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# INPUT-OUTPUT PRODUCT SPACE ANALYSES: POTENTIAL FOR AND LIMITS OF USING OUTPUT DATA

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# Input-output product space analyses: Potential for and limits of using output data

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## Abstract

This paper provides an outline of the theoretical underpinnings of the input-output product space (IO-PS) analysis approach. It explores the potential value that the various metrics can have in supporting industrial analysis. It also discusses the potential benefits of using output data instead of trade data which is usually used for IO-PS analyses. To ascertain whether it is possible to realize the potential benefits given the currently available output data, the IO-PS framework is applied to the case of the basic metals industry using both output and trade data, with a focus on Germany and Peru. The similarities and discrepancies between the results are highlighted. Based on these results, various recommendations are presented for future use of both trade and output data for IO-PS analyses. Specifically, it is argued that output data can be useful in the initial value chain mapping phase. It is advantageous, however, if this mapping is then converted into trade codes before the IO-PS calculations are performed to benefit from the better coverage and granularity of the trade data when compared to the output data.

# 1 Introduction

Recent research has reiterated the importance of industrialization for development but also highlights how this is becoming increasingly difficult for developing countries to achieve (Jesus Felipe, Mehta, & Rhee, 2019). Developing countries are thus under increasing pressure to ensure their industrial policymaking is evidence-based and provides the greatest industrial and social returns as efficiently as possible. Recently developed approaches have shown promising results in the use of trade data (Hausmann et al., 2011; Hidalgo, Klinger, Barabasi and Hausmann, 2007), and even corporate sustainability disclosures (Du Plessis and Bam, 2018) to support reliable identification of industrial activities that could most effectively drive development while aligning with countries' existing industrial structures. These methods seem to hold significant potential to help developing countries improve the efficiency and effectiveness of their industrial policy decision making.

The *product space* approach developed by Hidalgo et al. (2007) has made a crucial contribution to the quest of how to use the growing availability of data to better inform industrial policymaking. Their seminal work has inspired a variety of alternative approaches and extensions. The product space approach is still evolving, and much remains to be done to further refine it and promote its widespread adoption among policymakers to improve their decision making processes. This includes consolidating the range of theoretical developments in the burgeoning product space literature as well as packaging it in a way so it can be easily used by policymakers and intuitively navigated. An important step towards this goal has been the establishment of the online "Observatory for Economic Complexity" developed as part of MIT Media Lab's research (OEC, 2019b). The platform presents a number of factors based on which countries can be analysed. This includes a breakdown of each country's export and import basket for various time periods, using different trade classifications and trade classification levels of analysis. Based on the country's export basket, the platform also presents its position in the "product space" and calculates an "economic complexity" value for each country. The platform can also be used to explore different products, where each product's "product complexity" can be evaluated, as well as which products within the product space have a "high proximity" to other products.

To address the divide between the traditional sector-specific input-output flow-based methods used for industrial policy analysis and the product space approach, Bam & De Bruyne (2019) developed an "input-output product space" (IO-PS) methodology. This method is used to construct detailed input-output value chains of various activities and product groups within a focal industry, linking them to international trade codes and subsequently calculating the product space metrics for the resulting value chain. Furthermore, based on the various product space metrics, theoretically optimal development paths are identified for a case country seeking to develop its position within a particular value chain. This provides industrial policymakers with valuable industry-specific guidance and bridges the more traditional approaches to value chain-based industrial policy analysis and the product space approach.

Both the product space and IO-PS make use of the same trade data to conduct analyses. There potentially, however, is an opportunity to make use of output data instead of trade data. This could allow identification of industries that are key to development, the outputs of which are often consumed locally instead of exported.

This working paper details the theoretical underpinnings of the IO-PS (Section 2) and explains how each of the key metrics could be interpreted and used to support industrial policymaking. The paper also outlines the potential benefits of using output data instead of the commonly used trade data for IO-PS analyses (Section 3). Furthermore, the paper sets out to test whether the output data available in UNIDO's INDSTAT database is suitable for comprehensive IO-PS analyses. To do so, an IO-PS analysis of the basic metals industry is carried out using both trade data and INDSTAT data. Section 4 outlines the detailed methodology used, and the results of the analyses are presented and discussed in Section 5. Section 6 concludes, summarizing the paper and highlighting the key implications for policy analysis.

## 2 Theoretical background

This section provides an overview of the key theoretical underpinnings of the product space and IO-PS analysis and explores the potential utility of each metric for industrial analysis. Section 2.1 includes a discussion of product space-based metrics. Section 2.2 focusses on the input-output extension of the IO-PS.

### 2.1 Product space metrics

The following sections present a number of product space-based metrics. These are revealed comparative advantage (RCA) (Section 2.1.1), proximity (Section 2.1.2), distance (Section 2.1.3), complexity (Section 2.1.4) and opportunity gain (Section 2.1.5). Section 2.1.6 discusses the use of product space-based metrics more generally.

### 2.1.1 *Revealed comparative advantage*

The product space approach was initially introduced in the seminal paper by Hidalgo et al. (2007). Since the publication of their seminal work, various extensions and adaptations of Hidalgo et al.'s approach have been suggested by a variety of scholars. These extensions and refinements are consolidated in the Atlas of Economic Complexity (Hausmann et al., 2011). The possibility to evaluate which products are already part of a given country's product space and which ones are not is key to the product space methodology. In other words, it determines which products are being "competitively" produced by a country and which ones are not. To identify which products are produced competitively, established product space literature applies the concept "revealed comparative advantage" (or RCA). There are various ways to determine whether a country has an RCA for a given product. The product space literature generally uses the Balassa (1965) definition[1]. According to this definition, a country can be considered as having an RCA for a given product if it accounts for a larger share of the country's export basket than in world trade. This can be mathematically represented as follows (Hidalgo et al., 2007):

$$RCA_{real,c,i} = \frac{x(c,i)}{\sum_i x(c,i)} \Bigg/ \frac{\sum_c x(c,i)}{\sum_{c,i} x(c,i)}$$

In this formulation, $x(c,i)$ denotes the exports of product *i* from country $c$. Using this definition of RCA, it is possible to define the binary $RCA_{bin,c,i}$ for country *c* and product *i* as equal to 1 when $RCA_{real,c,i} > 1$, and $RCA_{bin,c,i}$ as equal to 0 when $RCA_{real,c,i} \leq 1$. The value of 1 is thus assigned when a country's product *i* can be considered to have an RCA and 0 if it cannot.

The RCA, on its own, already provides a significant amount of information when analysing a given country. It identifies the industries that seem to be important to the local economy. Specifically, it highlights which industries make up a larger share of the respective country's export basket than can generally be expected. It also highlights an overreliance on a limited number of products, i.e. a lack of diversification. When the export of a few commodities (e.g. the export of minerals or oil) make up a significant share of a country's export basket, it dilutes the contributions of other sectors (in RCA terms), regardless of the absolute value of the other sectors' exports.

[1] Though Laursen (2015) recently argued that an adjusted "revealed symmetric comparative advantage" (RSCA) might be superior, this metrics has not yet seen widespread adoption in the product space literature.

### *2.1.2 Proximity*

The product space is underpinned by the notion that when we evaluate how often products are co-exported with an RCA (i.e. with $RCA_{real,c,i} > 1$ and $RCA_{bin,c,i} = 1$), we can infer how similar the products' capabilities are. If products are often co-exported, we can assume that they require similar capabilities[2]. For example, we may find that countries often co-exports apples and pears (as their production and export require the same skills, infrastructure and climate), but that the export of apples is not necessarily correlated with the export of, say, piston engines, which naturally involves different capabilities for efficient production and export.

