Value Chain Indicator: adding value to national exports and developing cross-country production chains

Addendum to the **ITC technical paper "Exploring Malawi's export potential"**,[1] Appendix III Export potential and diversification assessment methodology

Background

The ITC export potential and diversification methodology comprises two indicators:

- The Export Potential Indicator (EPI) spots for a country's established export sectors, new or existing target markets with room for export growth.
- The Product Diversification Indicator (PDI) identifies new products for horizontal export diversification, i.e. products, which require a similar set of capabilities than the products already successfully exported by the country.

Complementing the PDI, we introduce a new indicator, the Value Chain Indicator (VCI), to identify vertical export diversification opportunities that promote the transformation of domestically produced inputs. Like the EPI and PDI, it relies on detailed export, import and market access statistics, to spot a country's products with good chances for export success. Successful vertical export diversification strongly depends on the country's ability to transform locally available inputs. To capture the linkages between different sectors in a production process, we rely on Input-Output (I-O) tables.

Data

The VCI starts with a description of the production process. Inputs can be raw or semi-processed while outputs should be semi-processed or processed goods. The categorization of products as raw, semi-processed and processed follows the WTO classification of products by processing stage at the 6-digit level of the Harmonized System (HS) classification. Inputs and outputs are connected through technical coefficients, which measure the amount of inputs needed to produce one monetary unit of output. Technical coefficients are calculated using I-O matrices.

The I-O tables of the United States, Mexico and the Philippines are some of the most detailed matrices available. While the analysis could be conducted using one matrix, the introduction of data from multiple countries helps account for differences in production structures. Assuming that the I-O tables of these three countries can represent future input-output relationships in countries that target export diversification, their matrices can be used to estimate technical coefficients between current and new export products in other countries.

The 389 goods and services sectors in the US matrix[2] are based on the 2007 North American Industry Classification System (NAICS). The most recent matrix containing data for the year 2007 was published in 2014.

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[1] This is an unedited document, drafted by ITC staff following an extension of the Value Chain Indicator. The original ITC technical paper is available here: http://www.intracen.org/publication/Exploring-Malawis-export-potential/.

[2] In general, I-O accounts are a representation of interactions between sectors, including Use, Make, Direct Requirements and Total Requirements tables. The value chain analysis relies on technical coefficients calculated from the Use table, which specifies the inputs each industry requires for its production. For further information, please refer to https://www.bea.gov/papers/pdf/IOmanual_092906.pdf.

The Mexico matrix contains 822 goods and services sectors based on the 2012 NAICS classification and contains data from 2013. The Philippines matrix contains 240 goods and services sectors that comprise data from 2006. For the United States and the Philippines, we thus have to assume in addition that production processes have not changed significantly over the past decade.

Components of the Value Chain Indicator

The VCI identifies (semi-)processed products that have good prospects of export success and that could be produced by transforming raw or semi-processed products already exported by the country with comparative advantage.[3] Like the EPI and the PDI, the VCI combines three factors capturing supply, demand and market access conditions, and bilateral ease of trade:

$$VC_{ijk} = Supply_{ik}^{VC} \times Ease_{ij} \times Demand_{ijk}$$

Measures of ease of trade and demand are the same as in the EPI and the PDI.

At the core of the VCI's supply measure are conditional probabilities of exporting product l with comparative advantage if product k is already exported with comparative advantage, based on trade data from all countries worldwide. Hausmann and Hidalgo's product space measures the average proximity of a country to a new potential export product (the "density") from a matrix of conditional probabilities between all products. A similar measure is used in the PDI. The VCI departs from this approach in two ways: first, it establishes conditional probabilities only among products that are in an I-O relationship as indicated by the I-O table. To enforce a value chain approach, inputs have to be raw or semi-processed while outputs should be semi- or fully processed. Second, it uses the technical coefficient as a weight for the conditional probabilities. Technical coefficients are defined as

$$TC_{ks} = \frac{z_{ks}}{y_s}$$

where z_{ks} is the value of good or service k purchased as an intermediate input by sector s and y_s is the value of production by sector s. For simplicity, products are assumed to coincide with sectors.

