

# Mapping of Capabilities and Export Opportunities of Czechia

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## Abstract

Czechia is one of the most export-oriented countries, reaching high levels of economic complexity. However, its innovative capabilities remain limited. Taking these factors into consideration, we determined the country's optimal diversification path by identifying prospective export sectors which would enhance the country's competitiveness. We combine the product space and proximity methodologies on predicted export data together with a company-level analysis. We identified machinery for specialized industries and parts thereof (SITC 7284), machine-tools for specialized industries parts or accessories (SITC 7281) and power hand tools, pneumatic or non-electric, and parts thereof (SITC 7541) as the most prospective categories in terms of high complexity, expected trade volume growth, proximity to Czechia's existing production capabilities and manufacturing base operated by large, highly innovative Czech-owned firms.

**Keywords:** export, specialization, product complexity, comparative advantage, product relatedness, diversification

**JEL classification:** F14, F17, L60, O14, O33

## Introduction

It is widely acknowledged that countries can only produce goods for which they possess productive knowledge (factors of production, institutions, infrastructure) (Hidalgo and Hausmann, 2009; Hausmann et al., 2014). Diversification possibilities are thus largely dependent on the set of localized capabilities (Maskell and Malmberg, 2007) reflected in the type of products that

countries already produce and export. The relatedness of the productive knowledge, or so-called distance between products, is thus crucial for future regional diversification and hence also future economic growth (Breschi et al., 2003; Boschma et al., 2012). These ideas were further elaborated by Hidalgo and Hausmann (2009) and Hausmann et al. (2014), who proposed the Economic Complexity Index (ECI). It is a measure of the productive knowledge available in the country, given by the mix of exported products. Similarly, they quantify the productive knowledge needed to make an individual product using the Product Complexity Index (PCI). These concepts have gained increasing popularity in recent years, providing a tool for guidance in a country's diversification possibilities. Yet, the application to Central European countries has been rather limited so far.

One of the countries where this approach has not been implemented, at least to our best knowledge, is Czechia. Over the past thirty years, Czechia has become one of the most export-oriented countries in the world. This has been enabled by its favourable geographic location, industrial tradition, lower production costs as well as political and institutional changes after the transition (Drahokoupil, 2009; Pavlínek, 2012). Czechia is now largely integrated into world trade, but its innovative capabilities, though improving, have not yet reached the level of its western neighbours. Simultaneously, many domestic products are based on foreign inputs. Therefore, it is desirable for Czechia to increase the complexity of exported products as well as its domestic content in order to increase its competitiveness.

This paper aims to determine the optimal diversification path for Czechia based on the identification of prospective export sectors. Identification of strategic options is vital for future structural transformation. We focus on product categories with the highest potential for Czechia in terms of complexity and future growth possibilities. This approach allows us to ignore products that are becoming obsolete and could contribute to lock-in situations due to shifts in global demand (Hassink, 2010) and help us identify products that are highly complex, expected to grow and can be found close to existing production capabilities (i.e., are related to already exported Czech products with RCA<sup>1</sup>), but in which Czechia still lacks RCA.

The paper is structured as follows. In the first chapter we review existing literature related to innovation, exports and how these contribute to economic growth, including the recent concepts of product space and economic complexity. We also mention studies related to the post-communist transition of Czechia. The data and methodology section includes a detailed procedure which enables the identification of prospective sectors related to the existing production

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1 RCA stands for revealed comparative advantage; section Data and Methodology explains how RCA can be measured.

capabilities. In the discussion part, we first describe the top ten product groups we consider to be the most prospective for Czechia, then we analyse existing production capabilities, including successful firms already engaged in their production. In the conclusion, we sum up the key findings and discuss further research areas.

## 1. Literature Review

### 1.1 Product space and economic complexity

Extensive literature provides evidence that innovation and technology are the drivers of economic growth (e.g., Romer, 1990; Grossman and Helpman, 1991). Innovations are embodied in goods and services; these products thus reveal how an economy's knowledge assets are used to leverage resources and generate wealth. In general, exports represent the part of the country's production that is the most efficient as only a limited number of companies export and those that do export tend to be larger and more productive than non-exporting companies (Bernard and Jensen, 1999). Hence, countries exporting more sophisticated goods have experienced faster economic growth (Fagerberg, 1994; Hausmann et al., 2007).