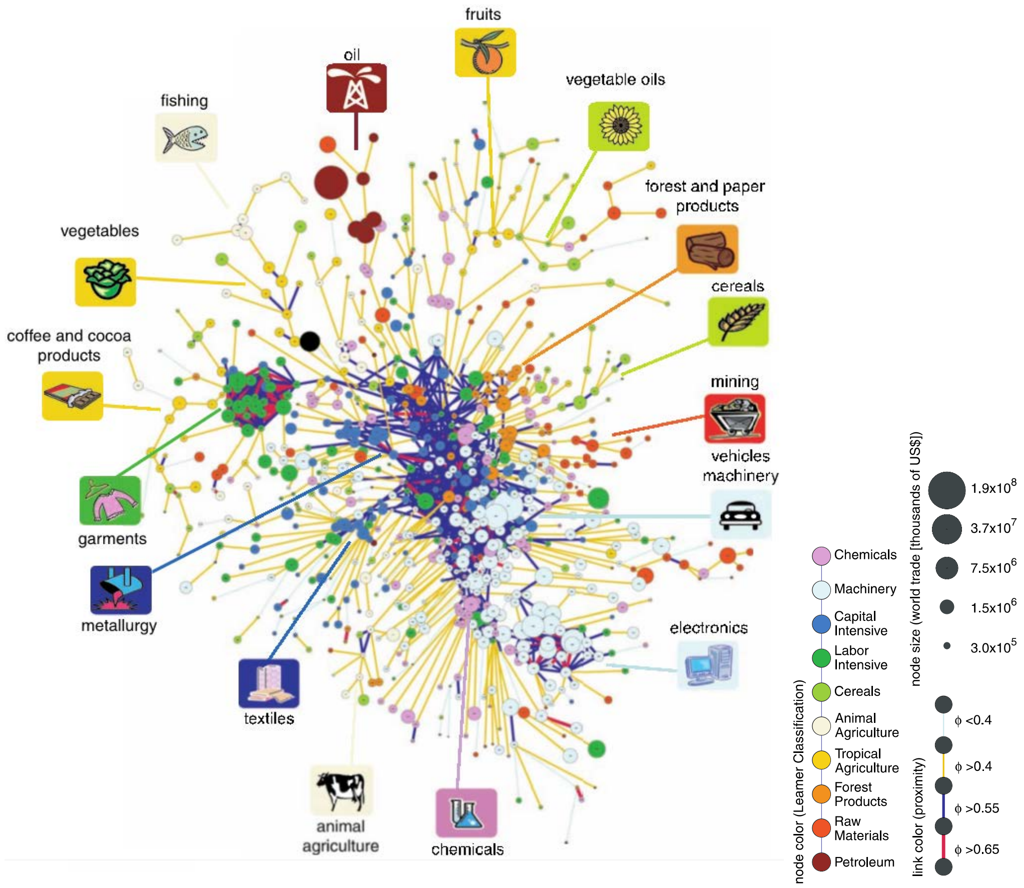
The relatedness of products' capability requirements can be estimated by using the measure of *proximity*. The proximity between two products *i* and *j* is defined as the probability of a country exporting product *i* with a comparative advantage, if it also exports product *j* with a comparative advantage or vice versa, whichever is the minimum. Thus, if all countries that produce product *i* also produce product *j* (and vice versa), their proximity will be equal to 1. Similarly, if no country produces both products, the products' proximity will be 0. Mathematically, the proximity ($\phi_{ij}$) between products *i* and *j* can thus be defined as

$$\phi_{ij} = min\{P(RCA_{bin,i}|RCA_{bin,j}), P(RCA_{bin,j}|RCA_{bin,i})\}$$

Using these proximity values, Hidalgo et al. (2007) develop what they call the 'product space' by calculating and plotting the maximum spanning tree of product proximities and superimposing the links between products where the proximity between these products lies above a certain threshold. Their approach is illustrated in Figure 1.

[2] Where *capabilities* are broadly defined to include know-how, skills, infrastructure, climate and any other factors that will influence a country's ability to competitively export a given product.

**Figure 1: Network representation of the product space (Hidalgo et al., 2007)**




The network illustrates that activities such as oil production, mining and agriculture fall into the periphery. This implies that these commodities are not consistently co-exported (with an RCA) with the majority of other products in the product space. We can thus conclude that the capabilities required to produce such products (with an RCA) are not used in the production of other products that lie at the core of the product space (with an RCA), such as machinery and electronics. By contrast, the capabilities required to produce the products that make up the core of the product space seem to enable the production of a large variety of related products that share similar capability requirements (Felipe, Kumar, Abdon, & Bacate, 2012; Hidalgo & Hausmann, 2009).

Considering the network structure of the product space shown in Figure 1, various network metrics can be used to describe the position of countries within the product space and the future opportunities this position implies. These include the three metrics of distance, complexity and opportunity gain, which are described in the following sections.

### *2.1.3 Distance*

Distance provides an indication of the position in the product space of a country's exports with an RCA relative to those products for which it does not yet have an RCA. Hence, if a country has a lower distance to a particular product (which it does not currently export with an RCA), it exports a high number of products with an RCA that are relatively proximate to the focal product. Thus, it could be assumed that the country possesses many of the capabilities to facilitate the focal product's export with an RCA (as a high number of countries that have an RCA for similar products also export the focal product with an RCA). Mathematically, the distance for country *c* to product *j* can be expressed as follows (Hausmann et al., 2011):

$$\Delta_j^c = \frac{\sum_i (1 - RCA_{bin,i}) \emptyset_{ij}}{\sum_i \emptyset_{ij}} \quad (for\ all\ i \neq j)$$

### *2.1.4 Complexity*

Complexity, as introduced by Hidalgo & Hausmann (2009), is based on the premise that countries systematically accumulate increasingly complex capabilities (which build on simpler capabilities previously accumulated), enabling them to produce ever more complex products. The estimation of the complexity of countries' economies and the products they produce is based on the notion that the most complex economies (countries that have accumulated a wide variety of complex capabilities) will be able to produce a wide variety of complex products, while less complex economies (which only possess a limited number of relatively less complex capabilities) will only be able to produce a limited number of relatively less complex products. At the same time, products that have a very high complexity will only be produced by a small number of complex countries, while less complex products will be relatively ubiquitous and be produced by the majority of economies.

There are some exceptions to the rule that low complexity goods are ubiquitous. For example, the production of various minerals and oil might be limited to a few countries due to the given natural distribution of these resources. However, this does not imply that these products are necessarily complex products. Similarly, smaller economies may accumulate complex capabilities and specialize in the export of complex products, but will not necessarily be as diversified as larger economies. To account for these considerations, the calculation of the complexity of products should reflect the complexity of the countries that export such products (and not just the number of countries that export them), while a country's complexity should reflect the complexity of the products it exports (and not just the number of products the country exports, i.e. its diversity).

This implies that the calculations for product complexity and country complexity will be interdependent. Consequently, Hidalgo & Hausmann (2009) made use of the so-called ‘method of reflections’ to iteratively calculate countries’ complexity (referred to as the economic complexity index or ECI) and the complexity of products (referred to as the product complexity index or PCI). They find that after enough iterations, the rankings within these indices stabilize. Furthermore, the resulting ECI values are correlated with a country’s per capita income and deviations from this correlation are predictive of future economic growth. This suggests that developing countries should foster the development of their productive structures towards higher complexity products (Hidalgo & Hausmann, 2009).

### *2.1.5 Opportunity gain*

Building on the concepts of both complexity and distance, opportunity gain provides an indication of whether achieving an RCA for a given product for which the respective country does not yet have an RCA will reduce its distance to other high complexity products. This is important, as countries with a production structure that is in close proximity to a high number of complex products for which they do not yet have an RCA tend to experience higher levels of economic growth (Hausmann et al., 2011). This close proximity of a country’s production structure to complex products is referred to as *opportunity value* and can be calculated as follows:

$$OV_c = \sum_j \omega_j^c \, PCI_j \quad where \quad \omega_j^c = \frac{\sum_i RCA_{bin,i} \phi_{ij}}{\sum_i \phi_{ij}} \quad (for\ all\ i \neq j)$$

Opportunity gain is thus the increase/decrease in a country’s opportunity value after achieving an RCA for a product for which it did not yet have an RCA. It provides an indication of the value of the capabilities that would be developed if an RCA were obtained for a focal product.

### *2.1.6 Using product space metrics*

The product space and its associated metrics provide analysts with information to inform industrial policy targeting. This information has been harnessed in a number of studies to evaluate the key industries that particular countries should prioritize for development. This has been pioneered by some of the authors involved in the initial development of the product space methodology, with studies focussing on South Africa (Hausmann & Klinger, 2008), the Caribbean (Hausmann & Klinger, 2009), and Rwanda (Hausmann & Chauvin, 2015), amongst others. Similar approaches have been applied by authors such as Golub, Mbaye, & Vasilyeva, (2019) (focussing on Senegal), González, Ortigoza, Llamosas, Blanco, & Amarilla (2018) and Hartmann, Bezerra, & Pinheiro (2019) (both studies focussing on Paraguay). Some of the key benefits of the product space approach is its ability to rapidly evaluate which products could potentially be easier to develop in a given country (by evaluating what products countries that have an RCA for similar products as those of the focal country, also export these products with an RCA, but which the focal country does not yet export with an RCA), while ensuring the development of capabilities aimed at supporting future economic growth (by targeting products that are generally only exported by countries that have higher overall complexity values or which are close to such products in the product space and should thus develop capabilities that facilitate achievement of an RCA in such products).

Although this approach allows for a rapid identification of industries that hold potential, the detailed results it provides have been criticized for lacking economic logic and intuitive appeal when applied in different settings and taken at face value (Golub et al., 2019). This is partly due to the fact that a wide variety of products are rapidly evaluated without contextualizing the market realities related to these products. Furthermore, visualizations of the various product space metrics have focussed on the network structure that underpins the calculation of these metrics.

