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The 'Sophistication' of Exports: A New Measure of Product Characteristics

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1. Introduction

Economists classify products by various characteristics to apply and test theories of trade, location, industrial structure, foreign investment and so on. In trade theory, for instance, tests of Heckscher-Ohlin theories involve grouping products by factor content (capital or skill intensity) and relating countries' trade patterns to their possession of these factors. Location models in economic geography focus on features like weight, transportability and linkage intensity to assess where products will be produced and if they will be traded.[1] Theories of trade fragmentation, analyzing 'vertically specialized' trade (subdivision of processes for a given product across countries to exploit differences in wages, logistics and other costs) use such characteristics as process divisibility and weight-to-value ratios.[2] Analyses of technical change, and accompanying applications to industrial structure and performance, distinguish products by technology intensity (research and development spending, use of scientists and engineers or patenting). FDI theory uses firm-specific assets like technology or brand names to explain the propensity of industries to engage in direct investment. And so on: empirical economics relies heavily on product classification.

Product characteristics are also very useful for development analysis. As development entails structural change (a shift of production towards greater capital, skill and technology intensity), it is important to analyze and trace changes in the production, trade, industrial and other structures, both within and across countries. With liberalization and globalization, the pattern and evolution of exports is attracting greater interest in developing countries. Primary products are steadily losing their shares of world trade, and within manufactures, technology-intensive products are growing faster than others (Lall, 2000). In addition, it is widely believed that technology-intensive exports imply greater development benefits to exporting countries: they often (though not always, see below) reflect higher skill and technical endowments in those countries and they imply more rapid transfer and diffusion of new technology. There is therefore considerable interest in analyzing the technological structure of exports in developing as well as developed countries. In the latter, it is now commonplace to compare shares of technically advanced products in production and exports (Hatzichronoglou, 1997), and a number of institutions – like the US National Science Board, the OECD and the EU – do so regularly.

As the organization of trade changes with 'fragmentation', there is also interest among developing countries in entering production networks that have the potential to raise exports and transfer new skills and technology.[3] Since, as noted, activities differ in the extent to which they can fragment, it is useful to analyze 'fragmentability' by looking at product characteristics like process divisibility, the value-to-weight ratio of components, technological needs and so on.

While product taxonomies are useful for analysis and policy, existing classifications have limitations, largely inherent in the industry-level data from which categories are drawn. This paper illustrates a method of classifying exports – we term it 'sophistication' – that does not require industry data, only information on exports of each product and per capita incomes of exporting countries. We calculate sophistication scores for 1990 and 2000 for 237 products at the 3-digit level (of SITC Revision 2), and for 766 products at the 4-digit level. We show export sophistication patterns for the main developing regions and leading developing and industrialized countries, and analyze export sophistication in a few selected industries.

Section 2 discusses problems with existing taxonomies, focusing on those dealing with technology intensity. Section 3 describes the export sophistication technique. Section 4 presents sophistication scores for 181 manufactured exports and relates them to the technological features of exports (as given by other classifications). Section 5 shows export

[1] See recent reviews by Deardorff (2004) and Harrigan and Venables,(2004).

[2] See, for instance, Arndt and Kierzkowski, (2000), Hummels *et al.*, (2001), Lall, Albaladejo and Zhang, (2004).

[3] See Lall (2000) and Lall, Albaladejo and Zhang (2004). East Asian exports have grown rapidly and their technological structure altered significantly by entry into high technology production networks.

sophistication by region and country. Section 6 deals with sophistication at the four-digit level and applies the measure to four selected industries. Section 7 concludes.

2. Classifying traded products: some problems

Most product taxonomies are based on data on respective 'parent' industries: for instance, a product is deemed technology-intensive if the industry under which it is classified has greater technological inputs or outputs than the average for industry. Factor content, in other words, is assessed by the average intensity of factor use by the parent industry. As the most commonly used classifications today relate to *technology,* we use this as the main example for our discussion.

Industry criteria to classify technology-intensity consist of 'input' or 'output' measures of innovation in the relevant product (used singly or in combination). On the 'input' side, the normal measures are research and development (R&D) as a share of sales and the employment share of scientists and engineers in total or R&D employment. On the innovation 'output' side, the most common measure is the number of patents (local or international) taken out by the industry.[4] Some measures of technology intensity also include technology 'embodied' in the inputs used by the industry.[5] The requisite data come from national R&D surveys or patent statistics (patents taken out in the US are used most often); however, some classifications also use the analyst's knowledge of technologies or rankings provided by technical experts.

Technology classifications of trade illustrate the methodological problems.[6] The main one is the large difference in the level of detail in data between industry and trade levels. Trade data are available at highly disaggregated levels: for instance, the Standard International Trade Classification (SITC) Revision 2, the classification used here because of its broad time and country coverage, has 236 items at the 3-digit level and 778 items at the 4-digit level. In the 2002 version of the Harmonized System, the new trade data recording system, there are over 1,200 items at the 4-digit level and over 5,000 items at the 6-digit level, and so on. In SITC Rev 2, meaningful product distinctions can be drawn only at the 3-digit level or more – the 2-digit level is far too aggregate – but technology data are not available at this level of detail.[7] US data on R&D, for instance, are available for only 38 manufacturing industries (NSB, 2002). The *OECD Science, Technology and Industry Scoreboard* provides cross-country R&D data for 19 industries.

Matching these to trade data to obtain technology classifications involves considerable aggregation, lumping together products from the same industrial category but with very different technological features. Thus, telecommunications equipment is a 'high technology' activity, but has products that are mature, do not involve intense R&D, or have simple production processes. Similarly, a 'low technology' industry like textiles has innovative products, while a 'medium technology' industry like machinery comprises the broad range of both innovative and non-innovative products. Moreover, the technological characteristics of activities can change rapidly over time, as innovations transform the product and process technologies of particular segments. Most aggregations are based on somewhat outdated information, and so may conceal important technological differences.[8]

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[4] Some measures also combine technology with marketing or capital intensity to yield more complex categories. For a review of 23 classification methods see Kaplinsky and Santos Paulino (2004).

[5] See Mani (2004). This technique uses input-output matrices to allocate 'indirect' R&D performed by input suppliers.

[6] See Kaplinsky and Santos Paulino (2004), Mani (2004) and Penender (2003).

[7] R&D is difficult to allocate by product even at the enterprise level because leading R&D performers are large companies whose research effort spans a vast range of products and who publish R&D data for the enterprise as a whole.

[8] Another problem with R&D or patent data is that neither measures technological activity accurately. Inputs of R&D may not indicate how effective the research effort is, and patenting does not indicate how valuable a new technology is in commercial terms. More important, these measures relate to innovation at the frontier and neglect informal technological effort. However, such informal effort, in quality management, process and product engineering, procurement and so on, is vital to technical change and competitiveness. In developing countries, most technological effort is informal but its intensity and effectiveness affects export activity (Lall, 1992). If formal

These problems may be reduced by using qualitative information or expert judgment to classify products at finer levels of detail and to update classifications. However, much depends on the ability of researchers to obtain comprehensive and reliable information. It would be expensive to obtain expert opinion on innovation-intensity spanning a broad range of technical disciplines, and experts may differ in their assessment of innovativeness. Building a consensus and updating expert opinions would be an even more daunting task. Thus, while qualitative judgment can play a useful role – in the end, technological taxonomies remain an art rather than a science – it does not lead to rigorous and practical solutions.

There is another problem in using industry-based taxonomies to analyze trade performance: the 'core' technical characteristics of products may not reflect the technologies used in their manufacture in a particular location. Trade fragmentation weakens the link between core technical characteristics and production processes: some of the largest exporters of hi-tech electronics are low wage countries that only assemble and test final products (advanced design and component manufacture remains in rich countries). As a result, classifying semiconductors as high technology leads to the result that the Philippines has a more technology-intensive export structure than the US or Japan (Lall, 2000). The normal assumption that products use the same technologies across countries no longer holds when discrete processes can be separated. Moreover, 'fragmentability' varies by activity. Within the hi-tech group, for instance, electronics is highly fragmentable (nearly 45 percent of world electronics exports come from developing countries[9]) while aircraft or pharmaceuticals are not (their exports remain largely the preserve of rich countries). Gauging the real technological content of national exports would require data by *process* rather than product, but such data are simply not available.

While researchers on technology are aware of these problems, they are constrained by the lack of industry data at the necessary level of detail. However, a recent, as yet unpublished, paper attempts to overcome the problem by a different route: Kaplinsky and Santos Paulino (2004) measure product innovativeness by *unit price changes over time,* hypothesizing that innovative products have rising prices while non-innovative ones have declining prices.[10] They calculate unit price changes for over 12 thousand products imported by the EU from 1988/9 to 2000/1 and use their results to assess existing technology classifications.[11] They also promise a detailed technology classification of their own in the near future. There are, however, two important deficiencies in this measure, which the authors note: it assumes away cost-reducing process innovation (or assumes it to be the same across activities) and it does not take into account the impact of different degrees of fragmentation between products (or, again, assumes it to be similar).

This technique gives interesting and plausible results and the promised technology classification should be very useful. However, its validity depends on the assumption that unit price changes reflect innovation rather than other factors like demand changes, non-technological barriers to entry, process innovation, fragmentation of the value chain, or policy-based trade distortions (or that the influence of these other factors is equal across activities). It is not clear that this assumption is always justified; where it is not, measuring technology levels by unit price changes may capture the impact of several factors apart from innovation.

R&D and patent data do not proxy accurately for such effort – and industries differ in their propensities to undertake 'minor innovation' – the usual measures may give misleading information.

[9] See Lall, Albaladejo and Zhang (2004).

[10] As they put it, " The rationale for using unit prices as an indicator of competitiveness is that it harks back to Schumpeter's discussion of innovation – low barriers to entry allow competitors into the market which has the effect of driving prices (and hence incomes and margins) down… [T]here is a direct relationship between unit price performance and innovative capabilities – rising unit prices are said to reflect growing product innovation and/or margins protected by barriers to entry, and conversely, falling unit prices reflect the inability to erect barriers to entry and/or to augment products." Kaplinsky and Santos Paulino (2004), p. 2. We are grateful to Professor Kaplinsky for sending us drafts of his paper.

[11] It is gratifying that the classification developed by one of the present authors (Lall, 2000) works best at distinguishing innovative products when assessed against unit price data.

