WP-01-2016.E

ITC WORKING PAPER SERIES

ITC ASSESSMENT OF THE TECHNOLOGY LEVEL OF EXPORTS: METHODOLOGY AND ANALYTICAL ISSUES

October 2016

Sebastian Klotz
International Trade Centre, Geneva
and
World Trade Institute, Bern

Dzmitry Kniahin
International Trade Centre, Geneva

Marion Jansen
International Trade Centre, Geneva

International Trade Centre

TRADE IMPACT FOR GOOD

ITC ASSESSMENT OF THE TECHNOLOGY LEVEL OF EXPORTS: METHODOLOGY AND ANALYTICAL ISSUES

Sebastian Klotz[*]
Office of the Chief Economist,
International Trade Centre
and
World Trade Institute

Dzmitry Kniahin[+]
Market Analysis and Research,
International Trade Centre

Marion Jansen[x]
Chief Economist,
International Trade Centre

October 2016

Abstract

This paper outlines the development of the Technology Indicator as part of the country profiles in Part II of the SME Competitiveness Outlook 2016. As a starting point, we review four relevant technology classifications based on Broad Economic Categories (UN BEC), Process Stages (WTO), Skill- and Technology Intensity (UNCTAD) and High-Technology levels (OECD). While the classifications provide a useful first insight into the technological advancement of products, they share common drawbacks. First, the classifications do not allow a product ranking within technology groups. Second, the classifications are based on the characteristics and end-uses of the products which makes it difficult to assess their inferred technological intensity across different industries and sectors. To address these limitations, we review three alternative methodologies which exploit the characteristics of countries in order to draw conclusions on the technological intensity of the products they export. The discussion of the 'Sophistication Index of Exports', the 'PRODY' and the 'Product Complexity' methodologies concludes that a slightly adjusted version of the latter is the most suitable approach for the SME Competitiveness Outlook purposes. To verify the quantitative methodology and the results, we assess the correspondence between the classifications and the Product Complexity Index and conclude that the two approaches are complementary.

JEL Classification: F13, F14

Keywords: Competitiveness, complexity, export upgrading, technology, value chains

[*] klotz@intracen.org
[+] kniahin@intracen.org
[x] jansen@intracen.org

Introduction

International trade can be an engine for inclusive economic growth and poverty reduction, and contribute to the promotion of sustainable development. To realise these potential gains, firms, and in particular small- and medium enterprises (SMEs), must not only diversify their exports but also connect to and move up within international value chains (IVCs).

The country profiles in Part II of the SME Competitiveness Outlook 2016 employ ITC's Export Potential Assessment methodology to identify products with unrealized export potential and diversification opportunities. The quantitatively computed results are reconciled with country and product experts to develop a national export strategy. To foster sustainability and inclusiveness, products are not only evaluated on the basis of their export potential but also in terms of their feasibility for SMEs' production capacities, their ability to promote the entrepreneurial independence of women, and their technological intensity. The latter indicator captures the approximate position of a product in a value chain and therefore its importance for moving up within a value chain. But how exactly can the technological intensity of a product be assessed?

As a starting point, the first Section of this paper reviews four relevant product classifications based on Broad Economic Categories (UN BEC), Process Stages (WTO), Skill- and Technology Intensity (UNCTAD) and High-Technology (OECD) levels. While the classifications provide a useful first insight into the technological intensity of products, they share common drawbacks. First, the four classifications do not allow a product ranking within technology groups. Second, the classifications are based on the characteristics and end-uses of the products which makes it difficult to assess their inferred technological intensity across different industries and sectors.

To address these limitations, the second Section reviews three alternative methodologies which exploit the characteristics of countries in order to draw conclusions on the technological intensity of the products they export. The discussion of the 'Sophistication Index of Exports', the 'PRODY' and the 'Product Complexity' methodologies concludes that a slightly adjusted version of the latter is the most suitable approach for the SME Competitiveness Outlook purposes.

To verify the quantitative methodology and the results, the third Section assesses the correspondence between the computed Product Complexity Index and the mentioned classifications. The results indicate that the Product Complexity scores largely correspond to the classifications: On average, processed and high-tech products are indeed more technologically complex than primary, raw products and resource- and labour intense products, respectively. However, the results also show that there are some notable exceptions to this. Some raw and primary products, for instance, are found to have a relatively high technological complexity. Furthermore, some products that are classified as medium-tech are actually found to be more technologically complex than high-tech products.

Section 1: Review of technology classifications

1. Overview

This Section reviews and compares four of the most widely used technology classifications including the UN Broad Economic Categories (UN BEC) classification, the WTO Process Stage classification, the UNCTAD Skill- and Technology product classification and OECD High-technology classification of manufacturing industries.

Before outlining the technology classifications in more detail in the following Section, Figure 1 and Figure 2 illustrate their composition. Figure 1 shows the composition of the technology classifications by the number of classified products.[1] More than half of the products in the UN BEC and the WTO classifications are processed products. Whereas the UNCTAD classification defines a quarter of all products as high-tech, the OECD classification only defines 8% of products as such. The correspondence between the classifications is discussed in detail below.

Figure 1. Composition of technology classifications, by number of products

***Note**:* Bubble size reflects the number of products classified under the specified category.
***Source**:* Authors' calculations.

Figure 2 illustrates the importance of the different classifications in world exports (2014) and points to a first potential problem of the classifications. Considerable shares of world exports fall into the groups of "unclassified products" and "other" products which may present a problem for assessing the technological intensity of countries' export baskets.

[1] As discussed below, the four classification are based on different product and industry classifications and their revisions. To facilitate compatibility, product groups based on HS6 products are used. For details, please see Decreux and Spies (2015).

Figure 2. Composition of technology classifications, by world exports (2014)

***Note**:* Bubble size reflects world export value of all products classified under the specified category.
***Source**:* Authors' calculations.

1.1. Broad Economic Categories classification

The latest published version of UN BEC (Box 1) is the fourth revision from 2002, defined in terms of the Standard International Trade Classification (SITC, revision 3) and the Harmonized Commodity Description and Coding System (HS, third edition). (UNSD, 2002)

The original classification was issued in 1971. Since then, UN BEC was first revised in 1976 (conformed to the changes in SITC, revision 2), second revised in 1984 (conformed to changes in SITC, revision 3) and third revised in 1986 (corrected some oversights in the 1984 revision).

Box 1. Broad Economic Categories classification (fourth revision)

1 – Food and beverages
- 11 – Primary
- 12 – Processed

2 – Industrial supplies not elsewhere specified
- 21 – Primary
- 22 – Processed

3 – Fuels and lubricants
- 31 – Primary
- 32 – Processed

4 – Capital goods (except transport equipment), and parts and accessories thereof
- 41 – Capital goods (except transport equipment)
- 42 – Parts and accessories

5 – Transport equipment and parts and accessories thereof
- 51 – Passenger motor cars
- 52 – Other
- 53 – Parts and accessories

6 – Consumer goods not elsewhere specified
- 61 – Durable
- 62 – Semi-durable
- 63 – Non-durable

7 – Goods not elsewhere specified

***Source**:* United Nations Statistics Division (2016). UN BEC – Detailed structure and explanatory notes. Geneva. Available from http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=10.

In 2016, the latest, fifth, version of UN BEC was endorsed by the United Nation Statistical Commission (UNSD). This revision aims to re-define the UN BEC structure to better reflect current economic realities, give particular attention to intermediate goods and extend the scope to include services. With its adoption, focus has now shifted to finalizing the correspondence tables between the fifth revision of UN BEC and HS, the Central Product Classification (CPC), the Extended Balance of Payments Services Classification (EBOPS) and the International Standard Industrial Classification (ISIC). (UNSD 2016) Since the fifth revision is not published yet, this paper employs the fourth UN BEC revision.

