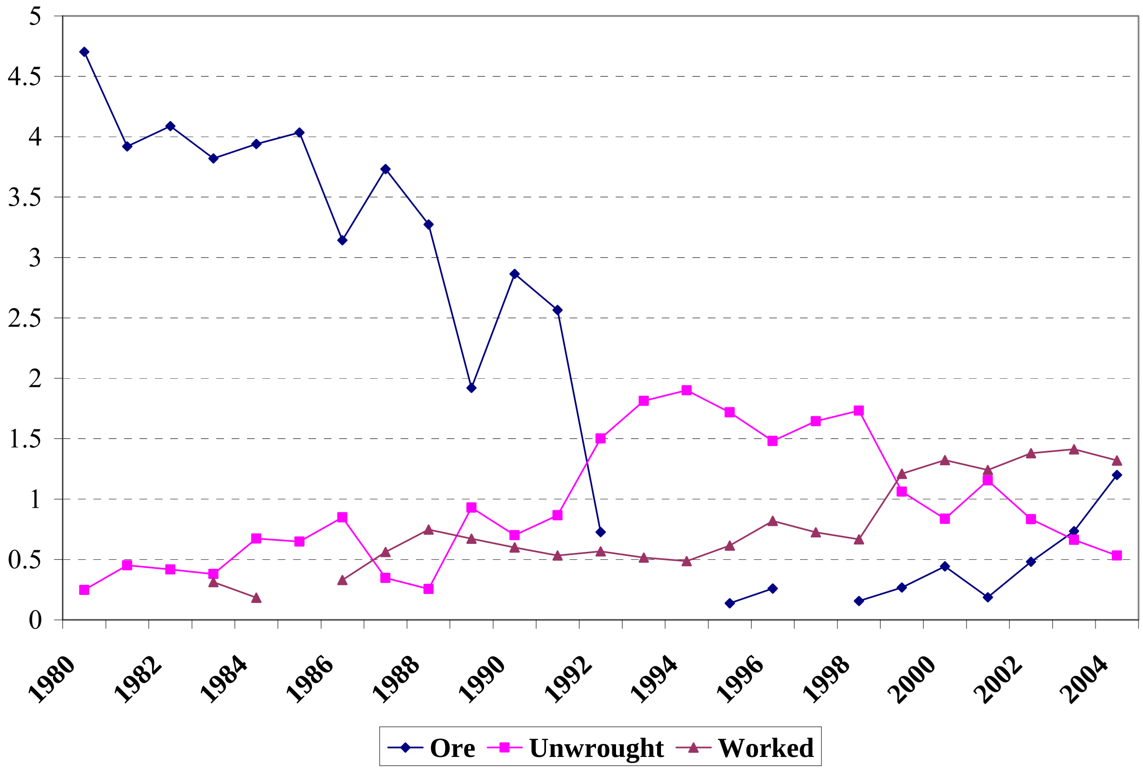


(a) Chile

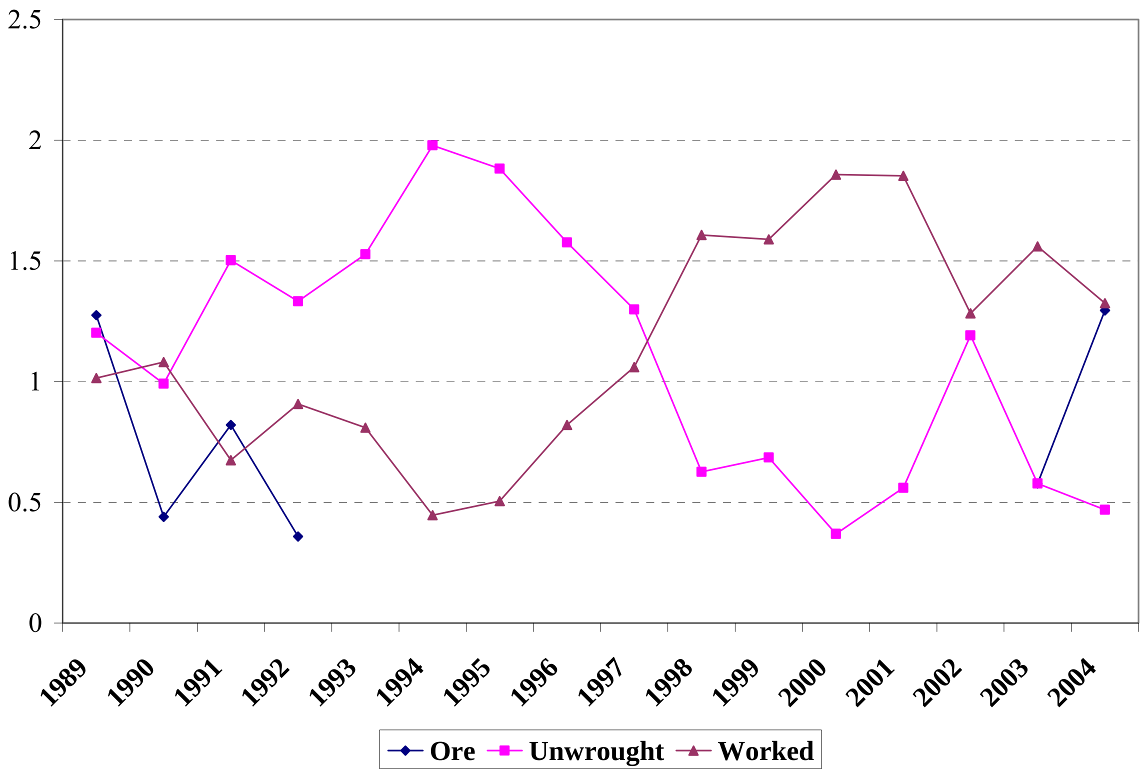


(b) Peru

<u>Figure 9</u>: Revealed comparative advantage for large Latin American copper exporters