Yet this network structure is difficult to navigate and use for decision making. As the structure relates to estimated shared capabilities and not the logical input-output flow of products in the economy, it is not directly relatable to the dominant input-output-based analysis frameworks (such as the global value chain and global production network frameworks) or even the manner in which economic actors generally organize themselves. This unrelatedness to existing industrial policy analysis approaches and constituencies might have contributed to a slower adoption of the product space approach to support industrial policy (and related) decision making than might have been expected.

## 2.2 An input-output perspective on the product space

The IO-PS seeks to address the uncontextualized nature of the product space metrics by specifically using an input-output lens to map an industry value chain before calculating the product space metrics for each product category within the value chain. The value chain mapping used for the IO-PS calculations is constructed based on an iterative multi-step approach.

First, the delimitations of the focal value chain need to be established. For example, Bam & De Bruyne (2019) map the steel value chain and use iron ore as the focal commodity to guide their investigation of the value chain and trace its usage further downstream, while Marais & Bam (2019) map the aerospace industry by identifying the key final commodities considered part of the aerospace industry, and work their way back from that point. Once the scope has been set, the commodities to be included in the mapping must be identified by drawing on various data sources and triangulation. This includes input-output tables, related academic and grey literature that describe the production processes relevant to the industry, and consulting experts on the subject matter, who work in the industry and have first-hand knowledge of the production processes and trade codes used for the trade of the various commodities that fall within the scope of the defined value chain.

The identified commodities that form part of the value chain are then aggregated into product categories of similar products to further improve the interpretability of the constructed value chain. The products within the product categories are, ideally, similar enough that any industrial policy targeted at supporting the product category will effectively support the production of all the products within the product category. Moreover, product categories should ideally consist of a similar number of products to improve comparability (Bam & De Bruyne, 2019).

Finally, product categories need to be arranged into tiers to reflect their input-output relationships. The purpose of this in the IO-PS is not to argue that product categories linked by input-output relationships will necessarily require similar capabilities (or even that they need to be targeted together), as this has been shown to not be the case (Hausmann, Klinger, & Lawrence, 2008). Rather, the input-output perspective provides context to support the targeting of specific commodities by presenting an appreciation of the markets for the commodity and the inputs required to produce that commodity. Furthermore, it supports more holistic industry-specific interventions by evaluating all of the country's opportunities within a specific value chain/industry. Finally, it supports improved engagement with industry stakeholders, as value chains are generally more intuitive to interpret for industry (and other) stakeholders than the more abstract product space.

Once the construction of the trade code-based value chain is complete, the generic average complexity values can be calculated at the tier-, product category- and individual product level. It is also possible to calculate the distances to the focal country's products for which it does not have an RCA at the same three levels of aggregation. The distance can then be compared to the opportunity gain and complexity implications of achieving an RCA for the particular product(s)/product categories or tiers. Bam & De Bruyne (2019) highlight the importance of considering at least the product category level results, because considering the tier level results only could lead to oversimplified development narratives. Bam & De Bruyne (2019) also show how simulations can be used to identify optimal industry-specific development paths for different distance scenarios.

In summary, the main advantage of the IO-PS approach is that it enables a contextualization of the product space metrics. Firstly, the IO-PS aggregates the trade code products into more intuitive product categories that represent products which are ideally produced by the same industry players and can be supported using similar measures. Secondly, input-output mapping makes it possible to contextualize product categories within the supply chains in which they operate. This, in turn, allows for an appreciation of the markets for the given products within the product category as well as of the inputs required to produce them. This is important because as highlighted in the rich global value chain literature, the governance and power dynamics between actors in different tiers of the value chain can have a substantial impact on the ability of players within a country to "insert" themselves into new global value chains and the rents they will be able to attain through such insertion. Furthermore, industry bodies and stakeholders often organically organize to include multiple input-output tiers due to mutual dependence, shared interests and market conditions dictated by the final market environment relevant to them. Consequently, government interventions are also often aimed at a particular value chain, spanning various activities and/or tiers or intervening in the power relations between different tiers.

## 3 The potential for using output data

The product space literature primarily uses international trade data to generate results. Hausmann et al. (2011) discuss the reasons for and implications of this approach. What makes trade data attractive is that it is the only comprehensive standardized data set in the public domain that provides insights into the products that the majority of countries produce. Trade data is generally much more comprehensive and accurate than local production data.

Trade data does not, however, include the products that countries produce but do not export, meaning these products are not visible in the trade data. This might conceal key developmental sectors (Franks, 2020). Moreover, countries may also export products that they do not produce. Hence, there is a need to filter for this secondary export effect when using trade data instead of production data. Furthermore, trade data inherently excludes services and non-tradeable activities, which have become increasingly important in the world economy.

Hausmann et al. (2011) argue that if countries produce goods but do not export them, they are likely not very efficient in the production of these products and therefore, the exclusion of these products is not necessarily a major drawback. The use of the binary RCA values in the product space calculations should lead to the exclusion of most exports that are not produced locally.

Nonetheless, if a reliable data set of production data were attainable, it would have three significant advantages over trade data. Firstly, important commodities that are produced and consumed locally, but are not exported although they are important for economic development, will become visible. Secondly, there would be no risk of counting products that are only cross-exported but not produced locally. Finally, various key supporting industries and services are generally captured in production data, but not in trade data. Hence, the role of these activities could also be evaluated for their role in development.

As countries continually improve their monitoring of economic activity, the data set of local production data available to UNIDO has been improving continuously. This paper investigates whether this data set is already sufficient enough to allow the use of production data rather than trade data to support product space-like analyses. To do so, we evaluate a value chain based on output data and compare the results with those obtained from applying a traditional IO-PS approach based on trade data. More details on the approach are provided in the following section

## 4 Methodology and data

To evaluate the potential of using output data for an IO-PS analysis, we had to identify a suitable case. The basic metals and metal items value chain was selected. Our choice was based on three considerations. The value chain represents a significant building block of industrialization and is linked to a variety of other industries. Secondly, the value chain encompasses a broad spectrum of activities with varying complexity levels. Finally, the closely related steel value chain has been analysed using the IO-PS approach for the case of South Africa (Bam & De Bruyne, 2019), making the results comparable to an existing study and providing a point of reference for the mapping of the value chain.

The value chain was constructed by considering the ISIC 4-digit industry codes that form part of the ISIC 2-digit basic metals (24) and metal items (25) as the core of the value chain. The 4-digit codes that form part of these two categories were then arranged according to their input-output relationships, using the make and use tables of the U.S. Bureau of Economic Analysis for 2002, and the methodology applied by Bam & De Bruyne (2019). The same resources were then used to further extend the value chain to include the key production inputs and supporting activities in the extended value chain. Due to the large variety of industries in which metal items are used, the further downstream part of the value chain was excluded to confine the focus of the analysis. The resulting mapping is presented in Figure 2 in Section 5.

Once the industry code-based mapping was completed, production/output data was required to facilitate the calculation of the various metrics. The output data used for the analysis was 4-digit level ISIC data extracted from UNIDO's INDSTAT platform. The year 2016 was chosen as the year of analysis, as it was the most recent year for which data were available. The data set for the chosen year contained output values of countries that were aggregated according to different combination codes. To enhance the data's comparability between countries, all 4-digit codes that were combined by any country at the 4-digit level were collapsed into a single code. Although this reduced the data's granularity, it improved their comparability – which is crucial for the comparative nature of product space-related analyses.

To operationalize the production data to calculate the value chain's metrics used by Bam & De Bruyne (2019), we replaced the binary RCA value used by the majority of the product space literature and instead used a newly defined binary "revealed industrial capability" (RIC) metric. This was calculated as follows:

$$RIC_{real,c,i} = \frac{y(c,i)}{\sum_i y(c,i)} \bigg/ \frac{\sum_c y(c,i)}{\sum_{c,i} y(c,i)}$$

In this formulation, $y(c,i)$ represents the output of industry $i$ in country $c$. Similar to the binary RCA value, the binary $RIC_{bin,c,i}$ for country $c$ and product $i$ is equal to 1 when $RIC_{real,c,i} > 1$ and $RIC_{bin,c,i}$ is equal to 0 when $RIC_{real,c,i} \leq 1$. The value of 1 is thus assigned when a country can be considered to have an RCA for product $I$, and 0 if it cannot.