Box 2. HS sections (third revision)

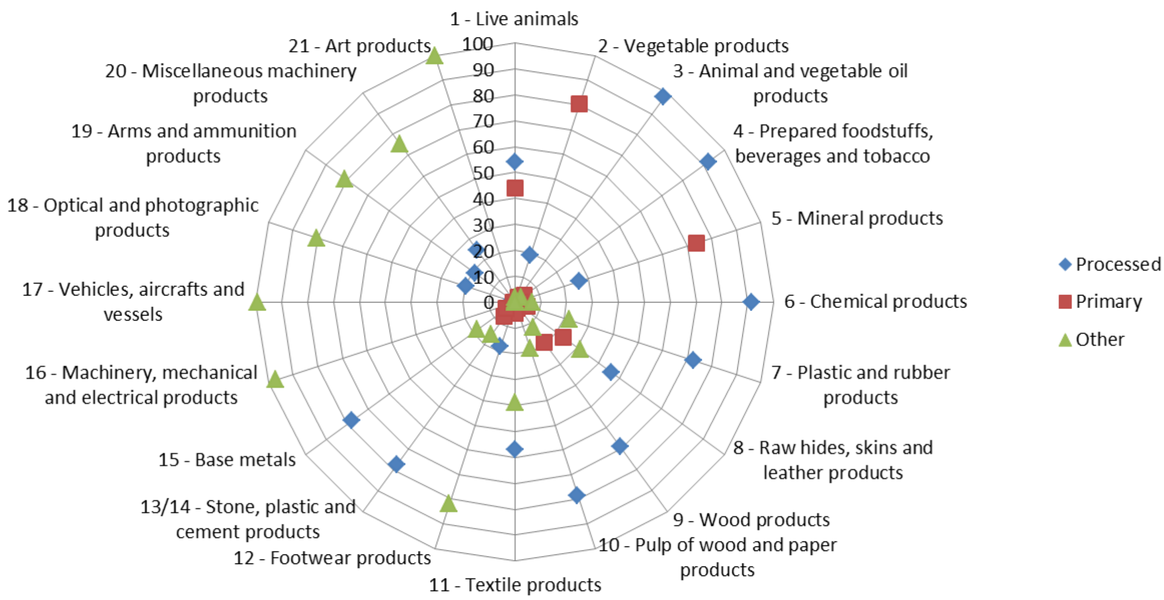
1 - Live animals; Animal products
2 - Vegetable products
3 - Animal or vegetable fats and oils and their cleavage products; Prepared edible fats; Animal or vegetable waxes
4 - Prepared foodstuffs; Beverages, spirits and vinegar; Tobacco and manufactured tobacco substitutes
5 - Mineral products
6 - Products of the chemical or allied industries
7 - Plastics and articles thereof; Rubber and articles thereof
8 - Raw hides and skins, leather, fur skins and articles thereof; Saddlery and harness; Travel goods, handbags and similar containers; Articles of animal gut (other than silk-worm gut)
9 - Wood and articles of wood; Wood charcoal; Cork and articles of cork; Manufactures of straw, of esparto or of other plaiting material; basket ware and wickerwork
10 - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard; Paper and paperboard and articles thereof
11 - Textiles and textile articles
12 - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; Prepared feather and articles made therewith; Artificial flowers; Articles of human hair
13 - Articles of stone, plaster, cement, asbestos, mica or similar materials; Ceramic products; Glass and glassware
14 - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewelry; Coin
15 - Base metals and articles of base metal
16 - Machinery and mechanical appliances; Electrical equipment; Parts thereof; Sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles
17 - Vehicles, aircraft, vessels and associated transport equipment
18 - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; Clocks and watches; Musical instruments; Parts and accessories thereof
19 - Arms and ammunition; Parts and accessories thereof
20 - Miscellaneous manufactured articles
21 - Works of art, collectors' pieces and antiques

***Source**:* United Nations Statistics Division (2010). HS Classification by Section. Geneva. Available from http://unstats.un.org/unsd/tradekb/Knowledgebase/50043/HS-Classification-by-Section.

The UN BEC classification is not a technology classification in the strict sense. However, its subcategories define primary and processed products which, in turn, provide a potential proxy for the technology content of products. To provide an idea of which products are defined as primary and processed products, Figure 3 relates the classification to the HS sections outlined in Box 2.[2]

[2] The focus of this paper is the technological intensity of products. It is therefore indicative to see which products are defined as primary and processed. The other groups (UN BEC 4 – 7) are less relevant in this context and are therefore grouped together under "Other" in Figure 3.

Figure 3. Broad Economic Categories and HS sections



Note: A point represents the share of products of a specified category in the HS section (0 is 0%, 100 is 100%).
Source: Authors' calculations.

To understand Figure 3, consider the example of "1 – Live animals". Around 45% of products that fall under this HS section are defined by UN BEC as primary products. The remaining 55% of products under this HS section are defined as processed products. The "6 – Chemical products" HS section is much less divided – around 92% of products under this HS section are defined as processed products. If one accepts the process stage of a product as a proxy for its technological intensity, then the previous numbers confirm that chemical products are indeed more technologically advanced than live animals. The limitations to the applicability of this argument are discussed below.

The UN BEC classification provides a good starting point to think about the technological content of products. However, by definition the classification is concerned with economic categories and the end-use of products. As a consequence, important information for the purpose of this paper is lost. Not every HS6 product can be identified to be either a primary or processed product. For instance, UN BEC defines the large part of "16 – Machinery, mechanical and electrical products" as "4 – Capital goods". Electric sound amplifier sets (HS6 code: 851850), for example, are identified as capital goods. While it is safe to argue that electric sound amplifiers are processed products, this information is lost and the classification therefore not suitable for assessing the technological advancement of all HS6 products.

1.2. Process Stages classification

The process stage of products plays an important role in trade negotiations and tariff calculations. The term "tariff escalation", for instance, captures the common situation in which higher duties are applied on semi-processed products than on raw materials, and higher still on finished products. (WTO, 2016)

The WTO Process Stage classification (Box 3) is useful for the purpose of this paper because it groups products not only into processed and raw products but also semi-processed products.

Box 3. Process Stages classification

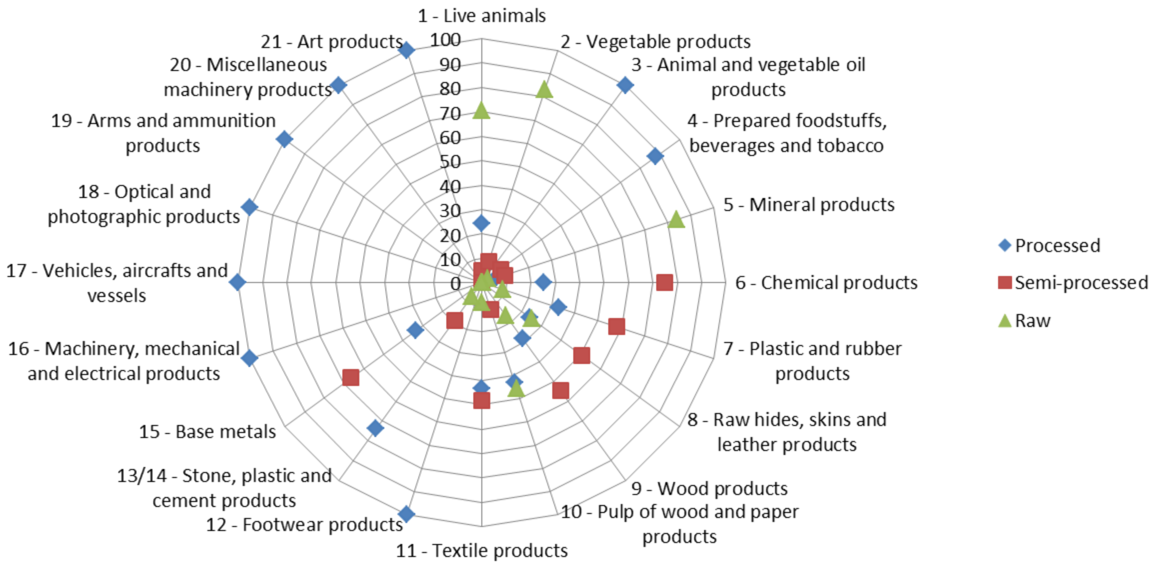
1 - Processed products
2 - Semi-processed products
3 - Raw products

Source: World Trade Organization (2001). Market Access: Unfinished Business — Post Uruguay Round Inventory. WTO Special Studies, No. 6. Geneva: World Trade Organization. Available from https://www.wto.org/english/res_e/publications_e/special_studies6_e.htm.

Figure 4 illustrates how different product groups are composed of processed, semi-processed and raw products. Unsurprisingly, “1 – Live animals”, “2 – Vegetable products” and “5 - Mineral products” are largely composed of raw products. Perhaps more interestingly, Figure 4 shows to which extent certain product groups are composed of processed and semi-processed products. The HS sections in the north-west area of Figure 4 are exclusively composed of processed products. Three quarters of “6 – Chemical products”, in contrast, are semi-processed products.

Does this indicate that chemical products are less technologically advanced than machinery and electrical products? Similarly, are “11 – Textile products” less technologically advanced than “12 – Footwear products” because the latter are exclusively composed of processed products while 50% of textiles are semi-processed products?

Figure 4. Process Stages and HS sections



Note: A point represents the share of products of a specified stage in the HS section (0 is 0%, 100 is 100%).
Source: Authors’ calculations.

The answer to both questions is, of course, no. Similarly to the UN BEC classification, the WTO classification provides only a first idea about the technological intensity of products by defining all HS6 products as (semi-) processed or raw products. And indeed, it is safe to argue that (semi-) processed products are technologically more advanced than raw products.

The same argument, however, cannot be made with regard to processed and semi-processed products. The fact that a chemical is rarely a final (processed) product but is most often used as an input (semi-processed) does not reveal much about the technological intensity of the chemical itself. This observation will be discussed in further detail in Section 3.

It follows that the WTO classification is more useful in measuring the technological intensity of products than the UN BEC classification because it covers a wider range of HS6 products. However, grouping products into processed, semi-processed and raw is still not a satisfactory measure of technological intensity for the reasons outlined above.