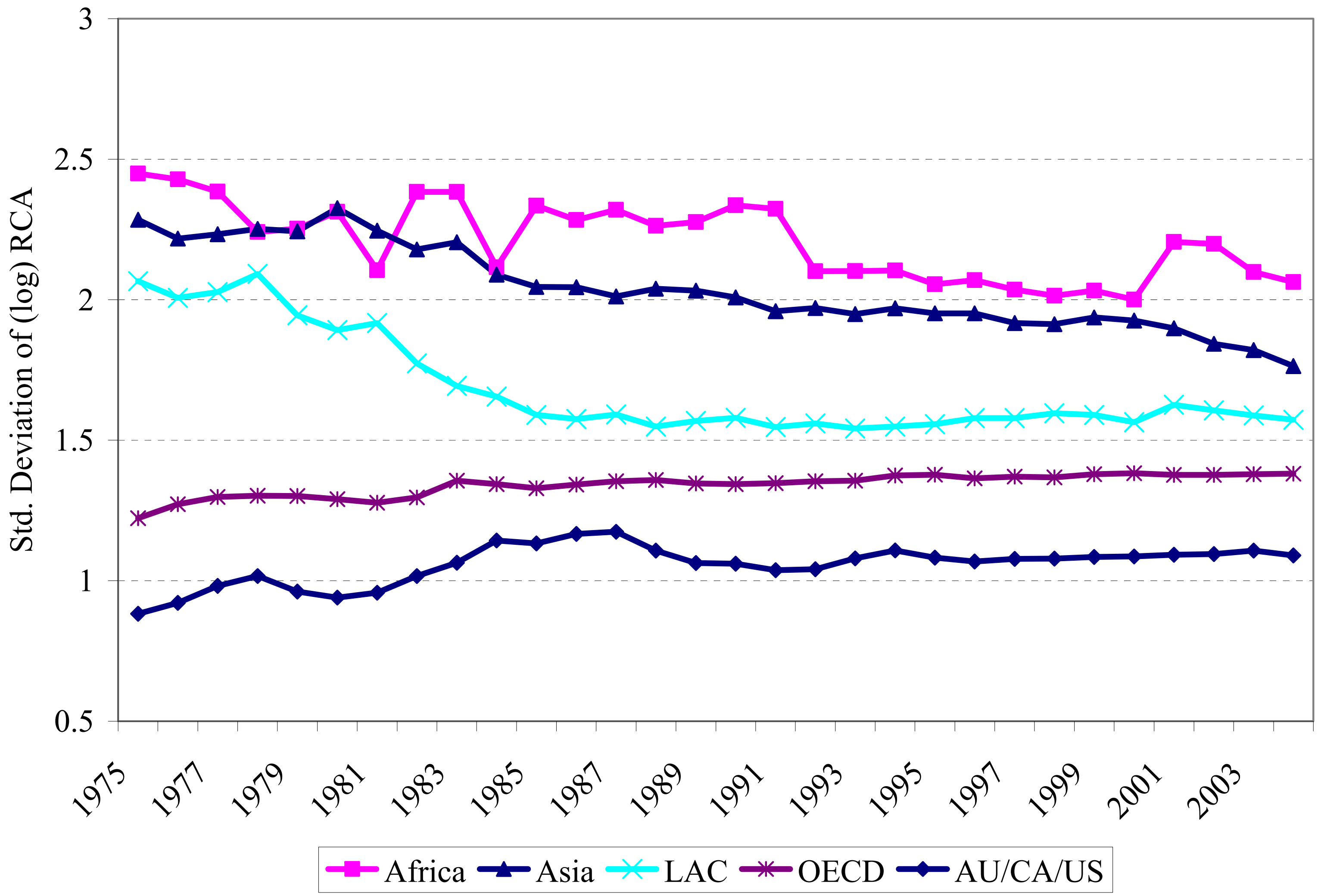


(c) Mexico



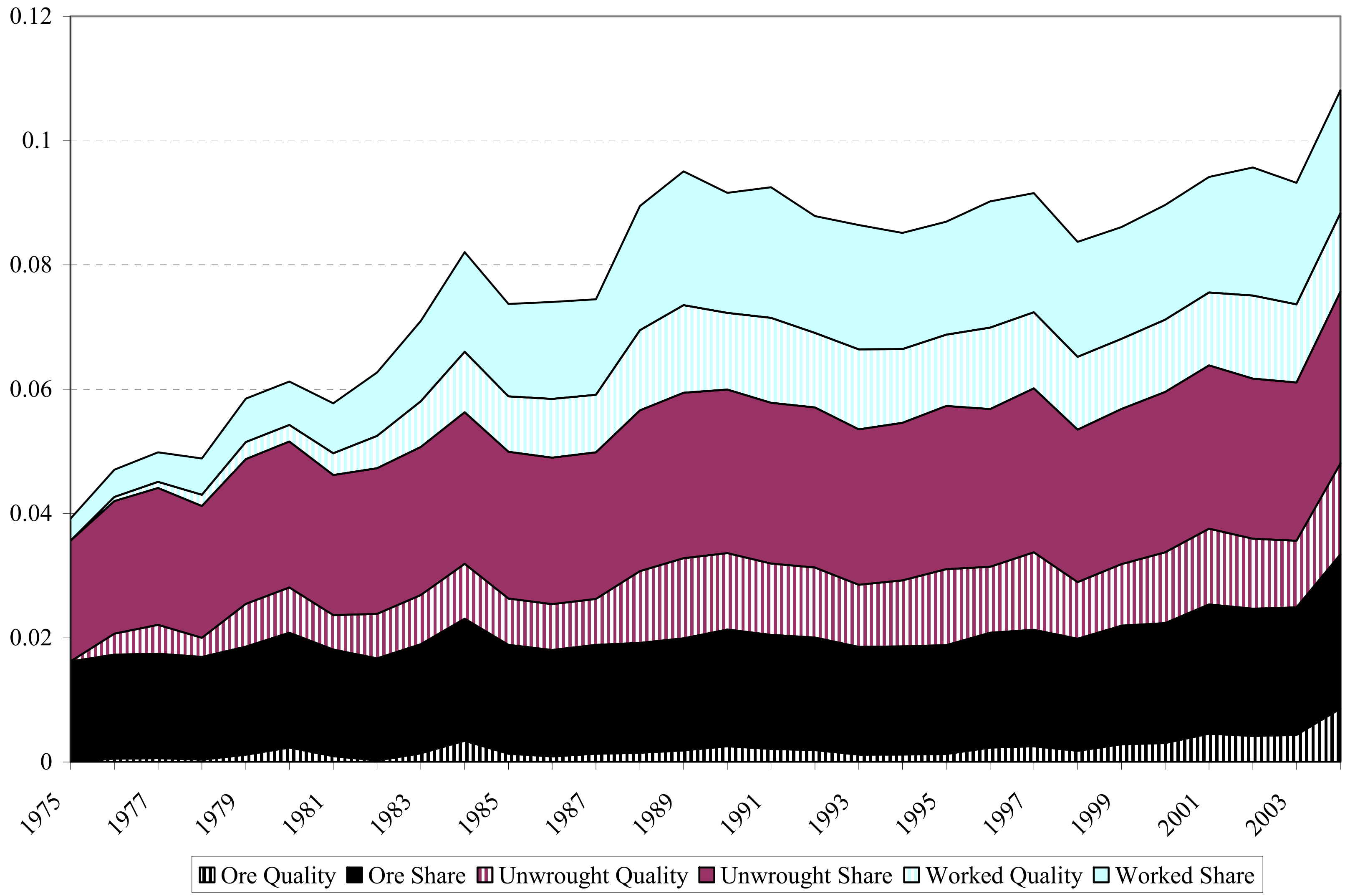
(d) Brazil

<u>Figure 9</u>: Revealed comparative advantage for large Latin American copper exporters



<u>Figure 10</u>: The dispersion of RCA measures across value added categories[4]

[4] Shown for each country group are annual measures of the standard deviation of ln(RCA) across ore, unwrought and worked products within country-sector pairs.



<u>Figure 11</u>: LAC metal market share along the value chain and share growth due to intra-product upgrades

Appendix

<u>List of LAC countries</u>

Antigua, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguilla, St. Lucia, St. Vincent, Suriname, Trinidad & Tobago, Turks And Calicos Islands, Uruguay, US Virgin Islands, Venezuela.

<u>Metal Commodity Classifications in the NBER-UN Trade Flows Data</u>

<u>Aluminum SITC rev.2 4-digit categories</u>

1. 2873: Aluminium ores and concentrates (including alumina)
   a. 28731 Aluminium ore and concentrate
   b. 28732 Alumina (aluminium oxide)
2. 6841 Aluminium and aluminium alloys, unwrought
3. 6842 Aluminium and aluminium alloys, worked
   a. 68421 Aluminium bars, rods, angles, shapes, etc, wrought; wire
   b. 68422 Aluminium plates, sheets and strips, wrought
   c. 68423 Aluminium foil, of a thickness not exceeding 0.20 mm
   d. 68424 Aluminium powders and flakes
   e. 68425 Aluminium tubes, pipes and blanks; hollow bars of aluminium
   f. 68426 Aluminium tubes and pipes fittings