To compare the results of the analysis with those of the trade data-based IO-PS approach, the ISIC value chain mapping had to be converted for trade code-based mapping. For this analysis, the SITC (revision 2) trade code system was selected because it is commonly used in product space-related literature due to the availability of SITC trade data over a long time horizon, which improves the potential future use of the mapping. Furthermore, as the ISIC codes were limited to the 4th digit, the greater granularity the competing HS codes could offer over the use of SITC codes was not necessary. Using concordance tables from the World Bank's World Integrated Trade Solutions (WITS) website, the SITC codes were converted into ISIC revision 2 codes. These were then further mapped to ISIC revision 4 codes using concordance tables from the UN Trade Statistics website. This integrated concordance table was then used to convert the ISIC-based value chain to an SITC-based value chain. The resulting mapping from the concordance tables was further refined by again referring to the initial sources used to map the ISIC-based value chain. This included removing any duplicates that were introduced by the transformation and ensuring that each commodity was linked to the most relevant activity. The SITC data used for the trade-based calculations was sourced from the OEC website (OEC, 2019a), which in turn is sourced from the UN Comtrade database.

These mappings enabled an initial generic analysis of the basic metals value chain using both an output and trade data perspective. This generic analysis was then elaborated by performing country-specific analyses using both data sets. A developed and a developing country were chosen as examples. Germany was selected as an example of a developed country due to its extensive footprint in the downstream part of the value chain and its relatively good representation in the trade and output data. Similarly, Peru was chosen as the developing country case due to its relatively good representation in the output and trade data. Peru also complemented Germany due to its strong footprint in the upstream portion of the value chain and the importance of basic metals to its economy.

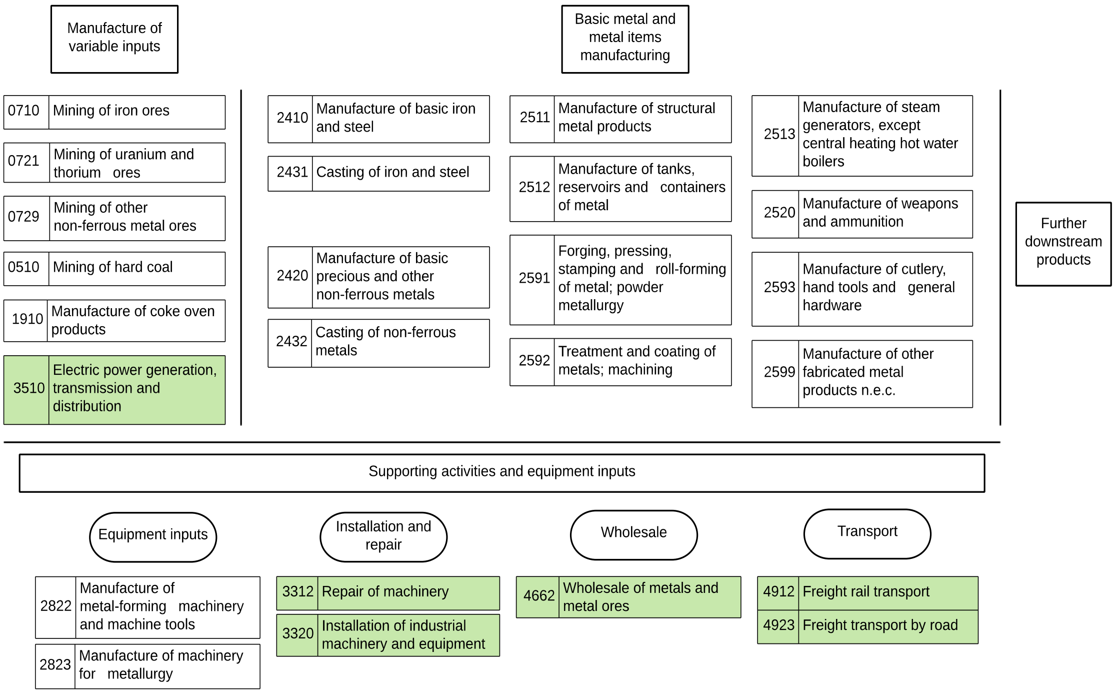
## 5 Case study results

This section provides an overview of the output and trade code-based value chain mappings (Section 5.1). It also presents the IO-PS results obtained from these different mappings (Section 5.2). Finally, Section 5.3 discusses the significance of the results.

### 5.1 Generic value chain results

The initial theoretical (i.e. without considering data constraints) ISIC-based basic metal and metal products value chain map that was developed is presented in Figure 2. The core is formed by the activities that make up the 4-digit basic metal and metal product ISIC categories. To the left of the core, the key input industries are included, and the key supporting industries are below the core. The part of the value chain further downstream was excluded to confine the focus of the analysis. The figure highlights the components that the ISIC data includes and which are typically not included in trade data. The output data, theoretically, allows for an inclusion of the supporting services as well as the electricity used as inputs.

**Figure 2: ISIC mapping of the basic metals industry (green indicates the components that have output codes but are not expected to be captured in trade data)**




The SITC mapping obtained by linking SITC revision trade codes to the ISIC-based value chain is illustrated in Figure 3. What the figure clearly shows is the additional level of detail obtained from the SITC mapping at the 4-digit level. This is one of the key advantages of using trade data for product space analyses – the improved granularity of data that is generally available in global data sets. The figure also highlights the activities for which no correlated trade codes could be found.

**Figure 3: SITC Mapping of the basic metal and metal products value chain (green indicates activities only expected in output data and yellow indicates activities that could not be isolated in the SITC data)**

## Manufacture of variable inputs

**Mining of iron ores**

| | |
|---|---|
| 2815 | Iron ore and concentrates,not agglomerated |
| 2816 | Iron ore agglomerates (sinters,pellets,briquettes) |

**Mining of uranium and thorium ores**

| | |
|---|---|
| 2860 | Ores and concentrates of uranium and thorium |

**Mining of other non-ferrous metal ores**

| | |
|---|---|
| 2874 | Lead ores and concentrates |
| 2875 | Zinc ores and concentrates |
| 2876 | Tin ores and concentrates |
| 2877 | Manganese ores and concentrates |
| 2871 | Copper ores & concentrates;copper matte/cement |
| 2872 | Nickel ores and concentrates;nickel mattes etc. |
| 2873 | Aluminium ores and concentrates (includ.alumina) |
| 2879 | Ores & concentrat.of other non-ferrous base metals |
| | |
| | |
| 2890 | Ores & concentrates of precious metals;waste,scrap |

**Mining of hard coal**

| | |
|---|---|
| 3221 | Anthracite,whether/not pulverized,not agglomerated |
| 3222 | Other coal,whether/not pulverized,not agglomerated |

**Manufacture of coke oven products**

| | |
|---|---|
| 3232 | Coke and semi-coke of coal of lignite or of peat |
| 3353 | Pitch & pitch coke obtain.from coal tar/miner.tars |

**Electric power generation, transmission and distribution**

## Basic metal and metal items manufacturing

**Manufacture of basic iron and steel**

| | |
|---|---|
| 2786 | Slag,dross,scalings and similar waste,n.e.s. |
| 6712 | Pig iron,cast iron and spiegeleisen,in pigs,blocks |
| 6713 | Iron or steel powders,shot or sponge |
| 6716 | Ferro-alloys |
| 6724 | Puddled bars and pilings;ingots,blocks,lumps etc. |
| 6725 | Blooms,billets,slabs & sheet bars of iron or steel |
| 6727 | Iron or steel coils for re-rolling |
| 6731 | Wire rod of iron or steel |
| 6732 | Bars & rods,of iron/steel;hollow mining drill st. |
| 6733 | Angles,shapes & sections & sheet piling,of iron/st |
| 6744 | Sheets & plates,rolled >4.75mm of iron/steel |
| 6745 | Sheets & plates,rld.thickns.3mm to 4,75mm irn/stl. |
| 6746 | Sheets & plates,rolled;thickness of less than 3mm. |
| 6747 | Tinned sheets and plates,of steel |
| 6749 | Other sheets and plates,of iron or steel,worked |
| 6760 | Rails and railway track construction material |
| 6770 | Iron/steel wire/wheth/not coated,but not insulated |
| 6782 | seamlesstubes and pipes;blanks for tubes & pipes |
| 6783 | Other tubes and pipes,of iron or steel |
| 6785 | Tube & pipe fittings(joints,elbows)of iron/steel |
| 6793 | Steel & iron forgings & stampings,in rough state |
| 6931 | Stranded wire,cables,cordages and the like |
| 6932 | Wire,twisted hoop for fencing of iron or steel |
| 6935 | Gauze,cloth,grill of iron steel or copper |
| 6940 | Nails,screws,nuts,bolts etc.of iron,steel,copper |
| 6973 | Domestic-type,non-electric heating,cooking appar. |
| 6974 | Art.commonly used for dom.purposes,pot scourers |
| 6975 | Sanitary ware for indoor use, and parts |
| 6992 | Chain and parts thereof,of iron or steel |
| 6993 | Pins & needles,fittings,base metal beads,etc. |
| 6994 | Springs & leaves for springs,of iron/steel/copper |
| 6997 | Articles of iron or steel, n.e.s. |