1.3. Skill- and Technology Intensity classification

The United Nations Conference on Trade and Development's (UNCTAD) Skill- and Technology intensity classification is more promising. The classification (Box 4), developed in Basu and Das (2011) and Basu (forthcoming), builds up on UNCTAD (1996, 2002) and Lall (2000, 2005) and groups products into high-, medium-, and low technology, resource intensive, minerals and commodities.

Box 4. Skill- and Technology Intensity classification

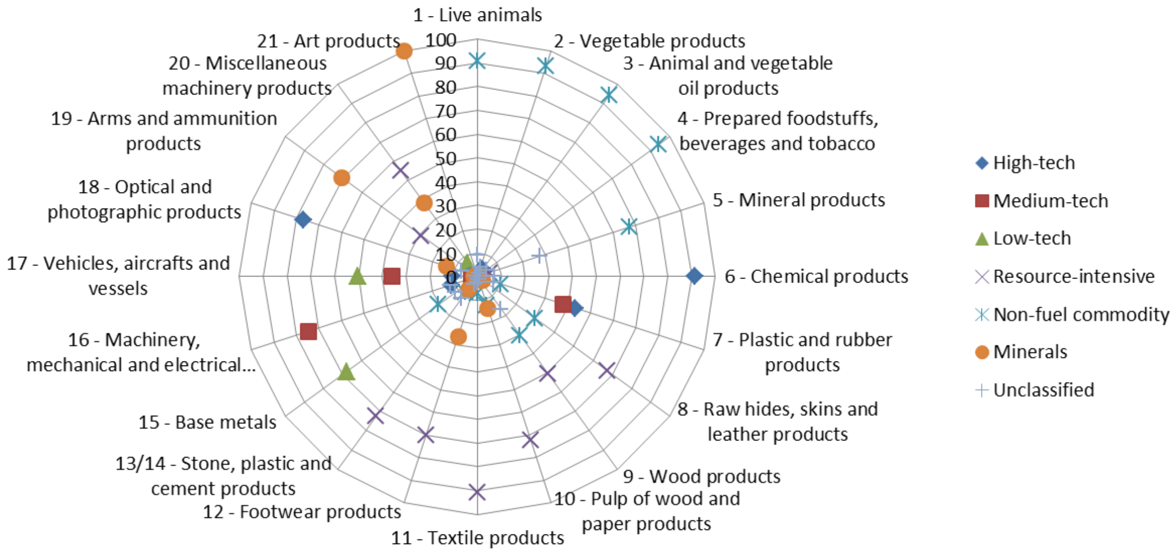
1 - High skill- and technology intensive manufactures
2 - Medium skill- and technology intensive manufactures
3 - Low skill- and technology-intensive manufactures
4 - Resource-intensive manufactures
5 - Non-fuel primary commodities
6 - Mineral fuels

***Source**:* Basu, S.R. and Das, M. (2011). Export Structure and Economic Performance in Developing Countries: Evidence from Nonparametric Methodology. Policy Issues in International Trade and Commodities Study Series, No. 48. Geneva: United Nations Conference on Trade and Development. Available from http://unctad.org/en/Docs/itcdtab49_en.pdf.

To do so, the classification takes into account the mix of different skill, technology, capital and scale requirements at the final product stage (UNCTAD, 1996). Figure 5 illustrates how the classification corresponds to different product groups.

"6 – Chemical products" and "18 – Optical and photographic products" are the most technologically intense product groups. "7 – Plastic and rubber products", "16 – Machinery, mechanical and electrical products" and "17 – Vehicles, aircrafts and vessels" include mainly medium-tech and low-tech products. Resource-intensive products, which to a large extent include labour-intensive products, account for more than 90% of "11 – Textile products".

Figure 5. Skill- and Technology Intensity classification and HS sections



***Note**:* A point represents the share of products of a specified category in the HS section (0 is 0%, 100 is 100%).
***Source**:* Authors' calculations.

In summary, the UNCTAD classification is useful for the purpose of this paper because it not only allows differentiating between technology-intense and other products but also within technology-intense products. It furthermore covers the full range of HS6 products.

1.4. High-technology classification

The origins of the OECD High-technology classification date back to 1984, when the Secretariat developed the initial classification based on direct research and development (R&D) intensity, measured by R&D expenditure in relation to output, weighted by sector and country. The initial classification, based on the second revision of ISIC, differentiated between high, medium and low technology industries.

The classification was refined in 1997 to take the importance of direct and indirect R&D intensity into account and to correspond to the third revision of ISIC. The former captures the extent to which an industry produces technology whereas the latter captures the extent to which an industry uses technology. The direct indicator is obtained by weighing each sector with its share in the production or value added of all OCED countries, taking GDP purchasing power parities as exchange rates. The indirect intensity is based on the R&D expenditure embodied in intermediates and capital goods purchased on the domestic market or imported. (Hatzichronoglou, 1997) Industries classified in a higher category have a higher OECD-average technology intensity than industries in a lower category. The resulting classification is outlined in the Box 5.

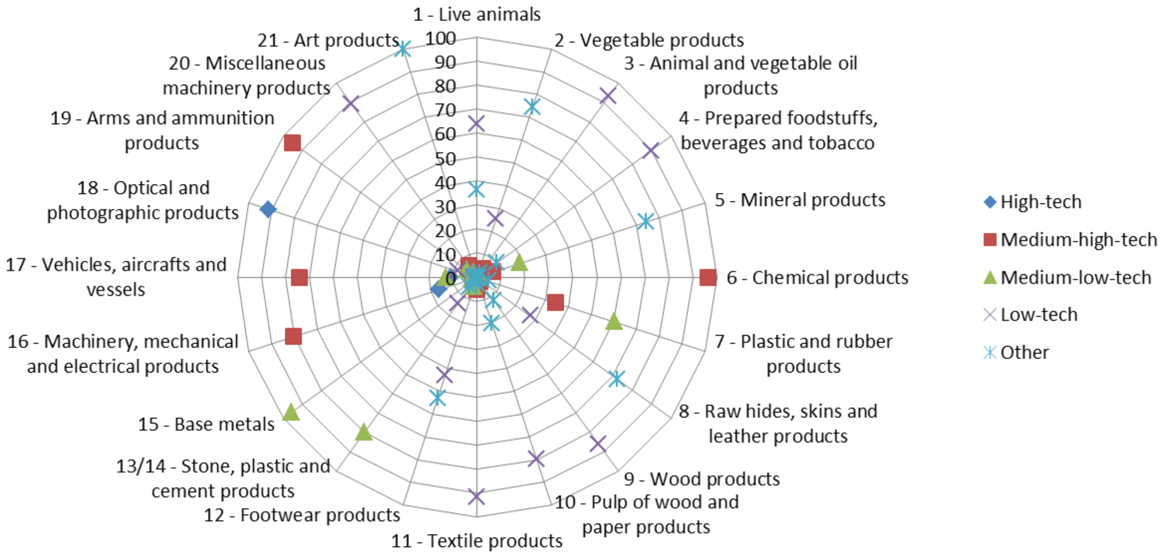
Box 5. High- technology classification

1 - High-technology
2 - Medium-high technology
3 - Medium-low technology
4 - Low-technology
5 - Other

Source: Organisation for Economic Co-operation and Development (2011). Technology Intensity Definition. Paris. Available from http://www.oecd.org/sti/ind/48350231.pdf.

Figure 6 illustrates which product groups are identified to be technology intense. “18 – Optical and photographic products” are by far the most technologically intense products with more than 90% of products in this group being considered as high-tech. “6 – Chemical products”, “19 – Arms and ammunition products”, “16 – Machinery, mechanical and electrical products” and “17 – Vehicles, aircrafts and vessels” include mainly medium-high tech products. Low-tech products account for more than 90% of “11 – Textile products”.

Figure 6. High-technology classification and HS sections



Note: A point represents the share of products of a specified category in the HS section (0 is 0%, 100 is 100%).
Source: Authors’ calculations.

The OECD classification is appealing because it is based on a quantitative methodology and allows a detailed differentiating between technologically intense products. The following Section summarises the reviewed classifications and assesses their correspondence.

2. Summary and conclusions on technology classifications

The four classifications reviewed in the previous Section provide a useful first insight into the technology intensity of products. The UN BEC classification allows differentiating between primary and processed products which are valid proxies for technologically less and more advanced products, respectively. The WTO classification has a similar approach but additionally differentiates between semi-processed and processed products. Whether processed products are necessarily more technology intense than semi-processed products is less clear-cut and will be discussed in further detail in Section 3. The UNCTAD classification and the OECD classification allow differentiating between high, medium and low technology-intense products.

Figure 3, Figure 4, Figure 5 and Figure 6 illustrated how the product classifications correspond to different HS sections. Table 1 aims to summarise the correspondence between the classifications. Of course, there cannot be a perfect correspondence between the classifications since they are designed for different purposes and are based on different methodologies. However, Table 1 shows that the classifications correspond fairly well.