3. Export 'sophistication': rationale and methodology

We propose a way of classifying traded products which, as with Kaplinsky and Santos Paulino, does not require industry data. It infers product characteristics from the characteristics of the exporter rather than from parent industry data on factor content. We call it export 'sophistication': *an export is more sophisticated the higher the average income of its exporter*. The rationale of the sophistication measure is simple. In the absence of trade interventions, products exported by richer countries will have characteristics that allow high wage producers to compete in world markets. These characteristics clearly include technology as an important determinant, but they also include other factors. The main factors affecting export location are:

- *Technology:* Advanced technology is probably the main source of competitiveness of high wage countries. 'Technology' here means not just (R&D-based) product or process innovation, but also the ability to handle technologies efficiently (production capabilities) and improve them over time (minor innovation), realize scale and agglomeration economies, organize suppliers efficiently or tap efficient supply chains. Products that need advanced technologies in all these forms will tend to be exported by countries that have the requisite skills, technological capabilities and strong innovation systems supporting enterprise technology (R&D institutions and universities, strong intellectual property protection, good quality and metrology institutions and tight links between firms and technology institutions). Thus, high sophistication will tend to reflect technological complexity, in turn capturing technical effort, skills, supply chains and innovation systems.[12]
- *Marketing*: Advanced design and packaging, strong product branding, customization of products to demands of customers, control over distribution channels. Highly differentiated products will tend to be exported by rich countries, though increasingly if production is not technology-intensive it will tend to be relocated in lower wage areas while design and marketing remain in rich ones.
- *Logistics and proximity*: Transport costs significantly affect the location of export production for products with high weight-to-value ratios or rapid delivery requirements. Since rich countries are the main markets for most exports, the location of production can reflect proximity advantages.
- *Fragmentability:* In activities where production processes are divisible (and logistics suitable) the location of export production can reflect the technical possibilities of separating segments and placing them in low wage countries. Thus, high sophistication scores can reflect the low fragmentability of particular products and low sophistication a high degree of fragmentability.
- *Information and familiarity:* The location of sourcing of products by major markets may reflect information on the production capabilities of particular countries, familiarity with their business systems and procedures, language, legal systems and so on.
- *Natural resources:* Resource-based exports often (but not in every case) depend on the local availability of primary resources. High wage economies will be significant exporters of those products for which they have ample resources, or where they are more efficient in using new technologies than poorer competitors.[13]
- *Infrastructure*: Some products require advanced infrastructure, particularly ICT, to be competitive. Only countries able to provide and operate such infrastructure can be competitive.
- *Value chain organization:* As global trade becomes organized in tighter-knit value chains,[14] the origin and organization of particular chains may influence geographical sourcing patterns. While value chain leaders (buyers, multinational investors or

[12] Note that we conflate technology with skills, but they are normally treated as separate factors in trade models.

[13] Leading exporters of primary products and resource-based manufactures are rich countries like the US, Canada, Australia and so on.

[14] On the nature and determinants of value chains see Gereffi, Humphrey and Sturgeon (forthcoming).

subcontractors) will respond to the factors noted above, there may be company-specific idiosyncratic factors that affect the choice of suppliers or location of subsidiaries.

These are the *economic* factors affecting the location of export production, and so the sophistication of each product. In addition, *policy factors* may also matter: trade restrictions and subsidies, trading blocs and trade preferences can affect where export production takes place. For instance, the quota system imposed by industrialized countries in textiles and clothing has affected the location of the exports between developed and developing countries and within the developing world; subsidies to and protection of agriculture by rich countries has held back exports by developing countries, trade blocs like NAFTA have affected the location of export activity in Latin America; preferences to banana and sugar exporters by the EU have supported inefficient producers in former colonies, and so on.

The sophistication index is thus an amalgam of these influences and *not a specific technological measure*. Technology is clearly a major factor in the index, but its role cannot be separated from that of other factors (at least without product-level data on each factor). While this is a drawback as a technological taxonomy, it is often possible to discern qualitatively how technology interacts with other determinants of export location. It is therefore possible to draw interesting insights from the index.

Table 1 shows a simple matrix of technology intensity (only divided between high and low) and export sophistication (high sophistication indicating that the product is exported mainly by rich countries). Products ranking either high or low in *both technology and sophistication* are typical of what standard trade theory predicts: rich countries have a comparative advantage in products using advanced technologies (and skills), poor ones in products using simple or mature technologies. The two other combinations are more interesting. That of high technology with low sophistication suggests that the production process is fragmented. That of low technology with high sophistication suggests that the products have specific natural resource, logistical or other needs that are out of reach of poorer countries – or that they are subject to policy interventions that deter their shift to low wage locations. The high-technology, low-sophistication combination provides a way of mapping fragmentation more clearly and comprehensively than by anecdotal evidence on global value chains.

Table 1: Export sophistication and technology intensity

Technology level	Sophistication level	
	Low	High
Low	Technologically simple products whose export production has shifted to low wage areas	Technologically simple products whose export production remains in high wage areas because of trade distortions, resource availability, logistical needs to be near main markets
High	Technologically advanced products with fragmentable processes located in low wage areas	Technologically advanced products without fragmentable processes where high wage countries retain strong comparative advantage

Note: The sophistication level is based on the average income of the exporter of a product, the level rising with income. The technology level is based on the R&D intensity of the core industrial process.

Another advantage of this technique is that, by allowing changes in exporter incomes (and so location between rich and poor countries) to be traced over time, it can permit analysts to track how various factors are interacting in the trade arena. In this paper, we present the scores for an index that covers all countries, but it is possible to construct more specialized indices that distinguish between country groups. For instance, a useful index for development purposes would be one that focused on location within the developing world, say between medium and low income countries.

Sophistication analysis can also help competitiveness policy. More sophisticated products presumably embody greater skills, more advanced technologies and higher levels of processing in the value chain than less sophisticated ones.[15] It is thus desirable for countries to move up the sophistication ladder as they grow and the mapping of sophistication at detailed levels within industries may point to desirable patterns of upgrading. To the extent that such upgrading does not happen automatically with rising wages because of skill, technology, marketing or other deficiencies, there may be useful pointers to the need for policy support.

How is the sophistication index calculated? At the *product level*, the sophistication measure uses data on exports by all countries (separately) and the income level of each exporter. The sophistication score is calculated for each product by taking the weighted average (the weights being each country's shares of world exports) of exporter incomes. The scores are normalized to yield an index ranging from zero to 100. Scores can be calculated at any level of detail and, a major advantage for econometric analysis, are unique to each product. Problems of matching trade and industrial data at the disaggregated level do not appear: it is possible to distinguish products without having to use detailed industry data or qualitative criteria (though such data or judgment are needed if we wish to disentangle the factors affecting sophistication).

We calculate sophistication scores for *237 produc*ts at the 3-digit level and *766 products* at the 4-digit level (SITC Rev 2) for 1990 and 2000. We start with exports (from UN Comtrade) for each product by *97 countries* (all those with significant exports and also data for both years). To obtain an average value for exporter incomes, we divide these countries into *ten income groups* (using World Bank data on nominal per capita GNI) in each year (the composition of the groups differed as countries moved up or down the income scale). We multiply the share in world exports of each product for each income group by the group's average income to get a dollar value for each product. This is a unique dollar value for each product given by the weighted average income for the 10 income groups. We then standardize each dollar value to range between 0 and 100. The product with the highest dollar value out of the 237 products is set at 100 and the product with lowest at zero. This yields a unique score for each product; the whole range of scores provides the index.

[15] They also enjoy better unit-price performance than products exported by poorer countries. Kaplinsky and Santos Paulino, 2004, find "a clear inverse relationship between per-capita incomes of country groups and the unit-price of their exports to the EU" p. 3.

Table 2 Illustration of sophistication index calculation				
Product (year)	Income groups	Average income (US$)	Share of exports (%)	Unique scores (US$)
SITC 001 Live animals chiefly for food (2000)	1	31,482	12.73%	4,008
	2	24,090	54.70%	13,177
	3	15,223	14.78%	2,249
	4	7,712	5.67%	438
	5	4,242	3.00%	127
	6	2,807	1.41%	40
	7	1,819	1.32%	24
	8	1,111	1.27%	14
	9	548	5.12%	28
	10	283	0.00%	0
Total			100%	20,106

Table 2 illustrates the calculation. The general formula we apply to derive the sophistication index is

SI (i) = 100*(US (i)-US (min))/(US (max)-US (min))

where
SI is the normalized sophistication index of product (i)
US is the unique sophistication score as a dollar value for product (i)
US (max) is the maximum unique sophistication dollar value for all products
US (min) is the minimum unique sophistication score dollar value for all products.

In this illustration in 2000 the unique score of product 001 is $20,106. To normalize this following the above formula we require the maximum and minimum scores fro all products.

Product 951 has the highest unique score of all ($27,964), while product 264 has the lowest unique score value ($2,516). The normalized score of product 001 is 69.12, which is the sophistication index of product 001. This is derived as

SI (001) = 100*(US(001)-US(264))/(US(951)-US(264))
= 100*(20,106-2,516)/(27,964-2,516)
= 69.12

We focus initially on 181 manufactured products at the 3-digit level, as primary exports do not raise significant issues on technology or location of export activity, before discussing products in more detail at the four-digit level. For ease of presentation and analysis, we group the 181 products into *six sophistication categories*. We do not apply any *a priori* criteria in allocating products to these six groups: the total number is simply divided into sets of 30 each (31 for the last group) along the sophistication scale.

We use product sophistication data to calculate *country and regional sophistication scores* (again at the 3-digit level), weighting each country's or region's exports by the share of each product in its total exports. We calculated such scores for 30 countries at different levels of development and for all major developing regions.

These country and regional sophistication scores are useful in tracking national performance over time and benchmarking against other countries and regions. As discussed below, however, the interpretation of sophistication scores is not straightforward (say, in contrast to technological shifts, where a move up the scale is generally thought desirable). While there is a presumption that raising sophistication at the product level is beneficial – it implies making more advanced products and using more advanced processes – higher sophistication need not imply higher rates of export growth. There is no *a priori* expectation that products made by richer countries grow faster than those made by poorer ones; in fact, in the presence of rapid fragmentation and the shift in location of activities more generally, there are good reasons for the opposite. We return later to these issues.

Nevertheless, within product groups where growth rates are not an issue, the presumption that higher sophistication is desirable seems more defensible. Within apparel, for instance, products exported by rich countries – or processes undertaken by them – are likely to be more skill and technology intensive, and yield higher wages and margins, than standardized products exported by poor countries. Competition is likely to be fiercer and margins finer in the latter, and, as Kaplinsky and Santos Paulino suggest, lower entry barriers are likely to place much more pressure on prices.