**Casting of iron and steel**

| | |
|---|---|
| 6781 | Tubes and pipes,of cast iron |
| 6794 | Castings or iron or steel,in the rough state |

**Manufacture of basic precious and other non-ferrous metals**

| | |
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**Casting of non-ferrous metals**

**Manufacture of structural metal products**

| | |
|---|---|
| 6911 | Structures & parts of struc.;iron/steel;plates |
| | |
| 7919 | Rail&tramway track fixtures&fittings,signall.equi. |

**Manufacture of tanks, reservoirs and containers of metal**

| | |
|---|---|
| 6921 | Reservoirs,tanks,vats and similar containers |
| 6924 | Casks,drums,boxes of iron/steel for packing goods |

**Forging, pressing, stamping and roll-forming of metal; powder metallurgy**

| | |
|---|---|
| 6978 | Household appliances,decorative art.,mirrors etc. |
| 6991 | Locksmiths wares,safes,strong rooms of base metal |

**Treatment and coating of metals; machining**

**Manufacture of steam generators, except central heating hot water boilers**

| | |
|---|---|
| 7111 | Steam & other vapour generating boilers |
| 7112 | Auxiliary plant for use with boilers,of 711.1- |
| 7119 | Parts of boilers & aux.plant of 711.1-/711.2- |
| 7187 | Nuclear reactors and parts |

**Manufacture of weapons and ammunition**

| | |
|---|---|
| 8946 | Non-military arms and ammunition therefor |
| 9510 | Armoured fighting vehicles,arms of war & ammunit. |

**Manufacture of cutlery, hand tools and general hardware**

| | |
|---|---|
| 6951 | Hand tools of a kind used in agriculture etc |
| 6954 | Interchangeable tools for hand & machine tools |
| 6953 | Other tools for use in the hand |
| 6960 | Cutlery |

**Manufacture of other fabricated metal products n.e.c.**

| | |
|---|---|
| 6996 | Miscellaneous articles of base metal |
| | |
| | |
| 7499 | Other non-electric parts & accessories of mach. |
| 8121 | Boilers & radiators for central heating |
| 8124 | Lighting fixtures and fittings and parts |
| 8219 | Other furniture and parts |
| 8951 | Office and stationery supplies,of base metal |

## Supporting activities

**Equipment inputs**

**Manufacture of metal-forming machinery and machine tools**

| | |
|---|---|
| 7281 | Mach.tools for specialized particular industries |
| 7361 | Metal cutting machine-tools |
| 7362 | Metal forming machine tools |
| 7367 | Other mach.-tools for working metal or met.carbide |
| 7368 | Work holders,self-opening dieheads & tool holders |
| 7369 | Parts of the machine-tools of 736-- |
| 7371 | Converters,ladles,ingot moulds and casting mach. |
| 7372 | Rolling mills,rolls therefor and parts |
| 7373 | Welding,brazing,cutting,soldering machines & parts |

**Manufacture of machinery for metallurgy**

| | |
|---|---|
| 7413 | Ind.& lab.furnaces and ovens and parts |

**Installation and repair**

- Repair of machinery
- Installation of industrial machinery and equipment

**Wholesale**

- Wholesale of metals and metal ores

**Transport**

- Freight rail transport
- Freight transport by road

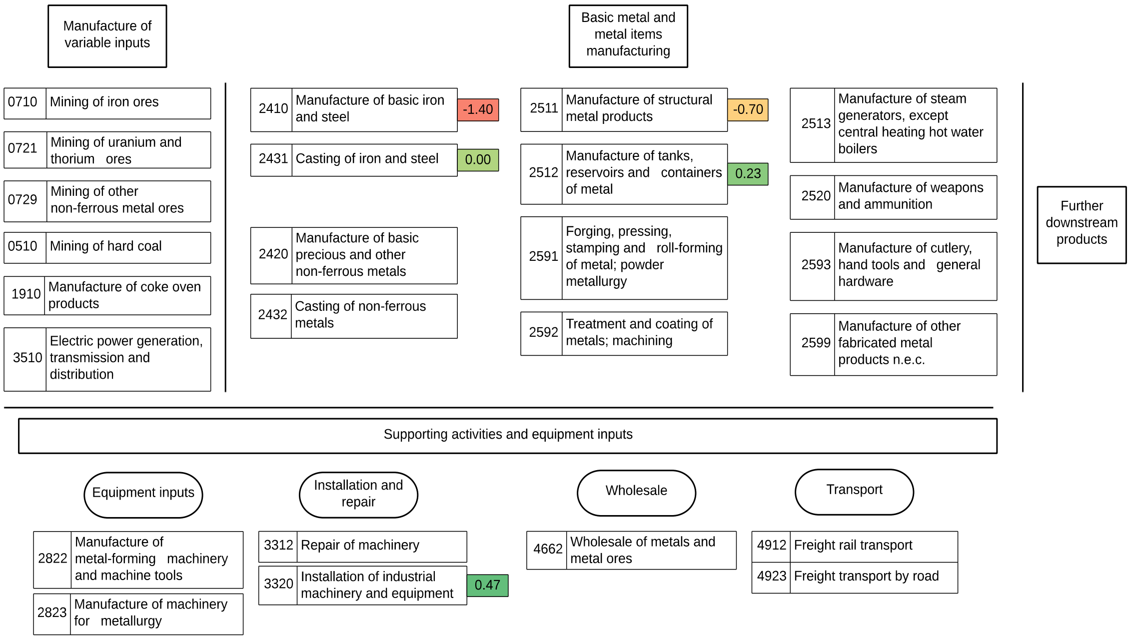
Once the mappings were complete, available trade and output data could be used to calculate the generic complexity values for the mapped activities. However, due to the limitations of data availability, the values could not be obtained for each of the activities using either of the data sources. Table 1 provides an overview of the data coverage for each data set. It indicates that the trade data has better coverage in terms of the number of codes for which data is available and the number of countries per code for which data is available. The complexity values that could be obtained using this data are illustrated in Figures 4 and 5.

**Table 1: Description of data set coverage**

| | SITC data set | ISIC data set |
|---|---|---|
| Total theoretical number of codes | 784 | 419 |
| Codes in data after consolidation for analysis | 755 | 31 |
| Number of countries for which data is available | 138 | 66 |
| Average number of countries for which data is available for each value chain activity | 108 | 51 |

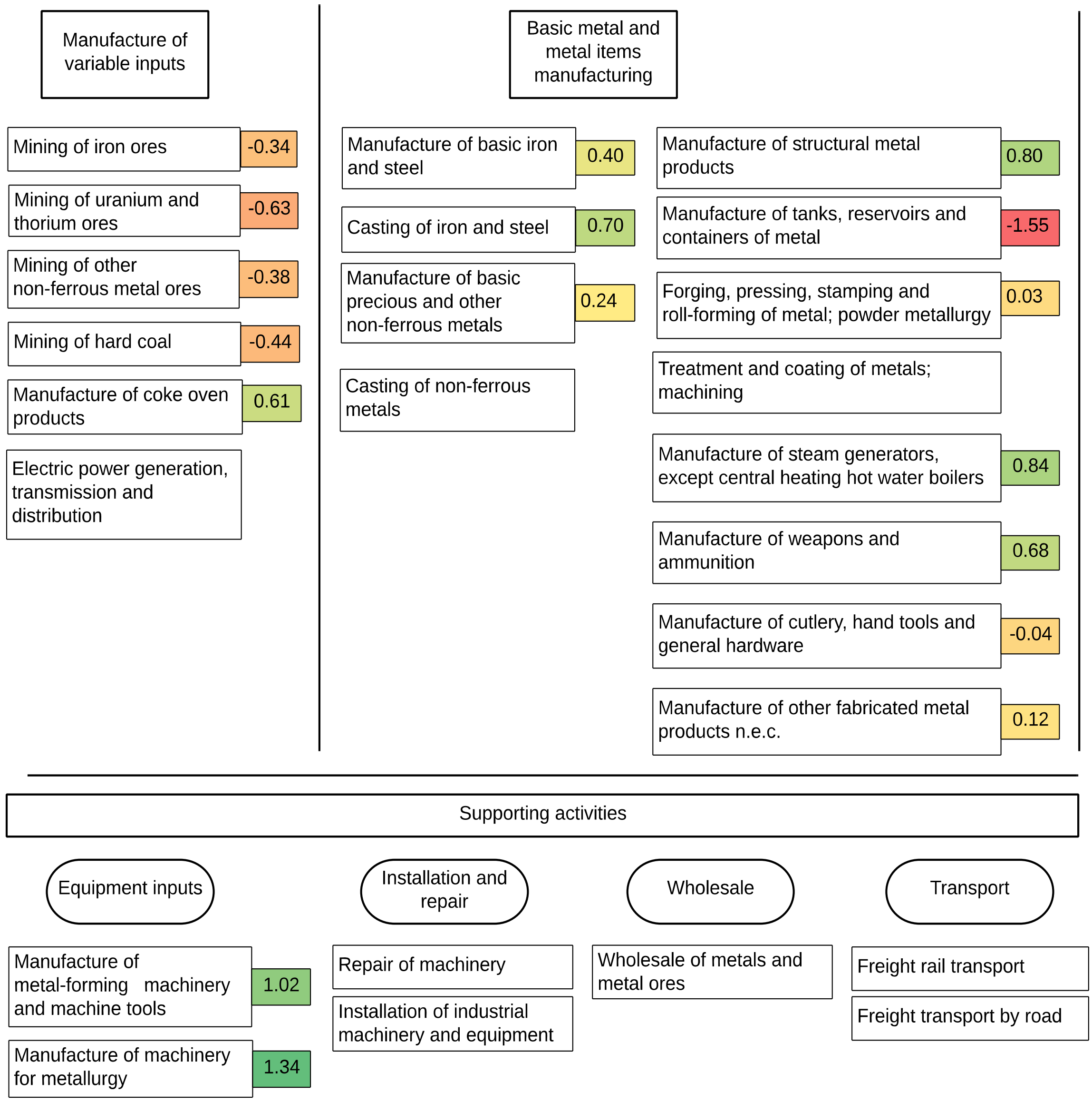
In Figure 4, the output data based-complexity is only displayed for those activities that represented not more than one additional output code after consolidation, and for which data was available for at least one country at the 4-digit level for 2016. Unfortunately, this constraint meant that the complexity value could only be calculated for five of the 25 activities considered. One of the reasons why none of the variable inputs were attained was the fact that the 4-digit codes starting with a ‘0’ (i.e. those associated with mining) are not included in the INDSTAT database and are instead captured by the MINSTAT database. Furthermore, the MINSTAT database does not yet include any data for 2016 and, reportedly, only has data up to the 3-digit level.