Table 1 should be read from left to right rather than from top to bottom. To understand the table, consider the correspondence between the UNCTAD and OECD classifications. 23.57% of the products that are identified as high-tech by UNCTAD are also considered to be high-tech by the OECD. The majority (70.4%) of UNCTAD's high-tech products are considered to be medium-high tech by the OECD. The largest amount (81.68%) of UNCTAD's medium-tech products are considered to be medium-high tech products by the OECD. Another example that illustrates the correspondence are the products identified as primaries by UN BEC. 88.94% of these products are identified by the WTO as raw products. UNCTAD identifies 90.21% of UN BEC's primaries as non-fuel commodities and the OECD 86.17% as 'other products' (which makes sense because 'other products' capture all non-manufacture products).

Figure 7 and Figure 8 respectively visualise the correspondence between the WTO and UN BEC classifications and the OECD and UNCTAD classifications since these share common approaches.

The four classifications correspond fairly well to one another and can therefore be used to provide an idea of the technological intensity of products. However, they also share a common drawback. The classifications do not allow ranking products within a technology group. Instruments and appliances used in medical, surgical or veterinary sciences (HS6 code: 901890), for instance, are identified by all classifications as processed and high-tech. But so are headphones and earphones (HS6 code: 851830). While both are high-tech products, one would think that the former product is more technologically intense than the latter.

Section 2 outlines a methodology that allows a technology intensity ranking at the product level. Section 3 tests how this methodology fits with the classifications in the present Section.

Table 1. Correspondence between different classifications

		Broad Economic Categories			Process Stages			Skill- and Technology							High-Technology				
		Processed	Primary	Other	Processed	Semi-processed	Raw	High-tech	Medium-tech	Low-tech	Resource-intense	Non-fuel commodity	Minerals	Unclassified	High-tech	Medium-high tech	Medium-low tech	Low-tech	Other
Broad Economic Categories	Processed				39.33	54.5	6.17	35.69	3.39	13.2	10.67	25.38	2.33	9.35	1.92	37.77	33.52	24.72	2.07
	Primary				3.83	7.23	88.94	1.28	0	0.21	2.13	90.21	0.21	5.96	0	0.85	0.85	12.13	86.17
	Other				99.35	0.29	0.36	16.92	44.11	11.42	12.51	0.8	7.74	6.51	19.02	50.11	12.58	13.23	5.06
Process Stages	Processed	35.85	0.83	63.32				17.65	29.82	12.58	14.06	12.12	7.05	6.73	13.87	38.66	18.62	24.56	4.29
	Semi-processed	96.59	3.05	0.36				50.36	2.69	13.17	6.27	17.2	0	10.3	0	50.72	38.44	7.97	2.87
	Raw	22.39	76.7	0.92				0.18	0	0	3.49	88.44	0.18	7.71	0	7.16	1.47	19.63	71.74
Skill- and Technology	High-tech	74.63	0.63	24.74	40.49	59.41	0.11								23.57	70.4	3.59	1.27	1.16
	Medium-tech	9.9	0	90.1	95.57	4.43	0								4.73	81.68	13.29	0	0.3
	Low-tech	62.14	0.24	37.62	65	35	0								0	16.19	83.57	0	0.24
	Resource-intense	53.55	2.54	43.91	77.41	17.77	4.82								0.51	2.79	33.5	49.49	13.71
	Non-fuel commodity	53.58	45.25	1.17	28.07	20.49	51.44								0	3.31	13.55	41.62	41.52
	Minerals	29.87	0.65	69.48	99.35	0	0.65								6.49	7.14	3.25	64.94	18.18
	Unclassified	61.06	9.24	29.7	48.18	37.95	13.86								11.22	34.32	33.66	10.56	10.23
High-Technology	High-tech	12.62	0	87.38	100	0	0	74.09	10.63	0	0.66	0	3.32	11.3					
	Medium-high tech	51.73	0.28	47.99	58.1	39.2	2.7	46.12	38.3	4.71	0.76	2.15	0.76	7.2					
	Medium-low tech	78.83	0.48	20.69	48.04	51.01	0.95	4.04	10.7	41.74	15.7	15.1	0.59	12.13					
	Low-tech	67.08	7.82	25.1	73.11	12.21	14.68	1.65	0	0	26.75	53.5	13.72	4.39					
	Other	7.95	78.49	13.57	18.02	6.2	75.78	2.13	0.39	0.19	10.47	75.39	5.43	6.01					

***Note**:* Each number represents the share of products classified under the category on the left that also fall under the category at the top (0 is 0%, 100 is 100%).
***Source**:* Authors' calculations.

Figure 7. Correspondence between Process Stages and Broad Economic Categories classifications

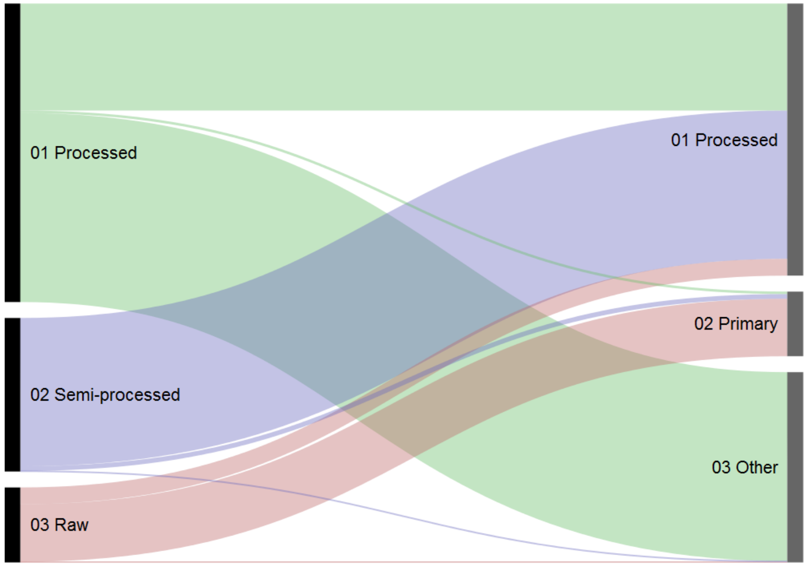
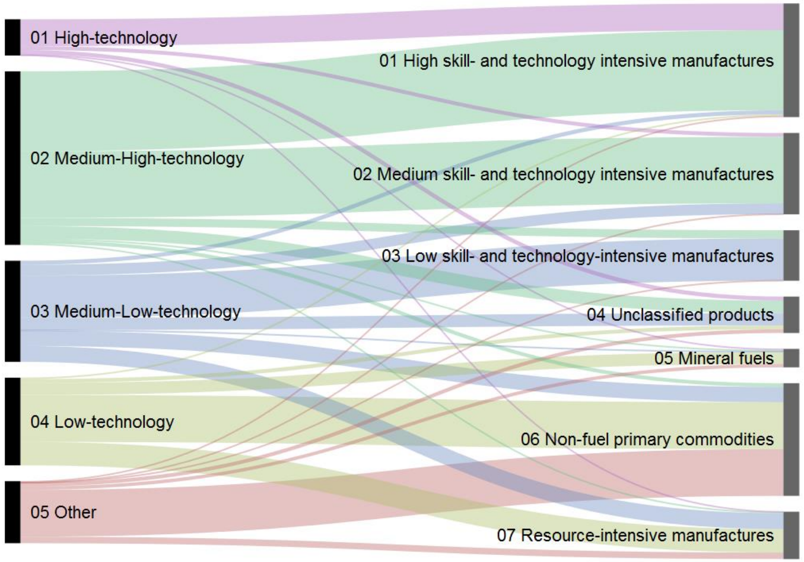


Figure 8. Correspondence between the High-technology and Skill- and Technology Intensity classifications



***Note**:* The figure maps products between two classifications. The height of each block represents the number of products in the category, the height of a stream represents overlapping products.
***Source**:* Authors' calculations.

Section 2: Review of technological complexity indicators

The four technology classifications outlined in the previous Section provide a good starting point to think about the technological intensity of products. As mentioned, there are some drawbacks, however. First, the four classifications do not allow for a product ranking within technology groups. Second, the classifications are based on the end-uses and characteristics embodied in the products, which makes it difficult to assess their inferred technological intensity across different industries and sectors.

To address these limitations, this Section reviews three alternative methodologies which exploit the characteristics of countries to draw conclusions on the technological advancement of products they export. The discussion of the 'Sophistication of Exports', the 'PRODY' and the 'Product Complexity' methodologies concludes that a slightly adjusted version of the latter is the most suitable approach for the SME Competitiveness Outlook purposes.

1. Sophistication of Exports and PRODY

The Export Sophistication Index, developed by Lall et al. (2005), is based on the assertion that a product is more sophisticated the higher the income of its average exporter. The authors note that the Index is an amalgam of different measures (technology, marketing, logistics and proximity, fragmentability, information and familiarity, natural resources, infrastructure, value chain organisation) and that, while technology is a major factor in the Index, its role cannot be separated from that of other factors. Hausmann et al. (2007) develop a similar argument.