4. Product sophistication scores

Annex Table 1 shows the sophistication scores for 181 manufactured exports at the 3-digit level in 1990 and 2000, ranked by the 2000 score. It also shows export values, world market shares and growth rates. Scores at the 4-digit level would take too much space to show here but are available from the authors on request (some findings are discussed in Section 6).[16] There is a general decline in sophistication scores over time as developing countries raise their share of world exports (for manufactures as whole, their share goes from 13% in 1980 to 16.6% in 1990 and 26.8% in 2000 (UNIDO, 2004)).[17] Only 18 products show a rise in sophistication. This decline does not have any technological connotations: it does not mean, for example, that production processes are becoming less technology or skill-intensive or that technical progress is slowing. In fact, it is likely that with technical change, most processes are becoming more complex and have higher entry levels for competitive production. The decline in sophistication simply reflects the growth of industrial capabilities in latecomer (lower income) countries that allows them capture market shares in gradually more complex activities, as well as the fragmentation of simpler processes in very advanced activities.

While export production *is* shifting to lower income sites, not all developing countries, particularly the lowest wage economies, are gaining. On the contrary, export success is accompanied by increasing concentration in the developing world: the share of the top 15 exporters in total manufactured exports by developing countries, for instance, has risen from 91% in 1990 to 94% in 2001.[18] Most dynamic exporters are middle-income countries (People's Republic of China (henceforth PRC) is the only low income country in the dynamic group) and most are in East Asia (Mexico is the outsider after the formation of NAFTA). Most low-income countries remain marginal to the dynamics of manufactured trade. The sophistication index as presently constructed does not capture this facet of export relocation, though it is possible to construct one that distinguishes between income levels within the developing world.

Consider the characteristics of the most and least sophisticated products. Level 1, with the 30 most sophisticated exports, includes complex, technology-intensive products like arms and armored fighting vehicles, precision instruments, aircraft, auto engines and pharmaceuticals. Level 6, with the 31 least sophisticated products, has simple products like textile and clothing products, footwear, travel goods and toys, as well as resource-based products like jute that can only be produced by poor countries. In broad terms, resource availability apart, technology levels seem to explain a significant part of the distribution of sophistication scores. As Annex Table 2 shows, most high and medium technology products score relatively high on the sophistication scale while most low-sophistication products are from the low technology or resource based technology categories.[19] There is no low technology product in the top two sophistication groups, and no high technology product in the bottom two. This is reassuring: the predictions of received trade theories are largely valid.

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[16] The data can be requested from Professor Lall at sanjaya.lall@economics.ox.ac.uk

[17] The decline in scores is tempered by the fact that most major developing country exporters move up the income scale. If we had retained the income groups based on 1990 incomes, the decline would appear greater.

[18] These countries are, in descending order of export values in 2001, People's Republic of China, Republic of Korea, Mexico, Taipei,China, Singapore, Malaysia, Thailand, Indonesia, Brazil, India, Philippines, Turkey, South Africa and Hong Kong, China. The calculation is based on Comtrade data.

[19] The technology classification is an adapted version of the one developed by Lall (2000).

However, many products do not conform to *a priori* expectations, and we may speculate about their location determinants. For instance, manufactured tobacco is in group 1 in 1990 (though it declines to group 2 by 2000): a product with mature and stable technology, and with most raw materials coming from poor countries, it is exported mainly by rich countries presumably because of its continuous and capital-intensive processes, the importance of marketing (cigarette branding) and perhaps trade barriers. 'Essential oils, perfumes and flavors' also appear fairly high (in group 2 in 2000, having moved up from group 4) and increase their sophistication, not because of technological innovation but the significance of marketing and perhaps specialized skills. Chocolates, though based on raw materials from poor countries, are in group 1 (and rising in sophistication) probably for similar marketing and skill needs. Some resource-based products like paper, salted fish, animal fats or cheese have high sophistication because their raw materials are located in rich countries, or because these countries are exceptionally efficient at producing them (cereals). Some, like milk or butter, reflect distortions caused by government subsidies to and protection of the agricultural sector.

Among low technology products, the 'fashion cluster' segment (textiles, clothing and footwear) starts low in the index but spans a wide range. The most sophisticated product is special textile fabrics (at rank 113), presumably industrial fabrics with advanced technological needs, followed by lace and embroidery (at 125), requiring a long accumulation of special skills. Standard textile and apparel exports like woven cotton fabrics, undergarments or non-knitted outerwear figure in the bottom 30 in the ranks. Some medium technology engineering products like radio receivers are very low in the sophistication ranks because their technologies are mature and standardized, allowing production to be located overwhelmingly in low wage countries.

High technology electronics products like semiconductors, office machines, automatic data processing (ADP) machines and telecom equipment are of particular interest. These are R&D intensive activities with complex manufacturing processes for critical components, but they move rapidly down the sophistication scale and by 2000 all are in sophistication group 4 (semiconductor at rank 98, ADP at 107 and office machine and ADP components at 115) apart from telecom, which is in group 3 (rank 89). This is clearly the outcome of production fragmentation, which started with final assembly but over time is deepening into the transfer of core component manufacturing in lower income countries, primarily in East Asia. While clearly responding to factor cost differences, the industry is unlikely to keep moving down the wage scale to the least developed countries, say in Africa, because its minimum entry levels are now much higher than when fragmentation started in the late 1960s and first movers have established strong scale, scope and agglomeration advantages.[20]

Other engineering industries like automobiles, industrial capital goods or aircraft also have discrete processes that can be separated economically, but are not fragmenting as much as electronics. The reasons may lie in higher skill needs, greater agglomeration economies, lower transportability (higher weight-to-value ratios) of components and the absence of simple assembly processes that can be easily relocated. Electronics has been something of an outlier among technology-intensive industries in the fragmentation process, a fact that shows up clearly in the sophistication index.

The performance of *electronics* is of particular interest because export values are very large and their growth very rapid. [21] The spread of their production networks raised dramatically export earnings by some countries.[22] In 1990, total exports of these four products came to $231 billion (9% of world manufactured exports); by 2000, they had reached $830 billion

[20] See Lall, Albaladejo and Zhang (2004).

[21] Three of these electronics products (semiconductors, telecom equipment and components of office and ADP machines) were *the* fastest growing exports in the world in 1990-2000 with the exception of optical products (a relatively small value export). The last product, ADP machines, came sixth, with pharmaceuticals and electric power machinery, doing slightly better.

[22] The major beneficiaries were East Asia, which accounted for over 90% of developing world exports of electronics in both 1990 and 2000. In the latter year, electronics products accounted for around one-third of their total manufactured exports.

(17%). They were among the world's six largest manufactured exports in 2000 (the other two being passenger cars, in first place, and refined petroleum products, in fifth). Their dynamism has had a significant effect on the sophistication scale, creating a 'bulge' in the levels (3 and 4) that they inhabit.

Table 3: World exports by sophistication levels

Sophistication level	**Value** ($ millions)		**Distribution**		**Growth Rate**
	1990	**2000**	**1990**	**2000**	**1990-2000**
Level 1	657,248.2	981,123.2	25.5%	20.1%	4.1%
Level 2	556,036.7	788,901.5	21.6%	16.2%	3.6%
Level 3	443,921.6	938,816.5	17.2%	19.2%	7.8%
Level 4	307,429.8	1,098,440.2	11.9%	22.5%	13.6%
Level 5	242,141.0	583,404.1	9.4%	11.9%	9.2%
Level 6	368,632.8	491,371.6	14.3%	10.1%	2.9%
Total	**2,575,410.1**	**4,882,057.0**	**100.0%**	**100.0%**	**6.6%**

Table 3 shows the distribution and growth rates of world manufactured exports by sophistication levels in 1990 and 2000 (the products are categorized here by the sophistication levels in each year separately, unlike Annex Table 1 which shows groups according to 2000 ranks only). The largest category in 2000 is level 4, which contains semiconductors, ADP equipment and accessories for ADP and office machines. The next largest category is level 1, but this grows relatively slowly and loses market share over the decade. The best 'positioning' for export growth is in categories 4, 5 and 3, where middle-income countries are the main exporters.

The smallest – and slowest growing – category is level 6, the one the poorest countries dominate.[23] These products are evidently not benefiting from the technological and relocation forces that now drive trade dynamism. There are many reasons for this, including political instability, poor governance and weak infrastructure. They also include technological ones: most of these countries are unable to develop the necessary capabilities for their economies to compete on their own or to attract FDI into efficiency seeking activities. The slow growth of their earnings may, as Kaplinsky and Santos Paulino (2004) suggest, also reflect the fact that they suffer most from declining export prices.

Despite the shifts in product sophistication ranks, there is considerable stability in sophistication scores between 1990 and 2000. The correlation coefficient is 0.88, suggesting that export location has considerable inertia. There is, however, no statistically discernible relationship between export growth rates and sophistication. A rise in product sophistication may be desirable in terms entering higher value processes and products, but this applies within given activities or products. When considered across products, there is no effect of a rise in sophistication on export growth.

5. Regional and country sophistication performance

We now consider regional and national export sophistication, starting with the *regional level.* Table 4 shows the overall scores of the main regions for 1990 and 2000, ranked by the score in 2000. The average score covers all manufactured exports at the 3-digit level (the method for obtaining the score is described earlier). The regions are constructed to take account of

[23] PRC was in the lowest income group of the ten groups in 1990 but had moved to the top of the 9th group by 2000.

outliers in each: PRC in East Asia, Mexico in LAC, South Africa in SSA and India in South Asia. The transition economies are excluded because of large data gaps for 1990.[24]

Table 4: Regional sophistication scores
(ranked by 2000 score)

Region	1990	2000
N America	84.06	74.47
W Europe	80.86	71.88
LAC 1 (including Mexico)	69.14	64.91
E Asia 2 (excluding PRC)	69.95	64.83
E Asia 1 (including PRC)	69.18	62.78
LAC 2 (excluding Mexico)	65.87	61.28
SSA 1 (including South Africa)	NA *	59.55
SSA 2 (excluding South Africa)	59.17*	55.93
MENA	62.60	55.72
S Asia 1 (including India)	58.53	50.68**
S Asia 2 (excluding India)	53.51	39.73**

Notes: * There are no export data for South Africa for 1990; this is why the SSA 1 and SSA 2 scores are identical.
** South Asian data for 2000 includes export data for 2001 for Bangladesh and Sri Lanka, which are missing 2000 data.