Applying these two changes, the density measure becomes

$$Density_{il}^{VC} = \frac{\sum_k (CA'_{ik} TC_{kl} \varphi_{kl})}{\sum_k (TC_{kl} \varphi_{kl})}$$

where φ_{kl} is the conditional probability of exporting transformed product l with a comparative advantage if the country already has one in untransformed product k. Current capabilities are reflected by CA', a corrected version of Balassa's Revealed Comparative Advantage.

A high density means that the country has comparative advantages in products surrounding product l that also serve as inputs into its production. This implies that product l can be reached relatively easily by transforming these inputs. By contrast, a low density means that the product is far from the country's current export structure or that essential inputs are not domestically available. Hence, product l is an unlikely candidate for value chain development. Note that density is zero if the country does not have a comparative advantage in any input to product l.

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[3] The measure of comparative advantage uses Balassa's concept of Revealed Comparative Advantage (RCA) corrected for re-exports and global tariff advantages. For details, see Decreux and Spies (2016). To be considered, a product must have been exported every year for the last three years.

Computing technical coefficients at the product level

I-O matrices define technical coefficients at the sector level. ITC export potential and diversification results however are available at the product level. We will illustrate the process of expanding the matrix to obtain technical coefficients at the product level using the matrix from the United States. An equivalent procedure is applied to the Philippines and the Mexico matrix.

The US I-O matrix represents the input requirements of 389 sectors, 225 of which correspond to goods and 164 to services. The ITC export potential and diversification methodology however distinguishes 4,388 product groups based on the HS 6-digit level. Given the lack of detail of export potential data for services the 164 services sectors are disregarded when expanding the matrix.

The first step of the expansion, from 225 to 4,388 columns, is to attribute to all output sub-sectors their respective sector's technical coefficient.[4] The second step of the expansion, from 225 to 4,388 rows repeats this procedure for the input sub-sectors resulting in a square matrix of size 4,388 x 4,388. This expansion would initially lead to a matrix containing 19,254,544 cells. However, not all of these pairings are interesting for value chain development. Excluding raw products from the list of output sub-sectors and fully processed products from the list of input sub-sectors leads to a matrix of 6,738,121 cells (1,769 input sub-sectors × 3,809 output sub-sectors).

Table 1 represents the first and second step of this expansion with four hypothetical sectors, two input sectors (I1 and I2) and two output sectors (O1 and O2) and their corresponding sub-sectors. Note that the technical coefficients at the sub-sector level are not yet final in table 1 as their re-aggregation would not lead to the original technical coefficient of the sector.

Table 1. Expansion of IO table from NACIS goods sectors to HS based product groups

	O1	O2
I1	c_{s11}	c_{s12}
I2	c_{s21}	c_{s22}

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	O1			O2	
	O11	O12	O13	O21	O22
I1	c_{s11}	c_{s11}	c_{s11}	c_{s12}	c_{s12}
I2	c_{s21}	c_{s21}	c_{s21}	c_{s22}	c_{s22}

→

		O1			O2	
		O11	O12	O13	O21	O22
I1	I11	c_{s11}	c_{s11}	c_{s11}	c_{s12}	c_{s12}
	I12	c_{s11}	c_{s11}	c_{s11}	c_{s12}	c_{s12}
I2	I21	c_{s21}	c_{s21}	c_{s21}	c_{s22}	c_{s22}
	I22	c_{s21}	c_{s21}	c_{s21}	c_{s22}	c_{s22}
	I23	c_{s21}	c_{s21}	c_{s21}	c_{s22}	c_{s22}

Note: input sector I1 corresponds to sub-sectors I11 and I12, input sector I2 corresponds to sub-sectors I21, I22 and I23. For output sectors, O1 corresponds to sub-sectors O11, O12 and O13, while O2 corresponds to O21 and O22.