The indicators in both papers compute the average income level of countries that export a product. The difference is in the weights. Lall et al. (2005) use a country's share in a product's world exports as a weighting scheme whereas Hausmann et al. (2007) use a product's share in a country's total exports. More formally:

$$S_k = \frac{\sum_i X_{ik} Y_i}{\sum_i X_{ik}}$$

$$PRODY_k = \frac{\sum_i x_{ik} Y_i}{\sum_i x_{ik}}$$

where S_k – sophistication of product k according to Lall et al.; Y_i – income level of country i (per-capita GDP); X_{ik} – exports of product k by country i; $x_{ik} = {X_{ik}}/{X_i}$- share of product k in country i's export basket.

Both methods allow ranking products based on their sophistication score (S) or PRODY as inferred from the income level of its exporters. However, there are three important limitations to the two methodologies. First, both methods do not recognise the processing stage of a product or any other characteristics of it. As a consequence, this may lead to some unexpected and counterintuitive results such as, for instance, synthetic rubber (a raw product) having a PRODY five times higher than that of rubber inner tubes (a processed product). Second, the country-wide measure of income (measured by GDP per capita) does not necessarily capture the technological level of a specific export sector within a country. McMillan and Rodrik (2011), for instance, point out that there can be considerable differences across sectors within a country. Third, today's global economy is characterised by international outsourcing and investment. When a multinational enterprise (MNE) decides to relocate a production plant from a developed to a developing country, it is not entirely clear how to capture the technological level of its sector. Should the Sophistication Score and PRODY calculations be based on the income level of the host country or the home country? The next Section outlines a methodology which, to a large extent, addresses these concerns.

2. Product Complexity

In contrast to the previously discussed methodologies, the Product Complexity methodology, developed by Hausmann and Hidalgo (2011), is based on a theoretical model. The model posits that in order for a country to export a product it has to have necessary 'capabilities'. Countries that have accumulated a lot of capabilities are able to export a larger variety of products including the most complex ones ('export diversification is good'). The term 'capabilities' captures all non-tradable inputs that go into the production of the product and that cannot be easily imported from abroad (Hausmann and Hidalgo, 2010). These include laws, procedures, know-how, institutions, and also different physical and geographical factors[3].

Since these 'capabilities' cannot be measured explicitly, Hausmann and Hidalgo propose an outcome-based approach of measuring product complexity by looking at the actual country-product specialization matrix M_{cp}. Its element m_{ik} is equal to 1 if country i has export specialization in product k and 0 otherwise. It is assumed that there are in total c countries and p products.

The following provides exposition of this method following the logic as in Hausmann and Hidalgo (2011). The methodology is based primarily on two concepts; diversity and ubiquity. Diversity is the number of products exported by a country with a revealed comparative advantage (RCA). Ubiquity is the number of countries that export a product with a RCA. The two concepts are interlinked in the following way. A country is considered to be economically complex if it exports a large number of different products (high diversity) that are only exported by a small number of other countries (low ubiquity). This is particularly true if these other countries also export a large number of different products (high diversity) that are only exported by a small number of other countries (low ubiquity), and so on. In other words, a country is economically complex if it exports a large number of products that are only exported by a small number of economically complex countries. By analogy, a product is considered to be economically complex if it is only exported by a small number of countries that export a large number of economically complex products. The concepts of diversity and ubiquity can therefore be used to correct one another.

More formally, ubiquity is calculated as:

$$q_{o,k} = Ubiquity_k = \sum_i m_{ik}$$

As mentioned above, ubiquity alone is not sufficient to capture complexity. Consider the case of rare natural resources such as diamonds. The fact that they are found in a few countries only, is not sufficient to argue that diamonds are very complex products. To learn more about the complexity of diamonds, it is necessary to check what other products diamond exporters export. Most diamond exporters only export few other products. In contrast, consider the example of space satellites. These are also only exported by few countries, mainly France and the United States. The important difference is that France and the United States also export a huge variety of other products.

To integrate this formally, the ubiquity score is augmented as:

$$q_{1,k} = \frac{\sum_i m_{ik} d_i}{\sum_i m_{ik}}$$

where $d_{o,i} = \sum_k m_{ik}$ is the diversity score of country i.

To improve this measure further, not only the number of other exported products (diversity) should be incorporated but also their ubiquity. Indeed, a product is complex if it is only exported by few countries which, in turn, export many complex products. This can be implemented by adding weights to the exported products in a country's diversity score where weights should be ideally complexities (q_k) of each product:

[3] For overview of 'capabilities' concept in Hausmann and Hidalgo framework see Kniahin (2014). For a specific example in one industry, see Hausmann and Rodrik (2006).

$$q_k = \frac{\sum_i m_{ik} \left(\frac{\sum_k m_{ik} \lambda q_k}{\sum_k m_{ik}} \right)}{\sum_i m_{ik}}$$

where λ is a scalar.

Since these complexities are the measure of interest in the first place (q_k), this problem can be rewritten as a classic eigenvector problem in linear algebra:

$$\tilde{\lambda} Q = \widetilde{M}_{cp}^T D = \widetilde{M}_{cp}^T \widetilde{M}_{cp} Q = AQ$$

where $Q = \left(q_1, \dots, q_p\right)^T$ – vector of product complexities q_k, A – linear transformation matrix, $\tilde{\lambda} = \lambda^{-1}$, $\widetilde{M}_{cp} = \frac{M_{cp}}{d_o}$, $\widetilde{M}_{cp}^T = \frac{M_{cp}^T}{q_o}$.

This matrix formula can be summarized in words as follows: "a product is considered complex if it is exported by countries that export predominantly complex products". Due to mathematical properties of the country-product matrix M_{cp}, the eigenvector associated with the largest eigenvalue is not informative[4]. Thus the eigenvector associated with the second largest eigenvalue is the final product complexity indicator.

3. Limitations of the Product Complexity methodology

The Product Complexity methodology addresses some limitations of the Sophistication Score and the PRODY methodology. However, this approach also has some weaknesses.

The first limitation is related to the methodology behind the Product Complexity. Since the measure is an outcome-based indicator, it might reveal some raw or simple products as being of a high technological level because they are exported only by a few developed economies. For example, paper envelopes and live swine score high on product complexity (in top 10%) because they are exported mostly by developed countries and China. However, the reasons behind this could be market-specific rather than technology-specific.

The second limitation, discussed in detail by Tacchella et al. (2013), is related to the mathematical formulation. The original formula uses an average diversity of a product's exporters (i.e. it is linear). However, one might be more interested to know the poorest countries that are capable of exporting a given product. Suppose product A is exported by the United States, Germany, China, Ghana, and Cambodia. Since the first three economies are sophisticated, on average, product A will come out as complex. However, the fact that this product is exported by Ghana and Cambodia is a hint that it could be of a low complexity and is probably reachable by Uganda or Myanmar. Tacchella et al. propose a non-linear variation of the Product Complexity formula where developing countries are assigned a bigger weight in the formula. Thus, the Product Complexity indicator could be improved in the future by taking into account this recent critique. Notwithstanding these limitations, the Product Complexity approach appears to be the most suitable for the purposes of the current edition of the SME Competitiveness Outlook. To see if the Product Complexity results are in line with the previously discussed product classifications, the next Section assesses the correspondence between them.

[4] For details see Hausmann et al. (2011), Inoua (2016).

4. Alteration of the Product Complexity methodology and its application in the SME Competitiveness Outlook

In the context of designing a national export strategy, the Product Complexity indicator can be useful for a policymaker in two ways:

- It indicates whether moving into a certain industry can improve the technological intensity of a country's export basket;
- It indicates whether moving into a certain industry is actually feasible, given the current level of a country's development.

In both cases there should be a country-specific average technological intensity of the current export basket against which the technological intensity of a specific product can be compared. In the case of PRODY, a country-wide benchmark could be EXPY. For the Product Complexity methodology this, however, does not exist in the literature.

In 2015, ITC authors (Decreux and Spies, 2015) designed a novel approach of measuring the average complexity of a country's export basket using the export-weighted median. It consists in arranging a country's exports in ascending order by Product Complexity and taking the Product Complexity value at the median point. Thus, 50% of a country's exports will be below this complexity level and 50% of country's exports will be above this complexity level. If the country manages to increase the exports of a product with a complexity that is higher than this median benchmark, this means that the country will be able to improve the overall technological complexity of its export basket[5].