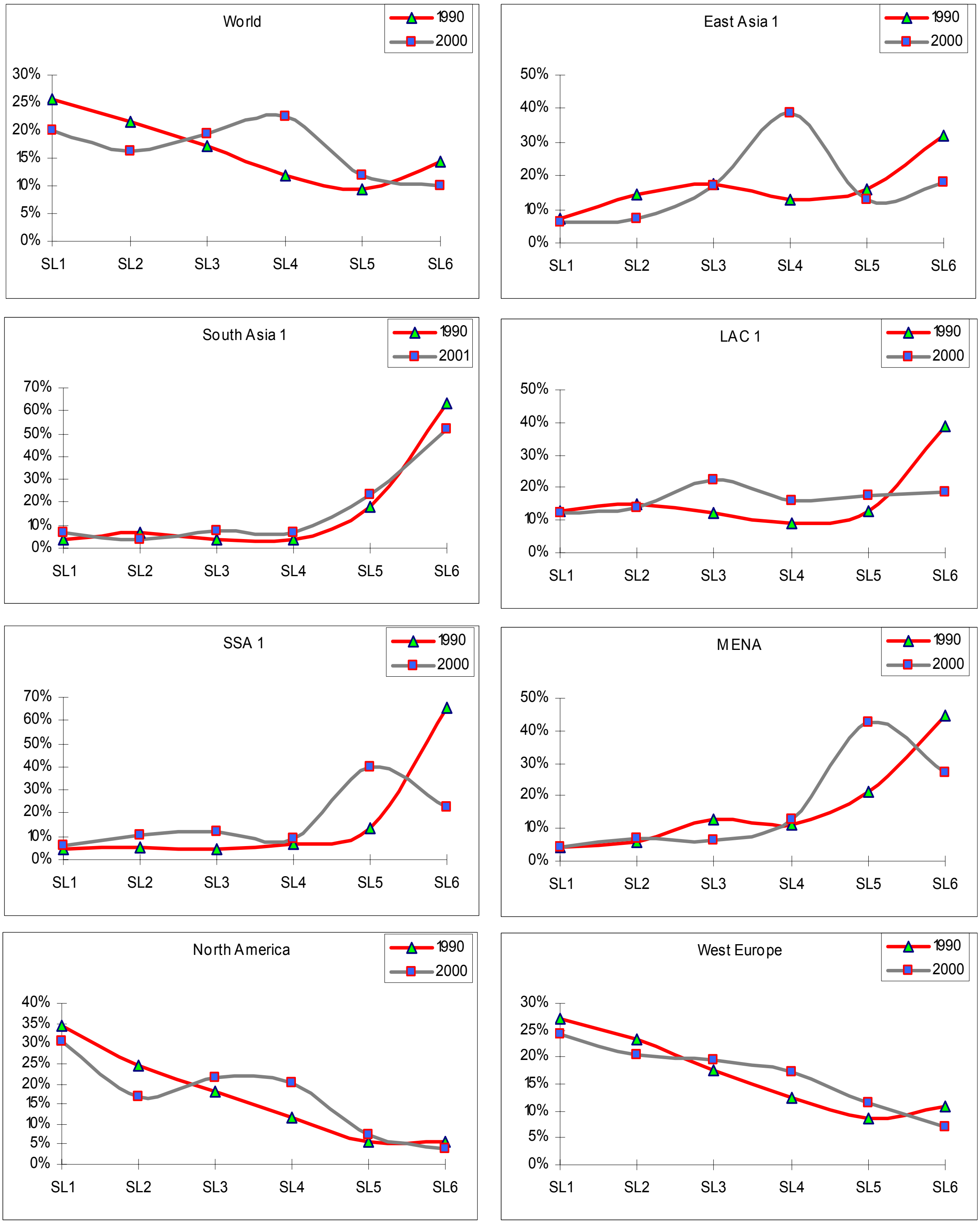
As expected, the two highly industrialized regions lead the scores in both years, with N America having a more sophisticated structure than W Europe. Both see a significant decrease in sophistication levels. In the developing world, LAC 1has the highest sophistication level in 2000 though in 1990 it slightly lagged East Asia, both including and excluding PRC. However, if we exclude Mexico (with its rapid growth of *maquila* activities in electronics and other industries) the region falls behind EA in both years. EA 2, excluding PRC, does better than EA 1 because of PRC's specialization in lower technology products. Rather surprisingly, SSA, with and without South Africa, does better than MENA and South Asia: this is because three of its major exports (wood roughly worked, wood sleepers and processed foods) happen to be in sophistication level 3, and its largest single export (precious and semi-precious stones) are in level 5. The region's rank, in other words, is not based on technological sophistication but the distribution of certain resource-based products in richer countries. MENA comes ahead of South Asia because the former's main exports (petroleum products) are in level 5 while South Asia's main exports (standard textiles and clothing) fall in level 6.

All developing regions see a decline in sophistication levels, with the most marked decline in South Asia 2: Pakistan, Bangladesh and Sri Lanka are even more dependent on textile and clothing exports than India. While Bangladesh and Sri Lanka have done relatively well in terms of export earnings from these products, the sophistication group as a whole is growing slowly. Moreover, the impending abolition of the Multi-Fiber Arrangement (under which quotas initially drove buyers to source in these countries) may affect adversely their export growth prospects.

[24] The acronyms are as follows: LAC 1 is Latin America and the Caribbean including Mexico, LAC 2 excludes Mexico. EA 1 is East Asia including PRC and EA 2 excludes PRC. SSA 1 is Sub-Saharan Africa including South Africa and SSA 2 excludes South Africa. MENA stands for Middle East and North Africa, and includes Turkey. S Asia 1 is South Asia including India and S Asia 2 excludes India.

It is interesting to trace the evolution of regional export sophistication in the regions. Figure 1 shows the distribution of manufactured exports over the six sophistication levels in 1990 and 2000 (note that the figure shows the entire regions, including outliers). For the world as a whole, the most notable change is the bulge in the middle, reflecting the growth of electronics exports in level 4. This bulge is most marked in East Asia, with its export engine driven by this group of hi-tech products. The share of level 1 remains constant, while the shares of levels 2 and 6 decline.

Figure 1: Evolution of regional exports by sophistication levels[25]



[25] For definitions of the regions see the footnote to Table 3.

LAC has steady shares of levels 1 and 2 (at higher levels than in EA, mainly because of the weight of automotive products in exports and also of aircraft exports by Brazil), and there is a rise in sophistication in levels 3, 4 and 5, with a decline in level 6.[26] While this pattern of export evolution seems very desirable, it goes hand in hand with relatively low rates of growth and, more important, with little progress in level 4 that contains the main dynamo of recent export growth. We should also reiterate that the picture for LAC is strongly influenced by Mexican performance.[27]

South Asia's very low sophistication and the stagnation in its export structure over time are evident in the figure. SSA and MENA have similar bulges in level 5 exports because of the rise in processed petroleum and gem exports, while the rest of its export structure remains stagnant.

Table 5 shows world market shares (WMS) of manufactured exports for the main regions by sophistication levels. East Asia (including PRC) has a significant global presence in all sophistication categories, with around one-third world market share in levels 4 and 6 and one-fifth in level 5. South Asia has a very low presence in levels 1 to 4, with slightly higher shares in 5 and particularly 6. LAC's market presence is spread relatively evenly, with a focus on levels 6, 5 and 3. MENA has a slightly larger overall market presence than South Asia, with its main focus on level 5. SSA is the smallest player, but its pattern is rather similar to that of MENA.

Table 5: World market shares of manufactured exports by sophistication levels, 1990-2000

	SL1	SL2	SL3	SL4	SL5	SL6	Total
1990							
E Asia 1	3.4%	7.9%	12.0%	13.1%	20.6%	26.6%	12.0%
S Asia 1	0.1%	0.3%	0.2%	0.3%	1.6%	3.6%	0.8%
LAC 1	1.1%	1.6%	1.6%	1.7%	3.0%	6.2%	2.3%
MENA	0.1%	0.1%	0.4%	0.4%	1.1%	1.5%	0.5%
SSA 1	0.0%	0.0%	0.0%	0.1%	0.2%	0.7%	0.1%
W Europe	52.5%	53.3%	50.4%	51.4%	45.8%	36.9%	49.3%
N America	20.7%	17.4%	16.2%	15.2%	9.5%	6.2%	15.4%
ROW	22.1%	19.4%	19.2%	17.8%	18.2%	18.4%	19.6%
2000							
E Asia 1	5.6%	8.3%	16.6%	32.7%	20.5%	34.2%	18.9%
S Asia 1	0.4%	0.3%	0.4%	0.3%	2.2%	5.7%	1.1%
LAC 1	3.1%	4.2%	5.7%	3.5%	7.2%	9.1%	5.0%
MENA	0.3%	0.6%	0.4%	0.7%	4.6%	3.5%	1.3%
SSA 1	0.2%	0.5%	0.4%	0.3%	2.3%	1.6%	0.7%
W Europe	50.4%	52.3%	42.1%	31.9%	39.9%	29.4%	41.6%
N America	25.8%	17.5%	18.8%	15.2%	10.4%	6.3%	16.9%
ROW	14.3%	16.3%	15.5%	15.4%	13.0%	10.3%	14.5%

Note: ROW stands for 'rest of the world' and includes Japan, Australasia and transition economies.

At the *country level*, we calculated sophistication scores for 30 economies at varying levels of development. Table 6 gives the scores ranked by 2000 scores. The US has the highest score in 2000, up from second place in 1990, exchanging places with Japan. Germany

[26] Note that while the *share* of level 3 exports in EA is lower than in LAC, the *value* of EA's exports of level 3 products like electrical machinery and telecommunications apparatus are very large, over 2.5 times larger than LAC in value. A very large part of LAC's sophisticated exports come from Mexico, and its assembly operations distort the picture for the rest of the region.

[27] For a more detailed analysis see Lall and Weiss with Oikawa (2004).

retains third place in both years. The UK, Ireland and Finland exchange ranks in the next three places. Singapore leads the developing world in 2000, but Mexico led in 1990; both have high shares of hi-tech exports but Mexico has a significant share of low technology textiles and apparel. At the bottom of the list are South Asian countries with their overwhelming reliance on clothing exports.

Table 6: Country export sophistication (ranked by 2000 scores)

	Score	1990	2000
1	USA	84.44	74.83
2	Japan	85.14	74.62
3	Germany	83.87	74.57
4	Ireland	79.89	73.88
5	UK	81.82	73.59
6	Finland	82.84	72.97
7	Singapore	74.59	68.11
8	Mexico	80.38	67.42
9	Taipei,China	73.37	67.05
10	Republic of Korea	69.21	66.52
11	Argentina	66.90	64.64
12	Brazil	67.69	64.22
13	Philippines	60.53	64.08
14	Malaysia	68.08	63.43
15	South Africa	68.46	62.59
16	Costa Rica	69.26	62.51
17	Thailand	65.12	61.88
18	Saudi Arabia	65.79	59.70
19	Chile	65.16	57.16
20	PRC	65.04	56.55
21	Egypt	62.61	55.43
22	Indonesia	57.33	55.37
23	India	61.05	55.21
24	Turkey	60.28	54.27
25	Hong Kong, China	67.62	53.74
26	Syria	62.49	50.00
27	Morocco	59.87	48.32
28	Pakistan	55.24	41.61
29	Sri Lanka	54.60	41.50
30	Bangladesh	46.62	35.64

While the general configuration is as expected, there are interesting deviations. To explore these, we ran a linear regression between income levels (per capita gross national income from the *World Bank Indicators*) and export sophistication levels for the two years. The adjusted R-squares were high in both and the regression coefficients were significant at the 99% confidence level. The 1990 regression produced a better fit (adjusted R^2 =0.672) than in 2000 (adjusted R^2 =0.461), suggesting that over the decade fragmentation and local capability development led to greater divergence between income levels and export patterns.