The third step of the expansion therefore distributes the input sector's technical coefficient among the input sub-sectors included in it while ensuring that the sum of all technical coefficients of an output sub-sector equals the value of the technical coefficient at the output sector level ($\sum_{k \in s} c_k = c_s$). The simplest way to do this is to distribute the technical coefficient equally among input sub-sectors,

$$c_k = \frac{c_s}{n_s}$$

where c_k (c_s) is the technical coefficient associated with input sub-sector (output sector) k (s), and n_s is the number of input sub-sectors in the input sector. An example of this result is presented in table 1. Since the technical coefficient between the "Cheese manufacturing" output sector and the "Dairy cattle and milk

[4] In the following, we refer to output products as output sub-sectors and to input products are input sub-sectors.

production” input sector is 0.45, each of the five input sub-sectors in the input sector is attributed a technical coefficient of 0.09 for each of the output sub-sectors in the “Cheese manufacturing” output sector.

Table 2. Equal split of technical coefficient among corresponding sub-sectors

		Output sector 1	…	Cheese manufacturing					…	Output sector 225
				Fresh cheese	*Grated or powdered cheese*	*Processed cheese*	*Blue-veined cheese*	*Cheese, n.e.s*		
Input sector 1										
…										
Dairy cattle and milk production	*Low fat milk/cream*			0.09	0.09	0.09	0.09	0.09		
	Medium fat milk/cream			0.09	0.09	0.09	0.09	0.09		
	High fat milk			0.09	0.09	0.09	0.09	0.09		
	Natural milk constituents			0.09	0.09	0.09	0.09	0.09		
	Dairy spreads			0.09	0.09	0.09	0.09	0.09		
…										
Input sector 225										

1. Word-matching technique

The simple division of technical coefficients by the number of sub-sectors is applied in 90.6% of all cases. For 5.4% of the combinations, corresponding to 290,115 I-O pairs, a direct association of input and output sub-sectors leads to a significant improvement of results. We implement several word-matching techniques to link product descriptions at the input and output level with the objective to achieve a higher precision in the technical coefficients.

Product descriptions are analysed word by word, taking into account the possibility of plural. Only specific terms are considered, while excluding generic words. These key words are used to produce a list of input and output sub-sectors with partially matching descriptions. Matched pairings are manually checked to eliminate coincidences[5]. Output sub-sectors without any matching input sub-sectors are also manually checked to ensure that relevant input sub-sectors have not been ignored.[6] Depending on the result of the word matching, technical coefficient are then modified.

Tables 3 and 4 present an example of a possible outcome of this exercise: the NAICS output sector “Animal (except poultry) slaughtering, rendering, and processing” includes output sub-sectors such as frozen bovine carcases and half-carcases (HS 020210), frozen carcases and half-carcases of swine (HS 020321) and frozen lamb carcases and half-carcases (HS 020430). At the input sub-sector level, bovine animals are part of NAICS

[5] An example of an unintended match is “Meat of *horses*, asses, mules or hinnies” (020500) and “Acorns, *horse*-chestnuts, marc and other vegetable materials and vegetable waste, vegetable residues and by-products of a kind used in animal feeding” (HS 230800).

[6] The method has been implemented for
- The agro-food sector (HS chapters 01-23)
- Textiles (chapters 50-58 and 60-63, and some products in chapters 14, 43, 59, 65, 88 and 94)
- Minerals and metals (chapters 25, 27, 68, 71, 72 and 74-83, and some products in chapters 38 and 73)
- Wood, paper, rubber and plastics (chapters 39, 40 and 44-49, and some products in chapters 06, 14, 30, 38, 94, 96).

input sector “Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming”, while swine and other live animals are part of the NAICS “Animal production, except cattle and poultry and eggs” input sector.