The computed Product Complexity enter the SME Competitiveness Outlook in the form of a Boolean variable under the title "Technology Level" (Figure 9). It takes two values: (green square) and (red square). Value means that the complexity of the given product is above country average (as defined above) whereas means that this complexity is below country average. Policymakers can take this indicator into account when selecting prospective products for export diversification. Industries marked with might be more difficult to develop but will contribute to country's industrialization (i.e. a "strategic bet") whereas industries marked with will be less technologically-intensive but will be easier to move in (i.e., "a bird in the hand"). Note that this indicator does not address the second function of product complexity mentioned in the beginning of this section, i.e. it does not tell policymaker if the product is too complex to be reached by the country. This could be taken into account in the future, for example, by varying the colour shades of the indicator.

[5] Weighted median was preferred over weighted average for precaution reasons: it was not clear that outliers in terms of product complexity score actually reflected to the same amount the technological level of a product.

Figure 9. Potential of growth of current exports for Sri Lanka

Note: Top 20 products listed in decreasing order of their export potential to the world. Development indicators are relative to the country's current situation, green indicating performance above its trade-weighted median and red otherwise; a blank cell indicates data are not available. A blank cell in export potential means that the product was not consistently demanded over five years by any country in the respective region. Exports (US$ mn) corresponds to the yearly average exports to the world over the period 2009-13. Refer to Annexes I, II and III for details.

Source: ITC Export Potential Assessment, additional results are available at ITC Country Pages http://www.intracen.org/country/sri-lanka/

Section 3: Complexity scores and technology classifications

Section 1 outlined four product classifications based on Broad Economic Categories (UN BEC), Process Stages (WTO), Skill- and Technology Intensity (UNCTAD) and High-Technology (OECD) levels. Section 2 reviewed three quantitative methodologies and concluded that a slightly adjusted version of the Product Complexity approach is the most suitable for the SME Competitiveness Outlook purposes. This Section presents some preliminary analytical results to assess the extent to which the quantitatively computed Product Complexity scores correspond to the product classifications.

Table 2 indicates a positive significant association between the product classifications and the Product Complexity scores. The complexity of processed products, for instance, is on average 4.7 units higher than the complexity of semi-processed products.[6] The low R^2 value of around 0.2 indicates, however, that much of the explanatory power lies somewhere else and that a higher product classification may not be used to predict a higher Product Complexity score. A preliminary analysis suggests that the negative association between the UNCTAD classification and the Product Complexity scores is driven by a number of outliers and somewhat peculiar product allocations. A significant number of industrial products are defined as mineral fuels and assumingly high-tech products, such as cars, fall under medium-tech products.

Table 2. Simple linear regression: Product classification on Product Complexity scores

VARIABLES	(1) Product Complexity	(2) Product Complexity	(3) Product Complexity	(4) Product Complexity
BEC	12.22***			
	(0.495)			
WTO		4.723***		
		(0.202)		
UNCTAD			-0.524***	
			(0.139)	
OECD				3.413***
				(0.130)
Constant	60.01***	72.34***	88.81***	77.21***
	(0.916)	(0.511)	(0.332)	(0.333)
Observations	2,448	3,832	2,043	3,316
R-squared	0.199	0.125	0.007	0.173

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Any categories that could not be ordered, e.g. 'other', ‘resource-intensive’ or 'mineral resources', were removed.

Table 3 adds sector dummies to the regression to control for the variation of the Product Complexity scores between HS sections and, instead, to focus on the variation within a HS section. This analysis is particularly valuable in the context of value chains as it confirms that even within HS sections, products of a higher technology- or processing classification tend to have a higher Product Complexity score. The sign for the UNCTAD classifications changes but becomes insignificant.

[6] The Product Complexity scores are normalized using the standard min-max formula and rescaled it to 0-100.

Table 3. Simple linear regression: Product classification on Product Complexity scores, with sector dummies

VARIABLES	(1) Product Complexity	(2) Product Complexity	(3) Product Complexity	(4) Product Complexity
BEC	7.727***			
	(0.656)			
WTO		2.368***		
		(0.265)		
UNCTAD			0.341	
			(0.381)	
OECD				1.212***
				(0.280)
Constant	62.92***	70.74***	82.61***	74.28***
	(1.233)	(0.761)	(2.108)	(0.660)
Observations	2,448	3,832	2,043	3,316
R-squared	0.307	0.325	0.087	0.302

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Any categories that could not be ordered, e.g. 'other', ‘resource-intensive’ or 'mineral resources', were removed.

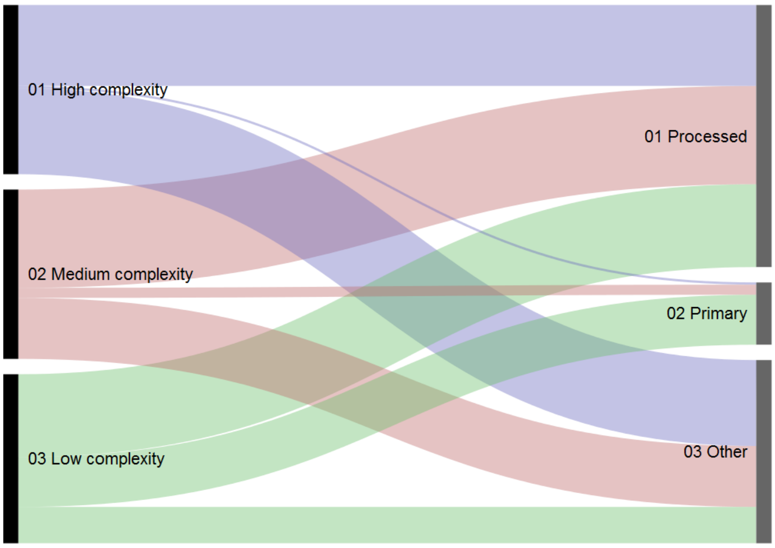
These preliminary results suggest that countries can increase the average complexity of their export baskets by diversifying into more sophisticated sectors such as moving from agriculture to electronics, but also by moving up the value chain within the sector they already specialize in, for example, from producing milk to producing cheese.

Having assessed the average correspondence between the product classification and the Product Complexity scores, the following sections look at the correspondence in more detail. For this purpose, the computed Product Complexity scores are divided into equal tertiles to capture products of ‘high’, ‘medium’, and ‘low’ complexity.

1.1. Broad Economic Categories classification

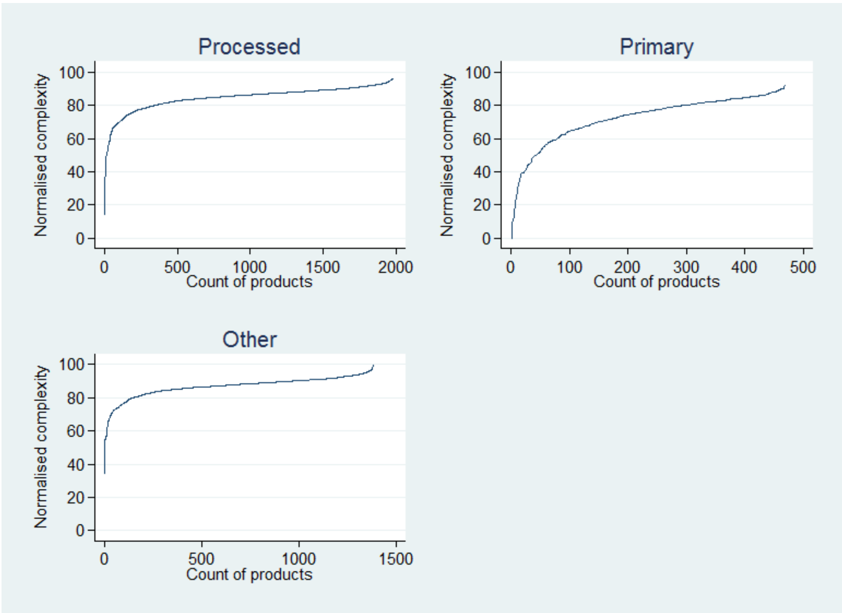
Figure 10 and Figure 11 visualise the correspondence between the complexity scores and the UN BEC product groups. Processed products are almost equally divided into high (30.89%), medium (37.51%) and low (31.60%) complexity products. The large majority (80.21%) of the primary products are found to be indeed of low complexity. However, there are also some primary products such as natural magnesium carbonite (HS6 code: 251910) and magnesium waste scrap (HS6 code: 810420) that fall into medium and highly complex products, respectively. High (46.93%) and medium (33.26%) complexity products account for the majority of the other products, the reason being that this group includes capital goods such as machinery as already discussed in Section 1.

Figure 10. Product Complexity scores and Broad Economic Categories



***Note**:* The figure maps products between two classifications. The height of each block represents the number of products in the category, the height of a stream represents overlapping products.
***Source**:* Authors' calculations.