<u>Copper SITC rev.2 4-digit categories</u>

1. 2871: Copper ore and concentrates; copper matte; cement copper
2. 6821: Copper and copper alloys, refined or not, unwrought
   a. 68211 Unrefined copper (blister copper but excluding cement copper)
   b. 68212 Refined copper, (including alloys except master alloys), unwrought
   c. 68213 Master alloy of copper
3. 6822: Copper and copper alloys, worked
   a. 68221 Copper bars, rods, angles, shapes, sections, wrought; copper wire
   b. 68222 Copper plates, sheets and strips, wrought
   c. 68223 Copper foil not exceeding 0.15 mm
   d. 68224 Copper powders and flakes
   e. 68225 Copper tubes, pipes, and blanks thereof; hollow bars of cooper
   f. 68226 Copper tubes and pipes fittings

<u>Lead SITC rev.2 4-digit categories</u>

1. 2874 Lead ores and concentrates
2. 6851 Name: Lead, and lead alloys, unwrought
3. 6852 Name: Lead and lead alloys, worked

<u>Nickel SITC rev.2 4-digit categories</u>

1. 2872 Nickel ores and concentrates; nickel mattes, etc

   a. 28721 Nickel ores and concentrates
   b. 28722 Nickel matte, sinters, etc
2. 6831 Nickel and nickel alloys, unwrought
3. 6832 Nickel and nickel alloys, worked
   a. 68321 Nickel bars, rods, angles, shapes, sections, wrought; nickel wire
   b. 68322 Nickel sheet, plates, strip, wrought; nickel foil, powders, flakes
   c. 68323 Nickel tube, pipe, blanks; hollow bars; tube and pipe fittings
   d. 68324 Electro-plating anodes, of nickel

<u>Tin SITC rev.2 4-digit categories</u>

1. 2876 Lead ores and concentrates
2. 6871 Tin and tin alloys, unwrought
3. 6872 Tin and tin alloys worked

<u>Zinc SITC rev.2 4-digit categories</u>

1. 2875 Lead ores and concentrates
2. 6861 Zinc and zinc alloys, unwrought
3. 6863 Zinc and zinc alloys worked

<u>Iron SITC rev.2 4-digit categories</u>

1. 2814 Roasted iron pyrites
2. 2815 Iron ore and concentrates, not agglomerated
3. 2816 Iron ore agglomerates
4. 6712 Pig iron, cast iron, spiegeleisen, in pigs, blocks, lumps, etc
5. 6713 Iron and steel powders, shot or sponge
6. 6716 Ferro-alloys
7. 6724 Puddled bars, pilings; ingots, blocks, lumps, etc, of iron or steel
8. 6725 Blooms, billets, slabs and sheet bars, of iron or steel
9. 6727 Iron or steel coils for re-rolling
10. 6731 Wire rod of iron or steel
11. 6732 Bars, rods (not wire rod), from iron or steel; hollow mining drill
12. 6733 Angles, shapes, sections and sheet piling, of iron or steel
13. 6741 Universal plates of iron or steel
14. 6744 Sheet, plates, rolled of thickness 4,75mm plus, of iron or steel
15. 6745 Sheet, plates, rolled of thickness 3mm to 4,75mm, of iron or steel
16. 6746 Sheet, plates, rolled of thickness less 3mm, of iron or steel
17. 6747 Tinned sheets, plates of steel (not of high carbon or alloy steel)
18. 6749 Other sheet and plates, of iron or steel, worked
19. 6750 Hoop and strip of iron or steel, hot-rolled or cold-rolled
20. 6760 Rails and railway track construction materials, of iron or steel
21. 6770 Iron or steel wire (excluding wire rod), not insulated
22. 6781 Tubes and pipes, of cast iron
23. 6782 Seamless tubes, pipes; blanks for tubes and pipes, of iron or steel
24. 6783 Other tubes and pipes, of iron or steel
25. 6784 High-pressure hydro-electric conduit of steel
26. 6785 Tube and pipes fittings, of iron or steel
27. 6793 Steel and iron forging and stampings, in the rough state
28. 6794 Castings of iron or steel, in rough state