The technical coefficient of “Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming” in the production of “Animal (except poultry) slaughtering, rendering, and processing” is 0.37. The technical coefficient for “Animal production, except cattle and poultry and eggs” in the production of “Animal (except poultry) slaughtering, rendering, and processing” is 0.14. An equal split of technical coefficients among the corresponding sub-sectors as in table 2 suggests for the production of frozen carcases of swine a larger requirement of bovine animals than of swine and an equal requirement of swine and of other animals.

Table 3. Modification of the technical coefficient following the implementation of word matching techniques: step 1

		Output sector 1	…	Animal (except poultry) slaughtering, rendering, & processing		…	Output sector 225
				Frozen bovine (half-)carcases	*Frozen swine (half-)carcases*		
Input sector 1							
…							
Beef cattle ranching & farming, including feedlots & dual-purpose ranching & farming	*Bovine animals*			0.37	0.37		
Animal production, except cattle & poultry & eggs	*Swine*			0.07	0.07		
	Other live animals			0.07	0.07		
…							
Input sector 225							

The word matching can significantly improve the precision of the technical coefficient both, for outputs sectors that are linked to a single input sector (scenario as in table 2) and for output sectors that are linked to multiple input sectors (scenario as in table 3).[7] In the case of several input sectors, technical coefficients are aggregated. The total technical coefficient is then distributed among matched input sub-sectors,[8] while other corresponding input sub-sectors are assigned a technical coefficient of zero. Going back to the example in table 3: the key word “swine” will associate swine with frozen swine carcases, while the key word “bovine” will associate bovine animals with frozen bovine carcases. Assuming that there are no further matches, table 3 would thus be transformed as illustrated in table 4.

[7] Input sectors are associated with output sectors if at least one key word in the sub-sector descriptions matches.

[8] If matching input sub-sectors belong to different input sectors, the technical coefficient is first distributed among input sub-sectors within each input sector, and then proportionately expanded to the total technical coefficient if one or more input sectors does not contain any matched input sub-sectors.

Table 4. Modification of the technical coefficient following the implementation of word matching techniques: step 2

		Output sector 1	…	Animal (except poultry) slaughtering, rendering, & processing		…	Output sector 225
				Frozen bovine (half-)carcases	*Frozen swine (half-)carcases*		
Input sector 1							
…							
Beef cattle ranching & farming, including feedlots & dual-purpose ranching & farming	*Bovine animals*			0.51	0		
Animal production, except cattle & poultry & eggs	*Swine*			0	0.51		
	Other live animals			0	0		
…							
Input sector 225							

Adding the technical coefficients of the "Beef cattle ranching & farming, including feedlots & dual-purpose ranching & farming" and the "Animal production, except cattle & poultry & eggs" input sectors results in a technical coefficient of 0.51 for the bovine and swine meat production, respectively. Non-relevant input sub-sectors such as bovine animals for frozen swine (half-) carcasses are assigned a technical coefficient of zero.[9]

2. Rules of Origin filter

Rules of Origin (RoO) data can help further improve results by filtering out input sectors in cases without matching product descriptions. This filter affects 4% of input-output sub-sector pairs. It eliminates 110,502 pairs from the US matrix, 73,245 from the Mexico matrix and 134,495 from the Philippines matrix.

The data comes from more than 70 Free Trade Agreements (FTA) and non-preferential schemes specifying conditions to assign originating status to transformed products that – when further exported – then will benefit from preferential tariff rates. According to the Kyoto Convention,[10] when more than one country is involved in the production process, the origin of a product is determined by the last substantial transformation. One of the ways to determine whether a substantial transformation has taken place is based on changes of tariff classification in the HS code. For instance, an FTA could demand that for tomato juice (HS 200950) to be considered as produced in a particular country, tomatoes (070200) and tomato paste (200290) used in the production should be nationally sourced. This situation indicates that other products in chapters 7 and 20 are not relevant inputs in the preparation of tomato juice.