Figure 11. Distribution of Product Complexity scores by Broad Economic Categories

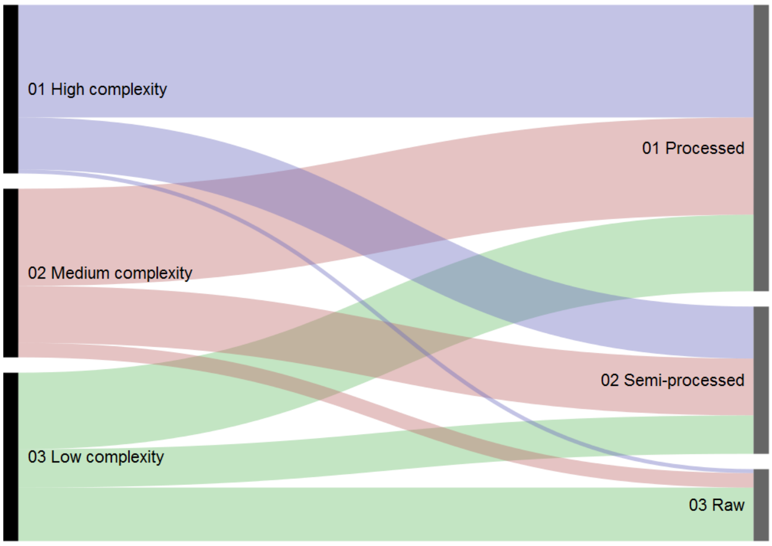


***Source**:* Authors' calculations.

1.2. Process Stages classification

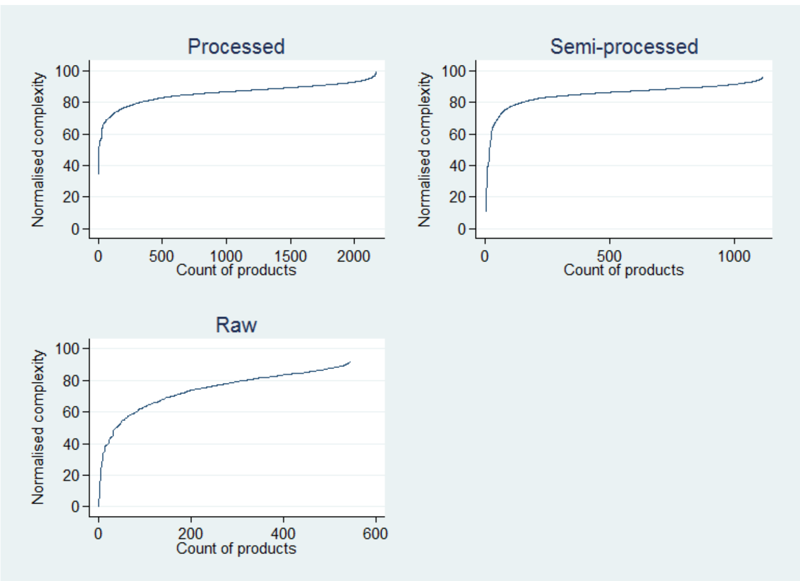
Figure 12 and Figure 13 illustrate the correspondence between the WTO classification and the computed product complexity scores. Similarly to the UN BEC classification, processed products of the WTO classification are almost equally dived into high (39.31%), medium (33.96%) and low (26.73%) complexity products. Similarly, semi-processed products include almost equal shares of high (35.3%), medium (38.62%) and low (26.08%) complexity products. The raw products are more clear-cut: Almost 75% of these products are found to have a low complexity. Raw products do, however, include products such as synthetic rubber (HS6 code: 400299) and forms of magnesia (HS6 code: 251990) that are found to be high and medium complex, respectively.

Figure 12. Product Complexity scores and Process Stages



***Note**:* The figure maps products between two classifications. The height of each block represents the number of products in the category, the height of a stream represents overlapping products.
***Source**:* Authors' calculations.

Figure 13. Distribution of Product Complexity scores by Process Stages

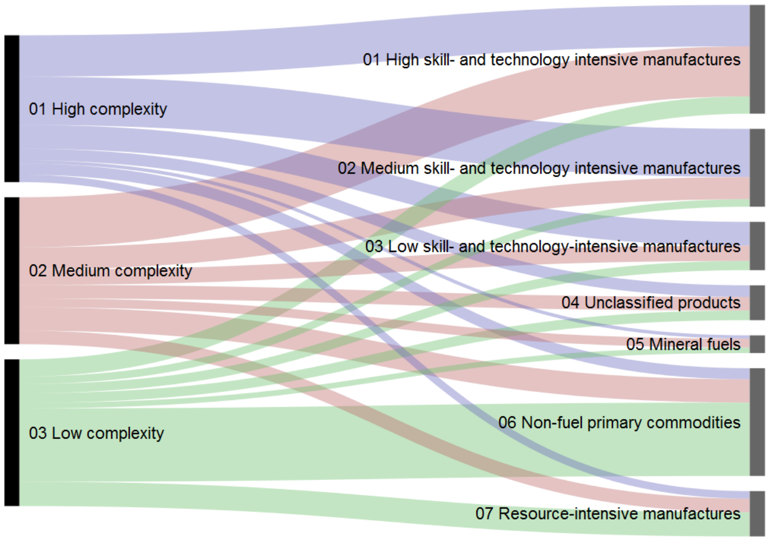


***Source**:* Authors' calculations.

1.3. Skill- and Technology Intensity classification

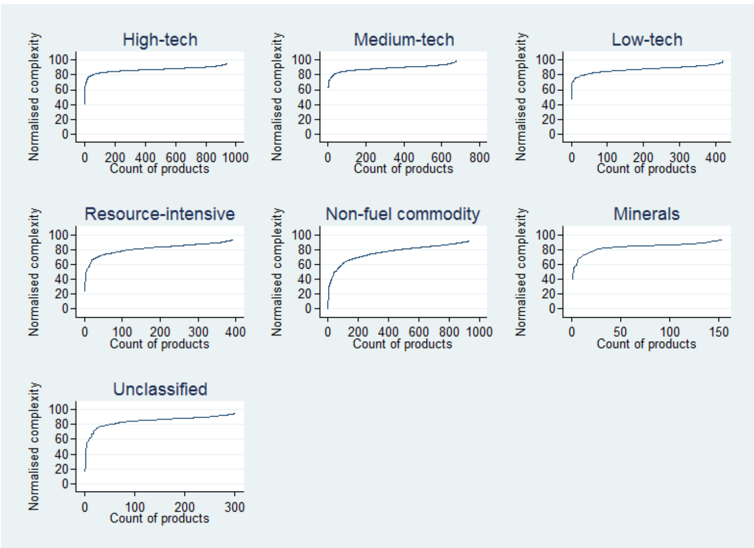
Figure 14 and Figure 15 visualise the correspondence between UNCTAD's Skill- and Technology classification and the computed product complexity scores. Interestingly, the largest part (46.09%) of high-tech products is found to be medium complex. Medium- and low tech products, in contrast, are largely composed of highly complex products – 61.89% and 49.29%, respectively. Half of mineral fuel products are medium complex; non-fuel primaries and resource-intense products are mainly composed of low complex products – 68.09% and 53.55%, respectively. But again, some resource-intense products such as, for example, woven fabrics of metal thread (HS6 code: 580900) have a fairly high complexity score.

Figure 14. Product Complexity scores and Skill- and Technology Intensity



***Note**:* The figure maps products between two classifications. The height of each block represents the number of products in the category, the height of a stream represents overlapping products.
***Source**:* Authors' calculations.

Figure 15. Distribution of Product Complexity scores by Skill- and Technology Intensity