**Figure 4: ISIC mapping with available calculated complexity values added**




In Figure 5, the SITC-based complexity values are provided for each ISIC activity. The complexity displayed in each case is the average complexity of all underlying product codes that are linked to the activity. Figure 5 clearly illustrates the impact of the superior coverage and the quality of the SITC data when compared to the ISIC data.

**Figure 5: SITC-based value chain with calculated complexity values**




When we compare Figures 4 and 5, it is clear that both the ISIC and SITC results indicate a higher complexity for the *casting of iron and steel* than for the *manufacture of basic iron and steel products*. However, the ISIC-based calculations indicate that *tanks, reservoirs and containers of metal* have a higher complexity than the *manufacture of structural metal products*. This stands in direct opposition to what the SITC-based calculations suggest. What is also disappointing is that the ISIC data could only provide a measure for one activity that was not included in the SITC data, namely the *installation of industrial machinery and equipment*. Interestingly, this activity seems to have a high complexity and seems to align with the SITC result which indicates a high complexity for the *manufacture of machinery for metallurgy* and the *manufacture of metal-forming machinery and machine tools*.

From the above results, it seems that the current quality of the ISIC data at the 4-digit level prevents its full-scale use to support industrial policy decision making through the application of the IO-PS methodology. However, this might be different at the ISIC 2 or 3-digit levels, as more complete data may be available at these levels, though the higher level of aggregation will inevitably reduce the granularity of the analyses that are possible.

Nonetheless, the ISIC codes provide a natural value chain type structure according to which trade codes can be arranged. This ensures that IO-PS calculations can be aligned with the analytical perspectives of policymakers to feed into existing decision-making processes. One challenge associated with the methodology used to link the ISIC codes with trade data was that there is no recognized concordance between ISIC revision 4 and SITC revision 2. In future, the use of HS codes instead of SITC codes should be considered when an extended timeseries of the data is not required. The use of HS codes could simplify the mapping between the output and trade codes, as the WITS website has an official concordance between ISIC revision 4 and HS revision 2, for which a large trade data set is available.

## 5.2 Country-specific value chain results

The country-specific analysis focussed on the calculation of RCA/RIC to evaluate the current "footprint" of each country in the value chain according to each data set – where 'footprint' is defined as the products/activities for which a country has an RCA/RIC within a value chain. This was followed by an analysis of the complexity of the products/activities within the value chain that each country does not yet have an RCA/RIC in. A similar analysis was performed for the opportunity gain these unattained products/activities could provide to each country. To complement these metrics, the distance to these unattained products/activities was calculated. Finally, to assist with prioritizing opportunities, the ratio of opportunity gain per distance unit was calculated for each product category/activity.

The RCA/RIC results are presented in Table 2. The SITC results clearly reveal Peru's dominant position in the mining of basic metals and hard coal as well as the production of basic precious and other non-ferrous metals. At the same time, the SITC results clearly show Germany's strong position in the basic metals and metal items manufacturing industry, and even the manufacture of machinery and equipment required for this industry. Germany has an RCA for five of the 10 products within the industry for which data were available, whilst having an RCA value larger than 0.9 for a further three. Germany also has an RCA for both supporting equipment product categories. By contrast, Peru only had an RCA for the manufacture of basic precious and other non-ferrous metals. Furthermore, Peru also does not have an RCA for any of the equipment categories.

When analysing the ISIC-based RIC values, the lack of data again becomes clear. However, the available results seem to broadly align with the SITC results. In particular, the RIC and RCA values for the manufacture of basic iron and steel and casting of iron and steel between the two data sets are almost identical for Germany. Although the RIC for the manufacture of basic iron and steel is visible more strongly than the RCA in the case of Peru, both data sets indicate that Peru does not have a strong casting of iron and steel industry. Similarly, the results between the data sets for the manufacture of structural metal products and the manufacture of tanks, reservoirs and containers of metal seem to broadly align for the case of Germany (though the RIC values are lower than the RCA values). In the case of Peru, the RIC value for the manufacture of structural metal products is considerably higher than in the SITC data. Finally, the RIC value for the installation of industrial machinery and equipment seems to broadly align with each country's footprint in the downstream part of the value chain.

When we compare the results, it seems that the RIC value is more sensitive and reveals higher values in the case of Peru. Although this might indicate a bias towards export-oriented developed countries in the RCA value, it is likely caused by the omission of the mining industry in the ISIC data. As the mining industry makes a considerable contribution to Peru's export basket in the SITC data, but not to its output basket in the ISIC data, it is to be expected that Peru's RIC value would have higher values for the various manufacturing industries than the RCA values calculated using the SITC data, which include mining.

**Table 2: RCA and RIC results**

| Activity | SITC - RCA Germany | SITC - RCA Peru | ISIC - RIC Germany | ISIC - RIC Peru |
|---|---|---|---|---|
| Mining of iron ores | 0.002 | 1.317 | N/A | N/A |
| Mining of uranium and thorium ores | 0.000 | 0.000 | N/A | N/A |
| Mining of other non-ferrous metal ores | 0.368 | 22.113 | N/A | N/A |
| Mining of hard coal | 0.054 | 1.415 | N/A | N/A |
| Manufacture of coke oven products | 0.168 | 0.000 | N/A | N/A |
| Electric power generation, transmission and distribution | N/A | N/A | N/A | N/A |
| Manufacture of basic iron and steel | 0.991 | 0.240 | 0.906 | 1.410 |
| Casting of iron and steel | 1.562 | 0.002 | 1.559 | 0.000 |
| Manufacture of basic precious and other non-ferrous metals | 0.948 | 5.536 | N/A | N/A |
| Casting of non-ferrous metals | N/A | N/A | N/A | N/A |
| Manufacture of structural metal products | 1.705 | 0.061 | 0.959 | 0.604 |
| Manufacture of tanks, reservoirs and containers of metal | 0.380 | 0.025 | 0.207 | 0.000 |
| Forging, pressing, stamping and roll-forming of metal; powder metallurgy | 1.024 | 0.048 | N/A | N/A |
| Treatment and coating of metals; machining | N/A | N/A | N/A | N/A |
| Manufacture of steam generators, except central heating hot water boilers | 0.711 | 0.025 | N/A | N/A |
| Manufacture of weapons and ammunition | 0.927 | 0.459 | N/A | N/A |
| Manufacture of cutlery, hand tools and general hardware | 1.206 | 0.027 | N/A | N/A |
| Manufacture of other fabricated metal products n.e.c. | 1.031 | 0.163 | N/A | N/A |
| Manufacture of metal-forming machinery and machine tools | 1.983 | 0.017 | N/A | N/A |
| Manufacture of machinery for metallurgy | 2.004 | 0.094 | N/A | N/A |
| Wholesale of metals and metal ores | N/A | N/A | N/A | N/A |
| Freight rail transport | N/A | N/A | N/A | N/A |
| Freight transport by road | N/A | N/A | N/A | N/A |
| Repair of machinery | N/A | N/A | N/A | N/A |
| Installation of industrial machinery and equipment | N/A | N/A | 2.621 | 0.000 |

Table 3 presents the average complexity of the remaining products within each product category (in the case of the SITC data) or only the complexity of an activity for which a country does not yet have an RCA (in the case of the ISIC data). In general, the SITC complexity values are higher for Peru than for Germany (one exception is the manufacture of weapons and ammunition). This indicates that Germany has already achieved an RCA for some of the higher complexity products within most product categories, whilst Peru has only achieved an RCA for relatively lower complexity products in each product category – hence, the higher complexity of the remaining ones. Germany has also achieved an RCA for all underlying products in three cases as indicated by N/A, with Peru having unattained products within each category.