Figure 2: Difference between actual and predicted sophistication scores

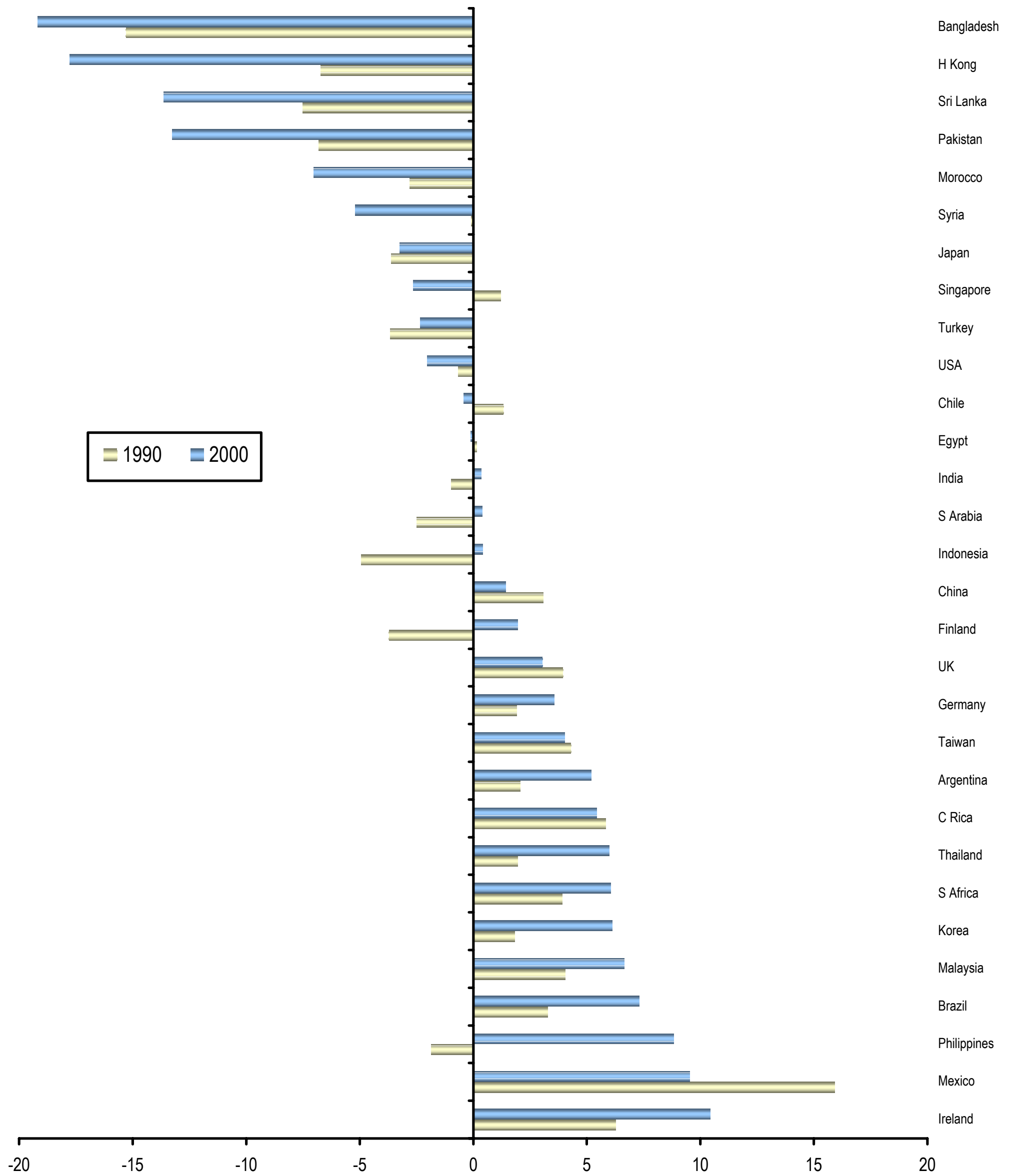


Figure 2 shows the divergence between actual and predicted sophistication scores in relation to income for both years, ranked by 2000 figures. Bangladesh has the highest divergence between actual and predicted sophistication scores in both years, with actual sophistication being much lower than its predicted level. Thus, even at its low income level, Bangladesh should have had a more sophisticated export structure. Hong Kong comes next in 2000. A relatively rich country (in the top group in 2000) its export structure is highly biased towards simple labor-intensive manufactures (and its exports have been declining, see below), clearly out of line with its income levels. Lall (1996) argues that this is largely the result of its failure to upgrade industrial technologies as its wages rose, in turn due to a *laissez faire* industrial policy. However, it has been able to sustain high incomes because of the growth of services aimed at PRC.

At the other end of the spectrum are countries whose export sophistication is much higher than predicted by their incomes. Ireland leads the list in 2000 and Mexico in 1990, the former because of its specialization in electronics and pharmaceuticals, the latter because of automotive products and various types of machinery and electronics. Most East Asian 'Tiger' economies also have higher sophistication levels than predicted by their income levels. The Philippines switches from lower than predicted to higher than predicted sophistication over the decade as its exports move from apparel and other low technology items to semiconductors and automotive components. Singapore, on the other hand, switches the other way, because at its relatively high income level a heavy specialization in electronics pulls down its sophistication level.

In the industrialized world, Finland switches from lower to higher than predicted export sophistication because of its strong performance in telecom equipment (in sophistication level 3). The USA and Japan have lower than predicted sophistication in both years due to the large share in their exports of fragmenting products like electronics. The UK and Germany, with stronger specialization in less fragmented products pharmaceuticals, machinery and automotives, have more sophisticated exports than predicted by their incomes.

Table 7: World market shares for manufactured exports by sophistication level

	1990	2000	1990	2000	1990	2000	1990	2000
	PRC		Republic of Korea		Taipei,China		Singapore	
Level 1	0.41%	1.30%	0.71%	1.04%	0.87%	1.08%	0.78%	1.23%
Level 2	1.52%	1.36%	1.28%	2.71%	1.71%	1.52%	1.45%	1.22%
Level 3	0.83%	3.88%	2.20%	3.15%	3.79%	3.15%	2.92%	1.99%
Level 4	0.98%	4.68%	3.78%	6.10%	2.54%	6.01%	1.97%	6.57%
Level 5	4.15%	7.18%	4.91%	3.52%	5.33%	2.36%	1.27%	2.65%
Level 6	5.47%	15.49%	4.70%	3.62%	3.03%	2.66%	3.70%	0.95%
Total	**1.87%**	**4.70%**	**2.42%**	**3.41%**	**2.48%**	**2.97%**	**1.90%**	**2.72%**
	Hong Kong, China		Malaysia		Thailand		Indonesia	
Level 1	0.26%	0.16%	0.23%	0.33%	0.08%	0.23%	0.03%	0.12%
Level 2	1.03%	0.16%	0.45%	0.36%	0.31%	0.45%	0.08%	0.47%
Level 3	1.08%	0.28%	0.40%	1.72%	0.64%	1.35%	0.10%	0.66%
Level 4	0.43%	0.39%	2.16%	4.16%	0.66%	1.82%	0.32%	0.73%
Level 5	1.42%	0.25%	1.35%	1.38%	1.04%	1.29%	0.77%	1.42%
Level 6	2.95%	2.23%	1.66%	2.24%	2.08%	2.57%	2.15%	3.08%
Total	**1.08%**	**0.45%**	**0.85%**	**1.78%**	**0.67%**	**1.20%**	**0.46%**	**0.87%**
	Philippines		Mexico		India		Brazil	
Level 1	0.01%	0.12%	0.53%	1.77%	0.10%	0.33%	0.48%	0.91%
Level 2	0.06%	0.06%	0.61%	3.02%	0.25%	0.25%	0.63%	0.64%
Level 3	0.06%	0.38%	0.47%	3.99%	0.18%	0.41%	0.57%	0.85%
Level 4	0.29%	2.25%	0.44%	2.42%	0.22%	0.25%	0.54%	0.34%

Level 5	0.30%	0.38%	0.52%	3.08%	0.71%	1.98%	1.30%	1.00%
Level 6	0.59%	0.90%	0.46%	4.15%	2.38%	2.93%	2.56%	2.23%
Total	**0.17%**	**0.75%**	**0.51%**	**2.94%**	**0.54%**	**0.77%**	**0.91%**	**0.87%**

Table 8: Percentage change in world market shares (1990-2000)

	PRC	Republic of Korea	Taipei,China	Singapore
Level 1	215.6%	46.7%	23.07%	58.84%
Level 2	-10.4%	112.0%	-11.36%	-16.41%
Level 3	369.1%	42.8%	-17.04%	-31.70%
Level 4	375.3%	61.2%	136.31%	234.36%
Level 5	73.1%	-28.3%	-55.77%	108.91%
Level 6	183.3%	-23.0%	-12.12%	-74.38%
Total	**151.8%**	**40.7%**	**19.48%**	**43.21%**
	H Kong, China	Malaysia	Thailand	Indonesia
Level 1	-39.8%	45.3%	204.04%	295.56%
Level 2	-84.2%	-20.2%	47.60%	462.27%
Level 3	-73.7%	329.9%	112.23%	536.42%
Level 4	-9.2%	92.4%	174.99%	128.90%
Level 5	-82.2%	2.3%	24.22%	85.58%
Level 6	-24.6%	35.2%	23.57%	42.88%
Total	**-58.0%**	**110.7%**	**79.44%**	**88.44%**
	Philippines	Mexico	India	Brazil
Level 1	849.7%	234.9%	232.69%	87.75%
Level 2	10.9%	396.8%	2.71%	1.68%
Level 3	494.8%	755.9%	131.92%	50.16%
Level 4	684.5%	450.0%	13.07%	-37.56%
Level 5	27.3%	492.3%	177.69%	-23.17%
Level 6	52.9%	809.9%	22.98%	-12.73%
Total	**333.1%**	**473.2%**	**42.28%**	**-4.46%**