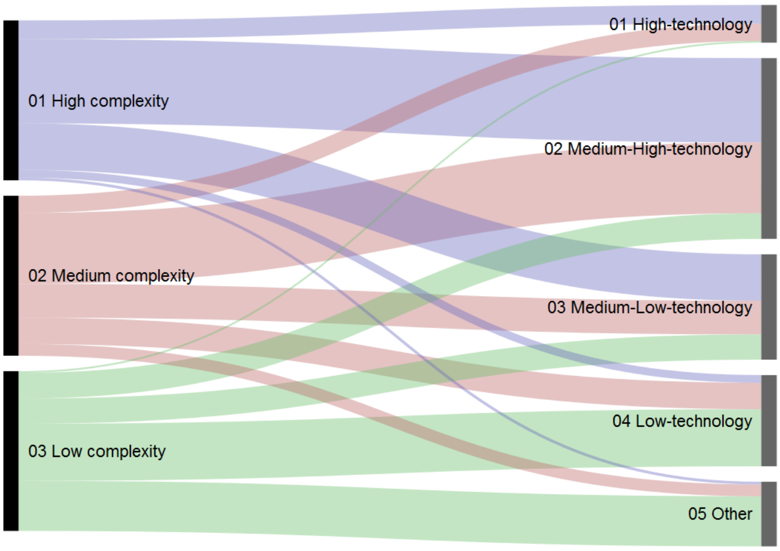


***Source**:* Authors' calculations.

1.4. High-technology classification

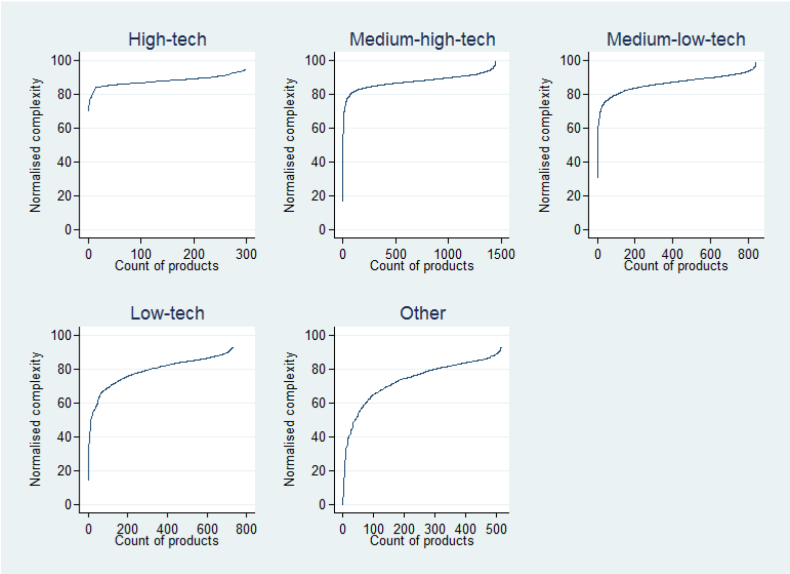
The correspondence between the complexity scores and the OECD classification on High-technology manufacturing products is shown in Figure 16 and Figure 17. High-tech products include largely highly complex products (49.5%) as well as medium complex products (45.85%). The majority of low-tech products (62.55%) is also found to be of low complexity. Similarly, non-manufacturing products (grouped together under 'other') include mainly low complexity products (77.52%).

Figure 16. Product Complexity scores and High-technology



Note*:* The figure maps products between two classifications. The height of each block represents the number of products in the category, the height of a stream represents overlapping products.
Source*:* Authors' calculations.

Figure 17. Distribution of Product Complexity scores by High-technology



Source*:* Authors' calculations.

Summary and Conclusions

This paper outlines the development of the Technology Indicator as part of the country profiles in Part II of the SME Competitiveness Outlook 2016. The ITC Export Potential Assessment methodology identifies products with unrealized export potential and diversification opportunities. The aim of the technology indicator is to capture the approximate position of a product in a value chain and therefore to suggest opportunities for moving up the value chain.

As a starting point, this paper reviews four relevant product classifications based on Broad Economic Categories (UN BEC), Process Stages (WTO), Skill- and Technology Intensity (UNCTAD) and High-Technology levels (OECD). The classifications are designed for different purposes and therefore vary considerably in their composition of products. It is found, however, that the classifications correspond fairly well to one another. For instance, products that are identified as primaries by UN BEC are largely also identified as raw products by the WTO. Similarly, products that are identified as technology intense by UNCTAD are largely identified as technology intense by the OECD, too.

While the classifications provide a useful first insight into the technological intensity of products, they share common drawbacks. First, the four classifications do not allow a product ranking within technology groups. Second, the classifications are based on the characteristics and end-uses of the products which makes it difficult to assess their inferred technological intensity across different industries and sectors.

To address these limitations, this paper reviews three alternative methodologies which exploit the characteristics of countries in order to draw conclusions on the technological intensity of products they export. The discussion of the ‘Sophistication Index of Exports’, the ‘PRODY’ and the ‘Product Complexity’ concludes that a slightly adjusted version of the latter is the most suitable approach for the SME Competitiveness Outlook purposes.

Finally, the paper assesses the correspondence between the computed complexity scores and the mentioned classifications. The results indicate that the complexity scores largely correspond to the classifications: On average, processed and high-tech products are indeed more technologically complex than primary, raw products and resource- and labour intense products, respectively. However, the results also show that there are some notable exceptions to this. Some raw and primary products, for instance, are found to have a relatively high technological complexity. Furthermore, some products that are classified as medium-tech are actually found to be more technologically complex than high-tech products. In conclusion, the two methodologies are complementary and may be used to control one another. Indeed, the correspondence of the technology classifications serves as a verification of the complexity scores. These, on the other side, allow ranking products within the technology classifications.

Bibliography

Basu, S.R., & Das, M. (2011). Export Structure and Economic Performance in Developing Countries: Evidence from Nonparametric Methodology. Policy Issues in International Trade and Commodities Study Series, No. 48. Geneva: United Nations Conference on Trade and Development. Available from http://unctad.org/en/Docs/itcdtab49_en.pdf.

Basu, S.R. (forthcoming). Retooling Trade Policy in Developing Countries: Does Technology Intensity of Exports Matter for GDP Per Capita? Policy Issues in International Trade and Commodities Study Series, No. 57. Geneva: United Nations Conference on Trade and Development.

Decreux, Y., & Spies J. (2015). Spotting Products With Export Potential: An ITC Assessment To Support Export Promotion Activities in 64 Developing Countries. Geneva: International Trade Centre. Available from http://www.intracen.org/publication/Spotting-Products-with-Export-Potential/.

Hatzichronoglou, T. (1997). Revision of the High-Technology Sector and Product Classification. OECD Science, Technology and Industry Working Papers, No. 1997/02. Paris: Organisation for Economic Co-operation and Development. Available from http://www.oecd-ilibrary.org/science-and-technology/revision-of-the-high-technology-sector-and-product-classification_134337307632.

Hausmann, R., & Hidalgo, C. (2010). Country Diversification, Product Ubiquity, and Economic Divergence. HKS Faculty Research Working Paper Series RWP10-045. Boston: John F. Kennedy School of Government, Harvard University. Available from https://dash.harvard.edu/bitstream/handle/1/4554740/RWP10-045_Hausmann_Hidalgo.pdf?sequence=1.

Hausmann, R., & Hidalgo, C. (2011). The Network Structure of Economic Output. Journal of Economic Growth, Vol 26, Issue 4, Dec 2011, pp. 309-342.

Hausmann, R., Hidalgo, C., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., & Yildirim, M. (2011). The Atlas of Economic Complexity: Mapping Paths to Prosperity. Puritan Press.

Hausmann, R., Hwang, J. & Rodrik, D. (2007). What You Export Matters. Journal of Economic Growth, Vol 12, Issue 1, pp. 1-25.

Hausmann, R., & Rodrik, D. (2006). Doomed to Choose: Industrial Policy as Predicament. Sep 2006.

Hidalgo, C.A. (2009) The Dynamics of Economic Complexity and the Product Space over a 42 year period, CID Working Paper No. 189, Dec 2009. Boston: Center for International Development, Harvard University. Available from https://www.hks.harvard.edu/centers/cid/publications/faculty-working-papers/cid-working-paper-no.-189

Inoua, S. (2016) . A Simple Measure of Economic Complexity, Jan 2016. Available from https://arxiv.org/ftp/arxiv/papers/1601/1601.05012.pdf.

Kniahin, D. (2014), Modeling International Trade Patterns with the Product Space Methodology, Master Thesis.

Lall, S. (2000). Selective industrial and trade policies in developing countries: theoretical and empirical issues. Queen Elizabeth House Working Paper, No. 48. Oxford: University of Oxford. Available from http://www3.qeh.ox.ac.uk/pdf/qehwp/qehwps48.pdf.

Lall, S., Weiss, J. & Zhang, J. (2005). The “Sophistication” of Exports: A new Measure of Product Characteristics. Queen Elizabeth House Working Paper, No. 123. Oxford: University of Oxford. Available from https://www.adb.org/sites/default/files/publication/156775/adbi-dp23.pdf.

McMillan, M. & Rodrik, D. (2011). Globalization, Structural Change, and Productivity Growth. NBER Working Paper No. 17143, Jun 2011.

Tacchella, A., Cristelli, M., Caldareilli, G., Gabrielli, A. & Pietronero, L. (2013). Economic complexity: Conceptual grounding of a new metrics for global competitiveness. Journal of Economic Dynamics & Control, No. 37 (2013), pp. 1683-1691.

United Nations Conference on Trade and Development (1996). Trade and Development Report 1996: Developing Countries in World Trade. Geneva. Available from http://unctad.org/en/Docs/tdr1996_en.pdf.

United Nations Conference on Trade and Development (2002). Trade and Development Report 2002: Developing Countries in World Trade. Geneva. Available from http://unctad.org/en/Docs/tdr2002_en.pdf.

United Nations Statistics Division (2002). Classification by broad economic categories. UNStats Statistical Papers Series, No. 53. Geneva: United Nations Statistics Division. Available from http://unstats.un.org/unsd/publication/SeriesM/SeriesM_53rev4e.pdf.

United Nations Statistics Division (2016). Classification by Broad Economic Categories. Geneva. Available from http://unstats.un.org/unsd/trade/classifications/bec.asp.

United Nations Statistics Division (2016). UN BEC – Detailed structure and explanatory notes. Geneva. Available from http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=10.

World Trade Organization (2016). Glossary Terms – Tariff escalation. Geneva. Available from https://www.wto.org/english/thewto_e/glossary_e/tariff_escalation_e.htm.