In the case of ISIC complexity values, the complexity is either the same as that indicated in Figure 4 (though with more decimal values indicated) or N/A, as there is only one ISIC code per activity for which a country either has or does not have a RIC. In Table 3, the greater granularity of the SITC data clearly holds an advantage, as it enables not only a binary value per activity, but a tailored average complexity value per country based on its existing production, and hence remaining products for which the country does not have an RCA within that country. The results again reflect the discrepancies between the data sets as highlighted in Section 5.1. Specifically, the *manufacture of basic iron and steel* and the *manufacture of structural metal products* have positive complexities in the SITC data and negative complexities in the ISIC data, while the opposite is true for the *manufacture of tanks, reservoirs and containers of metal*.

**Table 3: Complexity of unattained parts of the value chain**

| | Complexity of opportunities | | | |
|---|---|---|---|---|
| | SITC | | ISIC | |
| Activity | Germany | Peru | Germany | Peru |
| Mining of iron ores | -0.345 | -0.158 | | |
| Mining of uranium and thorium ores | -0.628 | -0.628 | | |
| Mining of other non-ferrous metal ores | -0.522 | -0.365 | | |
| Mining of hard coal | -0.441 | -0.334 | | |
| Manufacture of coke oven products | 0.613 | 0.613 | | |
| Electric power generation, transmission and distribution | | | | |
| Manufacture of basic iron and steel | 0.189 | 0.450 | -1.397 | N/A |
| Casting of iron and steel | N/A | 0.701 | N/A | 0.000 |
| Manufacture of basic precious and other non-ferrous metals | -0.016 | 0.557 | | |
| Casting of non-ferrous metals | | | | |
| Manufacture of structural metal products | N/A | 0.798 | -0.699 | -0.699 |
| Manufacture of tanks, reservoirs and containers of metal | -1.548 | -1.548 | 0.233 | 0.233 |
| Forging, pressing, stamping and roll-forming of metal; powder metallurgy | -0.684 | 0.028 | | |
| Treatment and coating of metals; machining | | | | |
| Manufacture of steam generators, except central heating hot water boilers | 0.830 | 0.836 | | |
| Manufacture of weapons and ammunition | 0.951 | 0.681 | | |
| Manufacture of cutlery, hand tools and general hardware | -2.788 | -0.038 | | |
| Manufacture of other fabricated metal products n.e.c. | -0.942 | 0.123 | | |
| Manufacture of metal-forming machinery and machine tools | -1.265 | 1.023 | | |
| Manufacture of machinery for metallurgy | N/A | 1.340 | | |
| Wholesale of metals and metal ores | | | | |
| Freight rail transport | | | | |
| Freight transport by road | | | | |
| Repair of machinery | | | | |
| Installation of industrial machinery and equipment | | | N/A | 0.466 |

Table 4 presents the expected opportunity gain if a country attains the rest of the products within an activity (according to SITC data) or attains an overall RCA for the activity (according to ISIC data). What the SITC data clearly shows is that Germany does not seem to have much to gain in terms of developing new capabilities within the basic metals value chain. The only exceptions are the attainment of the remaining products within the manufacture of *steam generator, except central heating hot water boilers* and the *manufacture of weapons and ammunition*, which promise some minor gains. In the case of Peru, a large number of activities still seem to hold some potential for improving the country's capabilities. Exceptions include the majority of the mining-related activities and the *manufacture of tanks, reservoirs and containers of metal*. The ISIC results do not align with the SITC results, as it indicates an opportunity for Germany in terms of the *manufacture of tanks, reservoirs and containers of metal*, and no positive opportunity gain avenues for Peru within the basic metals value chain.

**Table 4: Opportunity gain if products or activities without an RCA are to be attained**

| | Potential opportunity gain | | | |
|---|---|---|---|---|
| | SITC | | ISIC | |
| Activity | Germany | Peru | Germany | Peru |
| Mining of iron ores | -0.204 | -0.008 | | |
| Mining of uranium and thorium ores | -0.006 | -0.002 | | |
| Mining of other non-ferrous metal ores | -0.265 | -0.033 | | |
| Mining of hard coal | -0.178 | 0.049 | | |
| Manufacture of coke oven products | -0.114 | 0.198 | | |
| Electric power generation, transmission and distribution | | | | |
| Manufacture of basic iron and steel | -0.218 | 0.205 | -0.394 | N/A |
| Casting of iron and steel | N/A | 0.374 | N/A | -0.272 |
| Manufacture of basic precious and other non-ferrous metals | -0.206 | 0.255 | | |
| Casting of non-ferrous metals | | | | |
| Manufacture of structural metal products | N/A | 0.402 | -0.423 | -0.298 |
| Manufacture of tanks, reservoirs and containers of metal | -0.792 | -0.613 | 0.233 | -0.266 |
| Forging, pressing, stamping and roll-forming of metal; powder metallurgy | -0.303 | 0.110 | | |
| Treatment and coating of metals; machining | | | | |
| Manufacture of steam generators, except central heating hot water boilers | 0.028 | 0.291 | | |
| Manufacture of weapons and ammunition | 0.046 | 0.324 | | |
| Manufacture of cutlery, hand tools and general hardware | -1.189 | 0.023 | | |
| Manufacture of other fabricated metal products n.e.c. | -0.642 | 0.038 | | |
| Manufacture of metal-forming machinery and machine tools | -0.911 | 0.366 | | |
| Manufacture of machinery for metallurgy | N/A | 0.612 | | |
| Wholesale of metals and metal ores | | | | |
| Freight rail transport | | | | |
| Freight transport by road | | | | |
| Repair of machinery | | | | |
| Installation of industrial machinery and equipment | | | N/A | -0.252 |

Table 5 shows the average distance to all the products within an activity for which a country does not yet have an RCA (according to the SITC data) or the distance to the activities for which a country does not yet have a RIC (according to the ISIC data). For both data sets, Germany has a lower (average) distance to all activities for which both countries do not yet have an RCA/RIC, except for the mining of uranium and thorium ores. Although the distances provide an indication of which products/activities are expected to be easier to target (based on the experiences of countries that export products similar to those of the focal country), it does not on its own provide a useful way of prioritizing activities to target.

**Table 5: Distance to unattained products/activities**

| | Distance | | | |
|---|---|---|---|---|
| | SITC | | ISIC | |
| Activity | Germany | Peru | Germany | Peru |
| Mining of iron ores | 0.690 | 0.852 | | |
| Mining of uranium and thorium ores | 0.817 | 0.715 | | |
| Mining of other non-ferrous metal ores | 0.673 | 0.840 | | |
| Mining of hard coal | 0.663 | 0.844 | | |
| Manufacture of coke oven products | 0.524 | 0.911 | | |
| Electric power generation, transmission and distribution | | | | |
| Manufacture of basic iron and steel | 0.570 | 0.894 | 0.575 | N/A |
| Casting of iron and steel | N/A | 0.897 | N/A | 0.684 |
| Manufacture of basic precious and other non-ferrous metals | 0.585 | 0.893 | | |
| Casting of non-ferrous metals | | | | |
| Manufacture of structural metal products | N/A | 0.898 | 0.579 | 0.659 |
| Manufacture of tanks, reservoirs and containers of metal | 0.667 | 0.869 | 0.570 | 0.684 |
| Forging, pressing, stamping and roll-forming of metal; powder metallurgy | 0.635 | 0.908 | | |
| Treatment and coating of metals; machining | | | | |
| Manufacture of steam generators, except central heating hot water boilers | 0.550 | 0.913 | | |
| Manufacture of weapons and ammunition | 0.481 | 0.892 | | |
| Manufacture of cutlery, hand tools and general hardware | 0.759 | 0.913 | | |
| Manufacture of other fabricated metal products n.e.c. | 0.652 | 0.905 | | |
| Manufacture of metal-forming machinery and machine tools | 0.751 | 0.921 | | |
| Manufacture of machinery for metallurgy | N/A | 0.919 | | |
| Wholesale of metals and metal ores | | | | |
| Freight rail transport | | | | |
| Freight transport by road | | | | |
| Repair of machinery | | | | |
| Installation of industrial machinery and equipment | | | N/A | 0.686 |

To determine priorities, Table 6 indicates the ratio of the average opportunity gain that could be achieved by attaining an RCA for all remaining products within an activity (according to SITC data) or the attainment of a RIC for an activity (according to ISIC data) to the average distance of products within an activity for which a country does not yet have an RCA (according to SITC data) or the distance to the activity (according to ISIC data).