We now look at the export sophistication performance of leading newly-industrializing countries. Table 7 shows world market shares (WMS) of selected NIEs by sophistication level and Table 8 the percentage changes in shares over 1990-2000. Some salient features of the data are:

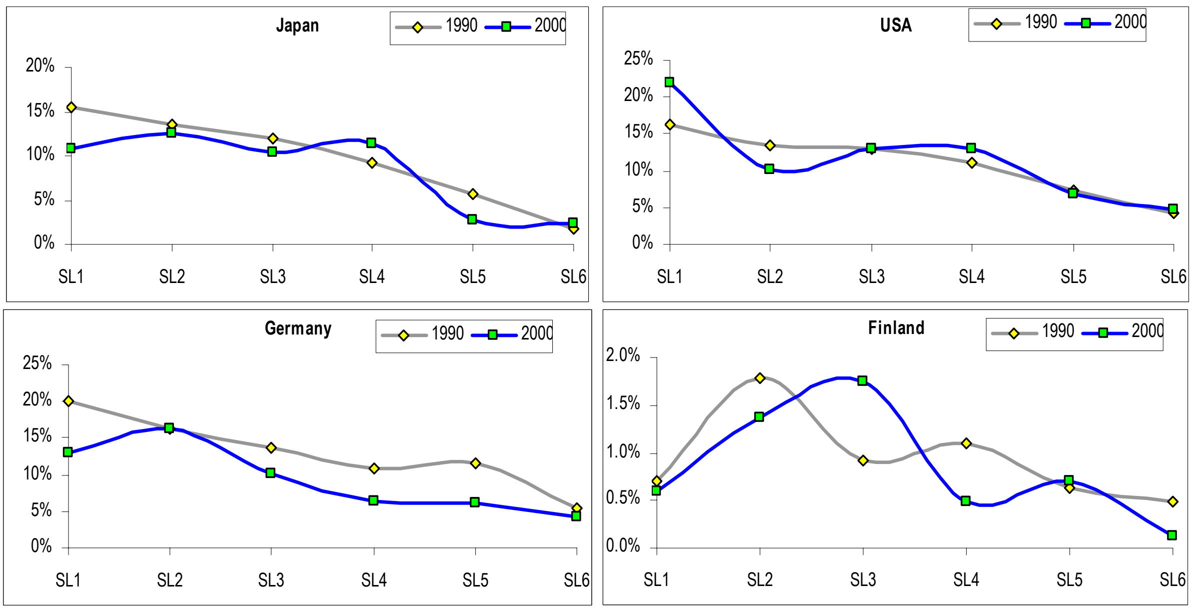
- The three mature Tiger economies with strong industrial sectors (Singapore, Republic of Korea and Taipei,China) hold the highest – and surprisingly similar – WMS in level 4 products.[28] All three lose WMS significantly in the bottom category, and Korea and Taipei,China also in level 5, a category where Singapore raises its WMS because of booming petroleum products exports.
- Korea makes the largest improvement of the mature Tigers in highly sophisticated products (levels 1 and 2), Taiwan the least. Hong Kong loses ground in all segments as it de-industrializes.
- PRC has a sophistication profile matching its relatively low income: in 2000, its highest WMS is in level 6 and its WMS declines steadily at progressively higher levels of sophistication. However, its largest percentage gains are in levels 3 and 4, driven not just by electronics products but also a vast range of other engineering products that denote high industrial capabilities.

[28] Singapore's WMS is exaggerated because its exports include substantial re-exports (around 40%).

- Malaysia and the Philippines show a profile similar to the three mature Tigers in terms of a bulge in level 4, but both retain relatively large level 6 exports. Both show significant rises in level 3 because of telecom exports (the dramatic percentage rises in Philippines' level 1 exports are due to booming auto components, but should be discounted because of the small initial base).
- Indonesia, the most resource-rich economy in East Asia and also the poorest (its GNI per capita is lower than in PRC by 2000 in dollar terms), is concentrated in sophistication levels 5 and 6. It has large increases in levels 1 to 3, but the small base exaggerates its real gains.
- Mexico has the largest percentage increases in WMS over the decade, turning from a typical Latin American economy with modest export growth into a Tiger in the Asian mould with rapid export growth (Lall, Weiss and Oikawa, 2004). However, Mexico has interesting differences from the typical East Asian Tiger. Its WMS structure is evenly spread over all sophistication levels in both years and sees large rises in all levels. Unlike the mature Tigers, it has a large increase in the lowest sophistication level (level 6). Its dynamism is due largely to trade privileges granted by NAFTA, but it has tapped them in different ways. Thus, its passenger car and auto component exports (driving its rises in levels 1 and 2) are the result of restructuring a long-established import substituting industry. Its growth in levels 3 and 4, by contrast, is based on the recent relocation of electronics assembly activity (with very low local content relative to than counterparts in East Asia). Its growth in level 5 is based on a mix of different types of non-electronic machinery and components, and in level 6 on textile and clothing, all driven by out-sourcing for the US market.
- India and Brazil concentrate in the lowest sophistication level, but in quite different products. India specializes in this level mainly in textile and apparel products, while Brazil specializes in iron ore, footwear and food products. Brazil has a slightly better showing in level 1 because of its aircraft and auto exports, while Indian exports consist mainly of pharmaceuticals. In level 5, India specializes in gems (cut diamonds) and jewelry, while Brazil is in wood products, ingots and petroleum products. India raises its overall WMS (and significantly in levels 1, 3 and 5) while Brazil loses overall WMS, particularly in the bottom three categories.

It is instructive to compare the WMS profile of the NIEs with that of industrialized countries like Japan, the US, Germany and Finland (Figure 3). The three large developed economies have a similar spread of market shares, highest in level 1 and lowest in level 6. However, they have somewhat different patterns and evolve differently over the decade.

Figure 3: World market shares for 4 industrialized countries by export sophistication levels



Japan loses market share overall (from 10.8% to 9.3%). It has a lower WMS in 2000 in level 1 exports (due to a fall in auto components) and a higher WMS in level 4 (ADP machines and components), with another fall in level 5. The USA, by contrast, raises WMS overall, from 11.9% to 12.8%. It sees a significant rise in level 1 (a broad-based improvement in several products) but loses it in level 2 (led by a fall in cigarette exports), raises it slightly in level 4 and maintains it in the other categories. Germany suffers a large decline in total WMS, from 14.2% to 9.8%, with a fall in all levels except for 2. Finland, a much smaller exporter than the others, loses overall WMS by one percentage point, but the structure of its shares changes quite sharply, with stagnant paper product exports shifting its 'bulge' from level 2 to level 3, where telecom apparatus drives its export earnings.

6. Sophistication at the four-digit level

Let us now consider sophistication at the 4-digit level. We start with the scores for all the 766 products. Table 9 shows the top 20 and bottom 10 products in 2000, with scores and ranks for these products in 1990.

Table 9: Top and bottom world exports in sophistication at the 4-digit level, 2000

SITC Code	Product	1990		2000	
		Rank	Score	Rank	Score
	Most sophisticated 20 products				
5843	Cellulose acetates	**50**	90.73	**1**	100.00
7223	Track-laying tractors	**2**	99.52	**2**	97.78
9510	Armoured fighting vehicles, arms & ammunition	**17**	93.65	**3**	96.43
6812	Platinum and other metals of the pl	**264**	80.71	**4**	95.56
7126	Steam & other vapour power units	**7**	96.13	**5**	94.57
8748	Electrical measuring, checking, analysing instruments	**24**	93.09	**6**	94.12
2120	Fur-skins, raw	**14**	93.95	**7**	93.79
7133	Int. combustion piston engines for marine propulsion	**9**	95.73	**8**	93.57
7239	Parts of civil engineering/contractors plant	**46**	90.89	**9**	93.30
2512	Mechanical wood pulp	**236**	81.94	**10**	93.03
8744	Instruments .for physical or chemical analysis	**37**	91.71	**11**	92.44
7741	Electro-medical apparatus	**5**	98.05	**12**	92.20
0459	Buckwheat, millet, canary seed, grain	**168**	84.87	**13**	91.37
2511	Waste paper, paperboard for use in papermaking	**35**	91.93	**14**	89.93
8933	Ornamental objects of resin, plastics, cellulose	**524**	64.13	**15**	89.87
7149	Parts of non-electrical engines & motors	**68**	89.30	**16**	89.21
5155	Other organo-inorganic compounds	**60**	89.68	**17**	89.08
7268	Bookbinding machinery and parts	**12**	94.34	**18**	89.03
6880	Uranium depleted in u235, thorium & their alloys	**539**	62.98	**19**	89.01
7144	Reaction engines	**347**	76.87	**20**	88.85
	Least sophisticated 10 products				
4245	Castor oil	**746**	16.31	**757**	9.22
0611	Sugars, beet and cane (raw, solid)	**733**	25.46	**758**	8.27
2613	Raw silk	**759**	8.55	**759**	6.69

2713	Fertilizers of natural calcium/alum. phosphate	**761**	6.65	**760**	5.66
2232	Palm nuts and palm kernels	**737**	21.73	**761**	5.54
2640	Jute & other textile bast fibres n.e.s.	**764**	4.25	**762**	5.43
2655	Manila hemp, raw or processed	**765**	2.01	**763**	4.68
4244	Palm kernel oil	**750**	13.76	**764**	4.35
2714	Potassium salts, natural or crude	**763**	5.07	**765**	4.19
2235	Castor oil seeds	**766**	0.00	**766**	0.00

The leading products are a mix of technologically complex items (e.g. arms or specialized equipment) and resource-based products exported by rich countries. In the latter category, the advantage of rich countries lies in the possession of primary inputs (e.g. fur-skins or wood pulp), the use of capital-intensive technologies, or the subsidization of local production (e.g. various grains). The bottom ones are also resource-based products, but here the raw materials are mainly tropical. As at the 3-digit level, the 4-digit scores are fairly stable over time (the correlation coefficient of the 1990 and 2000 scores is 0.88), but some products change ranks significantly. The most sophisticated product in 2000, cellulose acetates, moves up from 50th place in 1990, while the most sophisticated product in 1990, 'ships, boats, other vessels for breaking up', falls to 567th place in 2000.

6.1 SOPHISTICATION BY TECHNOLOGY CATEGORY

The sophistication index can be used, not only to compare products in general but also to assess how products at fine levels of disaggregation perform *within* technological categories or industries. The methodology is similar in both cases. The values for each product in each technological or industry category are calculated as before. However, we now standardize the values relative to the technology or industry norm. Hence within each category the product with the highest dollar value is normalized at 100 and the least at zero. Sophistication scores are now calculated *separately for each category (or industry)* at the four-digit level. They *are not comparable across categories (or industries) but they are comparable across countries and regions.* This set of scores does not match the scores for all the products together, though the *order* of activities according to sophistication within each category (or industry) is of course identical to that in the general score.
Table 10 gives summary results showing the weighted average scores by technological category for regions and some large exporting economies. [29] The data here can be subject to much richer analysis if broken down further, but a number of general points can be made from table 10.