Tables 5 and 6 explain how the RoO filter improves technical coefficients. In this example, 26 input sub-sectors are part of the "Copper rolling, drawing, extruding and alloying" input sector, which is used in the production of the "All other miscellaneous electric equipment and component manufacturing" output sector. Without the

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[9] Note that if the word matching had been done within every input sector instead of across all the linked input sectors, the production of frozen swine would be seen as requiring the input of swine animals with a technical coefficient of 0.14 (the TC of 0.07 assigned to swine plus the 0.07 assigned to other live animals), while the production of frozen bovine would require the input of bovine animals with a technical coefficient of 0.37.

[10] International Convention on the Simplification and Harmonization of Customs Procedures: http://www.wcoomd.org/Topics/Facilitation/Instrument%20and%20Tools/Conventions/pf_revised_kyoto_conv/Kyoto_New

RoO filter, the technical coefficient would be divided by all input sub-sectors, resulting in a very low technical coefficient of 0.00036, as seen in table 5.

Table 5. Results in the absence of the RoO filter

		Output sector 1	…	All other miscellaneous electrical equipment and component manufacturing	…	Output sector 225
				Electric conductors		
Input sector 1						
…						
Copper rolling, drawing, extruding and alloying	*Unwrought copper alloys*			0.00036		
	…					
	Copper wire (4 products)			0.00036		
	…					
	Bars, rods and profiles of copper			0.00036		
…						
Input sector 225						

However, the RoO data indicates a link between copper wire and electric conductors in the production process, and thus allows us to allocate a higher technical coefficient. In the absence of any word match in the product descriptions of the output sub-sector "Electric conductors" and the remaining input sub-sectors, the technical coefficient is transferred to "Copper wire", composed of four products. Table 6 presents the result of this process, where the technical coefficient between copper wire and electric conductors increases from 0.00036 to 0.002.

Table 6. Results following the application of the RoO filter

		Output sector 1	…	All other miscellaneous electrical equipment and component manufacturing	…	Output sector 225
				Electric conductors		
Input sector 1						
…						
Copper rolling, drawing, extruding and alloying	*Unwrought copper alloys*			0		
	…					
	Copper wire (4 products)			0.002		
	…					
	Bars, rods and profiles of copper			0		
…						
Input sector 225						

3. Aggregation

The process described above is applied to the I-O matrices from the United States, Mexico and the Philippines individually. However, a single matrix is not necessarily a good representation of the production process in another country for which diversification options are sought. The introduction of I-O matrices from multiple countries accounts for differences in the production structures.

For instance, Rum (HS 220840) belongs to the distillery sector in the United States but the matrix does not indicate sugar cane (HS 1701) as an input into this sector, which mostly produces non-sugar-based alcoholics such as whiskey and wine. This is different in Mexico and the Philippines, both of which have a rum manufacturing industry relying on domestic sugar cane. As a result, their respective matrices reflect the link between these two industries. In order to include the available technical coefficients in the calculation of densities, a weighted average technical coefficient is calculated, where the weight corresponds to each country's exports of the output sub-sector.

Supplier identification for complementary inputs

Products highlighted by the VCI as having good chances for value chain development rely on inputs that are (i) already available in the country and (ii) intensively used in its production (high technical coefficient). However, the realization of the export opportunity may require the use of complementary inputs, i.e. inputs for which the country does not have a comparative advantage, that are already fully transformed (e.g. packaging materials or car tyres), or services. Neither of these inputs is considered in the computation of the VCI, yet they may be available locally or else, can be sourced from regional or international suppliers.

This part of the analysis is done at the level of sectors. Services trade data is broadly available for 11 service categories. A correspondence is built between these categories and the services sectors available in the combined I-O table in order to provide a more complete picture of the inputs required in the production process for value chain development. Input sectors considered as complementary inputs must be essential for the production of the output, with a technical coefficient above 1.1%. If the country itself is a net exporter of the input sector, it is considered as the best source for the input.[11] If not, the EPI in supplier view allows the identification of trade partners with large export potential from which the missing inputs can be sourced.

[11] Based on five-year averages of a combination of reliable direct and mirror trade data reports. For details, see Decreux and Spies (2016).