**Table 6: Opportunity gain per distance unit to unattained products within an activity or an unattained activity**

| | Opportunity gain over distance | | | |
|---|---|---|---|---|
| | SITC | | ISIC | |
| Activity | Germany | Peru | Germany | Peru |
| Mining of iron ores | -0.296 | -0.010 | | |
| Mining of uranium and thorium ores | -0.007 | -0.003 | | |
| Mining of other non-ferrous metal ores | -0.394 | -0.039 | | |
| Mining of hard coal | -0.268 | 0.058 | | |
| Manufacture of coke oven products | -0.217 | 0.217 | | |
| Electric power generation, transmission and distribution | | | | |
| Manufacture of basic iron and steel | -0.382 | 0.230 | -0.686 | N/A |
| Casting of iron and steel | N/A | 0.417 | N/A | -0.398 |
| Manufacture of basic precious and other non-ferrous metals | -0.352 | 0.286 | | |
| Casting of non-ferrous metals | | | | |
| Manufacture of structural metal products | N/A | 0.447 | -0.731 | -0.452 |
| Manufacture of tanks, reservoirs and containers of metal | -1.187 | -0.706 | 0.409 | -0.389 |
| Forging, pressing, stamping and roll-forming of metal; powder metallurgy | -0.478 | 0.121 | | |
| Treatment and coating of metals; machining | | | | |
| Manufacture of steam generators, except central heating hot water boilers | 0.051 | 0.319 | | |
| Manufacture of weapons and ammunition | 0.095 | 0.362 | | |
| Manufacture of cutlery, hand tools and general hardware | -1.567 | 0.025 | | |
| Manufacture of other fabricated metal products n.e.c. | -0.985 | 0.042 | | |
| Manufacture of metal-forming machinery and machine tools | -1.213 | 0.398 | | |
| Manufacture of machinery for metallurgy | N/A | 0.666 | | |
| Wholesale of metals and metal ores | | | | |
| Freight rail transport | | | | |
| Freight transport by road | | | | |
| Repair of machinery | | | | |
| Installation of industrial machinery and equipment | | | N/A | -0.367 |

When we consider the SITC data, the only opportunities for Germany seem to lie in the attainment of the remaining products within the *manufacture of steam generators, except central heating hot water boilers* and the *manufacture of weapons and ammunition*, which promise some minor gains, with a slight preference for the latter. However, the ISIC data seems to contradict the SITC data by supporting the *manufacture of tanks, reservoirs and containers of metal* – which the SITC data, however, discourages. In the case of Peru, the SITC calculation promotes most downstream products, and a clear prioritization emerges, with the top 10 (together with their opportunity gain to distance ratio and distance value) presented in Table 7. For Peru, the ISIC data again contradicts the SITC data (except for the case of the manufacture of tanks, reservoirs and containers of metal), with the ISIC results indicating that no available activities would contribute to the development of capabilities in Peru.

**Table 7: Prioritized activities for Peru by opportunity gain to distance ratio (SITC data)**

| | | Peru | |
|---|---|---|---|
| # | Activity | Ratio | Distance |
| 1 | Manufacture of machinery for metallurgy | 0.666 | 0.919 |
| 2 | Manufacture of structural metal products | 0.447 | 0.898 |
| 3 | Casting of iron and steel | 0.417 | 0.897 |
| 4 | Manufacture of metal-forming machinery and machine tools | 0.398 | 0.921 |
| 5 | Manufacture of weapons and ammunition | 0.362 | 0.892 |
| 6 | Manufacture of steam generators, except central heating hot water boilers | 0.319 | 0.913 |
| 7 | Manufacture of basic precious and other non-ferrous metals | 0.286 | 0.893 |
| 8 | Manufacture of basic iron and steel | 0.230 | 0.894 |
| 9 | Manufacture of coke oven products | 0.217 | 0.911 |
| 10 | Forging, pressing, stamping and roll-forming of metal; powder metallurgy | 0.121 | 0.908 |

The data in Table 7 provide a first reference point for policymakers. It provides an indication of which activities entail the highest opportunity gain (as a proxy for capability development) per distance value (as a proxy for difficulty to develop). It also provides the absolute values of the average distance for the products within the category to provide a greater appreciation of the difficulty of attaining an RCA for the products within the given industry. The results should, however, be interpreted with caution and should only be used as an initial starting point for further in depth analyses. This is because the product space remains heuristic and does not, for example, consider market conditions or how a particular activity could be attained – or even whether it could practically be attained at all. This is because there are various important variables that are not directly considered in product space calculations. These include geo-political considerations, factor conditions and even the transportability of products to final markets.

## 5.3 Discussion of results

In terms of methodology, the conversion from ISIC to SITC was rather convoluted. An alternative approach would be to use HS trade codes. This could potentially improve the process, as an official concordance table between the ISIC codes and HS codes already exists. Although this would mean sacrificing some data in terms of the historical time horizon for which data is available, it would also improve the granularity of the available data (6-digits versus 4-digits), if required.

In terms of alignment of insights from the two data sets, the results outlined in Sections 5.1 and 5.2 present a mixed picture. First of all, the coverage of the SITC data is clearly much better than for the ISIC data. This is true along two dimensions. Firstly, significantly more areas of the value chain are covered by trade data than by output data. Secondly, due to its greater granularity, the trade data enabled more nuanced analyses at the activity level than the binary analysis afforded by the ISIC data.

The ISIC data and SITC data at times provided similar insights, while in some instances, the ISIC data contradicted the SITC data results. Specifically, for the RCA versus the RIC calculations, the RIC results indicated a greater sensitivity for Peru than the RCA values. This, however, is likely due to the exclusion of the mining data in the ISIC data set. The distance values between the data sets broadly aligned in terms of implications. The largest discrepancies were noted for the complexity and opportunity gain values. As the opportunity gain values did not align, the ratio of opportunity gain and distance also did not align – as would be expected.

Where we come across contradictory data, the question arises which results should be given more weight or should be considered more trustworthy. Intuitively, one might expect that the data set with better coverage will deliver better results, thus favouring the SITC data set. Furthermore, previous studies have shown that the more granular the data being used is, the stronger the results are in terms of predicting economic growth – a fundamental target of product space analyses (Ivanova, Strand, Kushnir, & Leydesdorff, 2017). The results from the analyses thus cast serious doubt on the reliability of using output data for IO-PS at this point in time. Instead, even if output codes are used to initially structure an analysis, it is recommended to use more granular trade data for calculations. This is because the output data is not yet of a sufficient quality (in terms of availability and level of granularity) to be relied upon for analytical insights from a product space perspective.

## 6 Conclusion

This working paper provides an outline of the theoretical underpinnings of the IO-PS (Section 2). Specifically, it discusses various product space metrics and the insights they provide (Section 2.1). It also discusses the IO-PS extension to the product space methodology. Section 3 addresses the potential benefits of using output data instead of the commonly used trade data for IO-PS analyses. Section 4 provides an overview of the methodology used to explore whether the available output data is sufficient in terms of coverage and granularity to justify its use for IO-PS calculations. Section 5 presents the results of the application of the IO-PS framework to the case study of the basic metals industry using both output and trade data. The results suggest that the output data does not yet provide the coverage that the trade data does. To further explore the differences in results between the two data sets, the IO-PS was applied to the cases of Germany and Peru. The two cases highlight the alignment and discrepancies between the results obtained by using the two data sets.

Due to the relatively poor coverage of the existing output data, it is recommended to use trade data for all product space calculations aimed at supporting policy decision making at this stage. Nonetheless, output data can be useful for providing an initial mapping of the value chain. The input-output tables, which are key resources when constructing the value chain, usually make use of output-based classifications instead of trade classifications. Thus, using output codes for the initial mapping is generally easier. Once the basic value chain has been mapped, the higher level output codes can subsequently be converted into the more detailed trade codes using concordance tables. However, it is suggested that future studies make use of HS trade codes instead of SITC trade codes, as better resources are available for the conversion from ISIC codes to HS codes than to SITC codes. The main advantage of using output codes for the initial mapping of a value chain is certainly that the resulting value chain can be more directly compared with other analyses that make use of output data – if such analyses are available or being used for a particular purpose. For applications where this is not the case, an IO-PS approach that bypasses the ISIC code mapping stage will likely remain the preferred methodological route.

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