Table 10: Average sophistication scores by technology category 2000 by region and countries

Category	Developed	East Asia	Republic of Korea	PRC	South Asia	India	Latin America	Mexico	Sub-Saharan Africa
RB1	74.49	55.34	72.58	56.77	54.26	53.63	59.58	69.29	55.96
RB2	68.44	60.24	60.69	61.74	57.21	57.16	44.59	60.99	52.83
LT1	48.15	40.89	51.52	36.14	33.52	35.54	41.01	39.94	40.88
LT2	66.95	58.38	64.77	50.57	58.57	58.91	62.27	61.69	63.58
MT1	73.39	65.85	72.58	53.21	67.74	67.71	72.51	72.51	73.12
MT2	68.85	58.30	57.94	50.09	54.47	56.96	58.18	62.54	47.43
MT3	71.45	56.83	59.23	51.85	71.18	70.86	58.46	56.16	66.97
HT1	52.51	46.49	46.50	45.28	52.43	52.48	45.06	44.80	50.62
HT2	79.05	65.10	78.04	59.01	71.00	70.99	64.74	69.01	71.78

Notes: The categories are as follows: RB1 is agro-based manufactures, and RB2 mineral-based manufactures. LT1 is "fashion cluster" and LT2 is other low technology manufactures. MT1 is automotive products, MT2 is process industry products and MT3 is engineering products. HT1 is high technology electronics and electrical products and HT2 is other high technology products. The classification follows Lall (2000).

[29] We use the technology categories in Lall (2000).

First, of the developing regions or countries in the table only Korea comes close to the average sophistication scores of developed countries as a group and even here only in four technology categories. Korea shows particular strength in its low technology sectors (textiles, footwear, garments and sports goods), which can be taken as an indicator of its technological upgrading in these areas.

Second, PRC, despite its rapid export growth, still had a relatively unsophisticated export structure. For example, its sophistication score in medium technology (such as engineering, capital goods and industrial chemicals) and high technology (such as electronics and electricals) is lower than that of India (but see point four below). It is also below Latin America in low technology and some medium and high technology goods.

Third, some resource-based manufactured exports are, not surprisingly, location specific due to the availability of natural resources. This may explain the relatively low sophistication scores for resource-based manufactures from Latin America: exporters may be specializing in goods using resources not widely available in developed economies.

Fourth, these scores take no account of *export volume* in each category. Hence there is the apparently anomalous result that Sub Saharan Africa and South Asia have relatively high scores in high technology goods, despite their relatively small exports. The explanation lies partly in the much narrower range of products exported by smaller players, and perhaps partly in that global networks have by-passed them, leading to little specialization in labor-intensive segments. Hence the small volumes of exports tend to be similar to goods from developed economies. PRC, on the other hand, has lower scores in these categories precisely because of its success in goods not exported by developed economies.

6.2 CHANGES IN SOPHISTICATION OVER TIME

Change in sophistication scores over time capture shifts in the location of export production between different income groups, and, by implication, the impact of changes in production fragmentation, local capabilities, transportability, trade arrangements, and so on. While the scores *per se* do not allow us to distinguish between these factors affecting location – sophistication analysis at higher levels of disaggregation may be more helpful – they do provide useful preliminary insights.

Table 11 shows changes in location patterns over the 1990s for selected product groups and broad technology categories. In the selected product groups, location is relatively stable (i.e. correlation coefficients between the 1990 and 2000 scores are relatively high) for textiles/yarn and telecom equipment, presumably because most shifts in export location took place before 1990.[30] There is more relocation in electrical machinery, office machinery and clothing & apparel. The group with the lowest correlation coefficient and the greatest shift is 'other transport equipment' (railway vehicles, aircraft and ships/boats). The shift here is mainly to the richer countries, with significant rises in sophistication scores for some railway equipment, most aircraft and warships.

Within each group, there are interesting differences at the product level in changes in sophistication scores, some products moving to poorer countries and others to richer ones. We could not explore these trends here, but there is clearly a rich area for further research here.

By technology groups, high technology products show relatively large shifts because of production fragmentation. Within RB products, agro-based products (RB2) show much larger shifts that mineral-based ones (RB1), perhaps because of greater opportunities for poor countries to improve their raw material base in the former by raising productivity or adding value in processing.

[30] As the three-digit scores for these industries show, both have low overall scores, with a substantial part of export activity based in lower income countries.

Table 11: Stability of sophistication scores by selected product and technology category (4-digit level)

Product group (SITC 2 digit group)	Number of 4 digit products	Correlation coefficients, 1990 & 2000
Iron and steel (67)	22	0.86
Textiles and yarn (65)	45	0.91
General industrial machinery (74)	25	0.66
Office machinery (75)*	11	0.55
Telecommunications (76)	12	0.91
Electrical machinery (77)	25	0.60
Other transport equipment (79)**	16	0.18
Clothing and apparel (84)	26	0.59
Technology category	**Number of 4 digit products**	**Correlation coefficients, 1990 & 2000**
RB1	104	0.92
RB2	89	0.76
LT1	77	0.88
LT2	78	0.80
MT1	16	0.93
MT2	84	0.85
MT3	104	0.81
HT1	38	0.70
HT2	28	0.68

* SITC 75 includes office machines and automatic data processing equipment

** Other transport equipment comprises railway vehicles, aircraft and ships & boats

For definition of technology categories see previous table.

In terms of the relation between overall sophistication scores (in 1990) and export growth (over 1990-2000) at the four-digit level, the correlation coefficient is low (0.26). As at the three-digit level, there is no significant relationship between the initial share of rich countries and subsequent growth: there is clearly industrial ‘catch-up’ in the export arena.

6.3 FOUR INDUSTRY CASE STUDIES

We illustrate further the application of the sophistication index for four industries*: textiles and clothing, automotives, electronics* and *industrial chemicals*. The index calculation at the industry level matches that for the technology categories explained above. Table 12 provides background on the selected industries, showing the number of four-digit products in each, the values of exports, the shares of developed and developing countries, and the shares of each major developing region. It also shows the highest ranking obtained by the most sophisticated product in each industry in the sophistication score for all 766 products in 2000.

Table 12: Background to industry cases				
	Textiles & clothing	**Automotives**	**Electronics**	**Industrial chemicals**
No. of 4-digit exports	100	10	30	41
Sophistication score of top product+	133	116	12	17
World exports 1990	$219.6 b.	$320.6 b.	$312.4 b.	$109.1 b.
World exports 2000	$343.0 b.	$570.4 b.	$997.2 b.	$197.4 b.
Compound growth rate 1990-2000	4.6%	5.9%	12.3%	6.1%
Share of developed countries, 2000*	52.2%	89.3%	75.2%	83.8%
Share of developing countries, 2000*	42.9%	4.7%	23.4%	11.6%
Regional share of developing world exports (2000)**				
All developing countries	**100%**	**100%**	**100%**	**100%**
East Asia	67.7%	34.3%	88.5%	60.9%
South Asia	10.8%	1.1%	0.2%	5.9%
LAC	9.1%	58.2%	10.4%	18.0%
MENA	10.3%	3.7%	0.4%	0.4%
SSA	1.7%	2.8%	0.1%	0.1%

Notes: + Ranking of most sophisticated product in industry group in scores for all 766 four-digit exports, 2000
* Shares of developed and developing countries do not sum to 100% because transition economies are excluded here.
** Developing regions include the relevant outliers: PRC in EA, Mexico in LAC, India in S Asia and South Africa in SSA

The textiles and clothing industry (defined broadly to cover all types of fabrics and yarn, including synthetics) has the largest number of items, the auto industry the smallest (but this does not include related components like tires, batteries, electronics and so on that are classified in the trade data under other industries). In technological terms, the most advanced industry is electronics, followed by industrial chemicals, automotive products, and textiles and clothing.
Within the developing world, East Asia dominates exports in all the industries apart from automobiles, in which LAC leads. South Asia is marginal in electronics and autos, but plays some role in the textiles and clothing and to a lesser extent in industrial chemicals. MENA is close behind South Asia in textiles and clothing (largely because of Turkey) and has some auto exports (Turkey again), but is marginal in the other two industries. SSA is marginal in all four, but its share is relatively large in the auto sector because of recent South African auto exports.

Table 13: Export sophistication scores by region for selected industries

Region	Textiles & clothing		Automotive		Electronics		Industrial chemicals	
	1990	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**
Developed	66.4	56.7	82.2	76.3	67.7	63.1	79.6	66.5
Developing	54.8	47.1	69.9	73.7	56.4	57.6	69.8	50.6
East Asia	56.0	48.4	72.0	75.3	56.4	57.8	75.6	53.8
S Asia	48.7	40.5	73.1	76.6	65.4	64.8	82.9	55.3
LAC	58.2	47.5	67.1	72.9	60.3	56.2	68.1	47.8
MENA	52.2	44.1	76.6	70.2	48.9	48.8	59.0	39.0
SSA	55.6	54.0	82.8	75.0	67.0	61.8	36.3	41.8

Table 13 shows the regional sophistication scores for the four industries. Not surprisingly, developed countries have higher scores than developing ones in all industries, though the sophistication level declines in all four. The highest average scores are in automotive products, where technological complexity and product weight combine to reduce the shift to poorer countries. The lowest score is in textiles and clothing, where low technology and labor-intensive processes have led to massive shifts in location. The electronics industry, as noted earlier, has undergone a substantial shift despite its high R&D intensity, while industrial chemical is somewhere in between it and the auto industry.

In terms of regional sophistication, the scores should be interpreted carefully bearing in mind the huge differences in export size (and thus the diversity of products) and the role of the dominant player in the region. In particular, scores for SSA may be misleading in that its exports are very small and are dominated by South Africa (very much a regional outlier in its level of industrial development). South Asian exports are also small and dominated by India. East Asia has highest level of sophistication in textile and clothing exports (if SSA is discounted), with LAC next and South Asia at the bottom. The higher sophistication of EA is likely to reflect the upgrading of exports in the advanced NIEs like the Republic of Korea and Taipei,China. The auto industry shows rather a narrow band of sophistication across the regions, probably reflecting the narrow range of products and their clustering in the high sophistication levels – there is, in other words, relatively little scope for specialization in different levels of sophistication in this industry.

The electronics pattern suggests that the three tiny exporters specialize in different segments of the industry: South Asia and SSA in high sophistication items and MENA in low sophistication ones. However, this pattern clearly cannot be taken as representative of national competencies. The two larger exporters, EA and LAC, have very similar sophistication levels, and the relocation of the industry to EA in fact determines the location pattern in the industry as a whole. If sophistication could be adjusted for local content, it is likely that EA would come out far ahead of LAC, where Mexico, the dominant exporter, has very low levels of local inputs. By contrast, Asian Tiger economies have made significant strides in terms of the design, development and production of products at all levels of the value chain. The industrial chemicals industry shows a pattern roughly matching levels of industrial development, with LAC and EA leading, South Asia in the middle, and SSA and MENA lagging.

6.4 SOPHISTICATION RELATION TO INCOME LEVEL

Another way in which we can use the sophistication index data by industry is to consider how the standing of individual countries by industry relative to their own income level has changed over time. Hence if countries show a rise in their outlier status, so that the difference between their actual index score and that predicted for their income level rises, this is prima facie evidence of upgrading within the industry category concerned. Conversely where their actual score is below that predicted and this gap widens this can be taken as evidence of downgrading. We conduct this simple regression analysis explaining the index by country income level within industries.

A few results are suggestive. In electronics PRC moves from a sophistication score over 20% below that predicted in 1990 to one almost exactly on the regression line for its income level. India on the other hand has a sophistication index 9%-11% above that predicted although there is a slight fall in the difference between actual and predicted levels between 1990 and 2000.

In textiles and clothing we find strong evidence of upgrading in Korea which moves from an index score slightly below that predicted to one 7% above. Somewhat surprisingly, Argentina appears to be upgrading in this industry: in 1990 and 2000 its index is well above the predicted level and this excess rises from 7% to 13% between 1990 and 2000. On the other hand, Sri Lanka and India have scores below that predicted, with the difference rising between 1990 and 2000.

In automotive products we find evidence of upgrading for both PRC and Tapei,China as they both move from situations of negative to positive outlier status between 1990 and 2000, with an excess of actual over predicted scores in 2000 of 11% and 14% respectively. In Korea we find the reverse with a move from a score nearly 20% above that predicted in 1990 to one 8% below that predicted in 2000.

For chemicals we find some evidence of downgrading in Korea with a score in 2000 5% below that predicted. India, on the other hand, has a higher than predicted score in both years, although the strength of its positive outlier status has diminished over time.

Such comparisons are only suggestive and it is difficult to draw strong inferences from these sophistication data without specific information on technologies and products, production capacities and determinants of location. The sophistication index cannot, as it stands, cast light on these factors; in combination with more data, however, it can be a useful tool to analyze competitive performance. We should also remember that further disaggregation may be necessary to understand complexity of products and processes in terms that would clarify if countries are moving up or down the value chain.

7. Conclusions

'Sophistication' provides a new and useful way of analyzing trade and location patterns and tracking competitiveness in developing countries. Its main advantage is that it can be calculated quickly at any level of detail and for any period. In this it has an edge over existing taxonomies that classify products according to parent industry characteristics and cannot provide unique scores for products at disaggregated levels. Its main disadvantage is that it is not a specific technology measure: it captures many other factors affecting export location, and care is needed in interpreting the results.

In general, however, our initial results are plausible. Let us reiterate some main ones.

- Sophistication correlates quite well with technology (for non-resource based manufactures) except when its impact is diluted by fragmentation, which allows technology-intensive activities to locate exports in countries that received theory would not predict. However, all 'fragmentable' activities (with discrete processes) do not fragment to similar extents: sophistication provides a useful tool to map this and identify activities with 'location inertia'. This can lead to further research on the causes of inertia – economies of agglomeration, links with innovation systems, special skill needs, government policy and so on – and provide insights to countries that wish to attract or upgrade those industries.
- Resource-based exports have the obvious pattern that has little to do with income levels (that ism countries export products for which they have the resources). However, there are exceptions caused by technological factors (accumulated skills), marketing and brands, and government protection and subsidization.
- In the aggregate sophistication does not have a strong relationship with growth rates. Exports by richer countries do not grow relatively fast: industrial catch-up means that exports by poorer countries is likely to grow more rapidly, aided by relocation of activities within global value chains. Thus, there is widespread (but not universal) 'de-sophistication' of manufactured products. However the strength of the relationship between sophistication and export growth in the 1990's varies by technology category with resource-based products having the closest relationship.
- Exports at the bottom of the sophistication scale do not grow rapidly. Most products in this category have low income-elasticity of demand and may be suffering declining prices. The poorest countries lack the industrial capabilities to move into more attractive products or attract hi-tech production networks. Low wages *per se* are not the driver of relocation but low wages for technically proficient workers, backed by modern infrastructure, suppliers and other capability and institutional factors needed for modern industry. By the same reasoning, having high per capita incomes is not a guarantee of a sophisticated export structure. Countries may become rich without building advanced industrial skills and capabilities; doing this requires specific strategies. This is clearly illustrated by the contrast between the low sophistication export structure of Hong Kong, China, one of the richest countries in East Asia, and the more advanced export structures of other mature Tigers in the region.
- The 'de-sophistication' process is highly skewed, a shift from high to middle income countries rather than to the poorest ones (a different sophistication index can illustrate this). There is a bulge in the middle of the sophistication scale, where the most dynamic exports concentrate.
- Regional sophistication scores in the developing world conform broadly to expectations, with Latin America and East Asia at the top and South Asia and Africa near the bottom.

While this paper is only a first cut at using the sophistication index, it suggests that the technique can be useful in several ways. First, the scores carry much information of practical and analytical value, if interpreted carefully. Second, the scores are product-specific and can be as detailed as needed. This allows qualitative and econometric analysis in a way that normal taxonomies do not.[31] Third, in conjunction with technology and value chain information, sophistication data can be used to analyze fragmentation and location inertia.

Fourth, sophistication can be used for country competitiveness analysis, allowing a rapid mapping of location shifts in exports of interest to a country.[32] Within narrow product segments it could locate the country with respect to its competitors in terms of the skill and technology level of its exports. More broadly, it could show if a country's sophistication structure of its exports is in line with its income level. It could also provide strategic insights on export performance, prospects and strategy.[33]

Sophistication is not a complete answer to the taxonomic needs of trade and industrial analysis – but then perhaps no single measure can be – but it does move matters forward. More work is needed to refine the index and construct other indices (geared to middle and low income countries or to finer levels of product detail). It is hoped that this preliminary exploration will stimulate such work.

[31] The advantage of the sophistication index is that it is a continuous variable. For an econometric analysis using sophistication data for Chinese and ASEAN exports, see Weiss and Gao (2003). The authors combine the absolute value of the sophistication index with dummies for technology categories in order to distinguish sophistication within a particular category like low or high technology and find that this interactive term is significant in explaining changes in market share.

[32] See, for instance, an application to Pakistan in Lall and Weiss (2004).

[33] Sophistication scores cannot be applied straightforwardly. Much depends on the nature of the product, the organisation of the value chain and the capabilities of the country in question. Take an export in which the country is doing badly and that is moving rapidly down the global sophistication scale. This would be undesirable if the de-sophistication denoted the relocation of a fast-growing, technologically advanced product; the policy implication would be to strengthen local capabilities and attract FDI in that industry. If, on the other hand, the product is technologically simple, the shift is likely to be caused by the entry of cheaper producers. Given that margins in the industry are likely to be low, technological benefits low and the possibility of competition growing very strong, the appropriate strategic response would be upgrade into much higher value segments, locate the low value segments elsewhere, or leave the activity altogether.

References

Arndt, S. W. and Kierzkowski, H. (ed.) (2001) *Fragmentation: New Production Patterns in the World Economy*, Oxford: Oxford University Press.

Deardorff, A. V. (2004) 'Local comparative advantage: trade costs and the pattern of trade', Ann Arbor: University of Michigan, Research Seminar in International Economics, Discussion Paper no. 500. http://www.fordschool.umich.edu/rsie/workingpapers/Papers476-500/r500.pdf

Gereffi, G., Humphrey, J. and Sturgeon, T. (forthcoming) 'The governance of global value chains', *Review of International Political Economy*.

Harrigan, J. and A. Venables (2004) "Timeliness, trade and agglomeration", New York: NBER, Working Paper no. 10404. http://www.nber.org/papers/w10404.

Hatzichronoglou, T. (1997) 'Revision of the high-technology sector and product classification', Paris: OECD, STI Working Papers, 1997/2.

Hummels, D., Ishii, J. and Yi, K. M. (2001) 'The nature and growth of vertical specialization in world trade', *Journal of International Economics*, 54(1), 75-96.

Kaplinsky, R. and Santos Paulino, A. (2004) 'Innovation and competitiveness: trends in unit prices in global trade', draft, Institute of Development Studies, University of Sussex.

Lall, S. (1992) 'Technological capabilities and industrialization', *World Development*, 20(2), 165-86.

Lall, S. (1996) *Learning from the Asian Tigers,* London: Macmillan.

Lall, S. (2000) 'The technological structure and performance of developing country manufactured exports, 1995-1998', *Oxford Development Studies*, 28 (3), 337-369.

Lall, S., Albaladejo, M. and Zhang, J. (2004) 'Mapping fragmentation: electronics and automobiles in East Asia and Latin America', *Oxford Development Studies*, 32 (3), 407-432.

Lall, S. and Weiss, J. (2004) *Industrial Competitiveness: The Challenge for Pakistan*, Islamabad: Asian Development Bank Resident Mission and Asian Development Bank Institute, Seminar Paper No 2. http://www.adbi.org

Lall, S. and Weiss, J. with H. Oikawa (2004) 'China's competitive threat to Latin America: an analysis for 1990-2002', Tokyo: Asian Development Bank Institute, Discussion Paper No 14. http://www.adbi.org

Mani, S. (2004) 'Exports of high technology products from developing countries: are the figures real or are they statistical artifacts?' in S. Mani and H. Romijn (eds.), *Innovation, Learning and Technological Dynamism of Developing Countries*, Tokyo: UN University Press, 12-47.

NSB (2002) *Science and Engineering Indicators*, Washington, DC: US National Science Board. Available on the NSB website.

Peneder, M. (2003) 'Industry classifications: aim, scope and techniques', *Journal of Industry, Competition and Trade*, 3:1/2, 109-129.

UNIDO (2004) *Industrial Development Report 2004*, Vienna: UN Industrial Development Organization.

Weiss, J. and Gao, S. (2003) 'China's export threat to ASEAN', Tokyo: Asian Development Bank Institute, Discussion Paper No. 2. http://www.adbi.org