Traditional trade theories, dating back to Adam Smith and Heckscher-Ohlin, see the competitiveness of the countries in terms of specialization, though new trade theories emphasize the role of variety (Helpman and Krugman, 1985; Fujita et al., 1999). The product space concept, in a seminal article by Hidalgo et al. (2007), represents a network of all globally traded goods illustrating their relatedness. Each product is represented by a node corresponding to the volume of its trade. The level of relatedness (proximity) between products is given by the frequency of co-occurrence of two products with comparative advantage ("revealed relatedness", Neffke and Henning, 2008) in the countries' export portfolios. Densely connected, generally more sophisticated, products are located in the core of the product space, while the periphery is occupied by less sophisticated products characterized by fewer connections to other products (Felipe et al., 2012). The ability to produce a new product is given by its similarity to already existing products close to the productive knowledge of currently produced products (Hausmann et al., 2014). Thus, countries with larger numbers of products occupying the core of the product space have better possibilities for diversification related to their current export basket (Kali et al., 2013). Poorer countries, on the other hand, tend to occupy more of the periphery of the product space, therefore the diversification path is longer, since great leaps in diversification are harder to achieve.

A country's productive capabilities are reflected in its export sophistication, which can be measured by the Economic Complexity Index introduced by Hidalgo and Hausmann (2009). The ECI comprises two dimensions: diversity and ubiquity. While diversity corresponds to the number of goods a country exports, ubiquity reflects the “uniqueness” of exports, which is related to the number of countries exporting the same goods. Hence, top-performing countries tend to have more diversified and less ubiquitous exports. Several studies have also provided evidence that ECI is positively correlated with per capita income and can be used to predict future economic growth (Hausman et al., 2014; Zhu and Li, 2017). At the product level, the Product Complexity Index (PCI) estimates the technological sophistication of individual products: the productive capabilities needed for its production. The most complex products include chemicals, electronics, machines and machinery; on the other hand, the least complex are mineral resources and simple agricultural products (Felipe et al., 2012; Hausman et al., 2014). Product space and economic complexity have been applied in regional and country-level assessment, e.g., for Sub-Saharan African countries (Abdon and Felipe, 2011), Asian and Latin American countries (Jankowska et al., 2012), Brazil (De La Cruz and Riker, 2012), Rwanda (Hausmann and Chauvin, 2015) and Mozambique (Sørensen et al., 2020).

The role of specialization and diversification for economic growth has also been analysed at the regional level (Glaeser et al., 1992; Beaudry and Schiffauerova, 2009). Similar to Hidalgo et al. (2007), the concept of related variety introduced by Frenken et al. (2007) points out that for effective knowledge spillover, shared or complementary competences between sectors are needed. A high degree of export-related variety has indeed been found to be essential for explaining economic growth in Spanish and Italian regions (Boschma and Iammarino, 2009; Boschma et al., 2012). In general, it is rare for new companies to engage in activities that are completely different from existing knowledge in the region (Pinheiro et al., 2018). These exceptional cases are usually related to the activities of actors from outside the region, such as multinationals (MNEs) (Trippel et al., 2015). Moreover, the probability of engaging in activities unrelated to the existing knowledge base is higher in liberal market economies (Boschma and Capone, 2015) and in innovative countries with higher incomes (Petrulia et al., 2017), making it less likely in a post-communist Central European country.

## 1.2 Post-communist transition in Czechia

Czechia became fully integrated into the world economy in the 1990s and is now highly dependent on exports (exports relative to GDP accounted for 70% in 2020; European Commission, 2022). Over the past 30 years, Czechia has undergone an extensive transition to a market economy,

which has been reflected in its export volume and structure. In the first half of the 1990s, the industrial products were rather uncompetitive due to lower quality and limited technological sophistication (Hoekman and Djankov, 1997). Since the mid-1990s, more manufactured goods have been traded, with a growing share of human capital and technology-intensive products (Hotopp et al., 2002). This has been associated with foreign capital and the entry of MNEs (Lankes et al., 1999), which have focused mainly on the production of intermediates for export (Myant and Drahokoupil, 2012). At the turn of the millennium, with the upcoming EU accession, export orientation became more profound, taking advantage of a relatively skilled and cheap labour force, particularly in the manufacturing sector (Benáček et al., 2000; Pavlínek et al., 2009). Cost-cutting reasons led to the relocation of production from other countries to Czechia, particularly in the electronics and automotive industries (Humphrey and Memedovic, 2003). As a small open economy, Czechia has become significantly integrated into global value chains/production networks (Vlčková, 2018). Despite large exports, foreign capital plays an important role in Czechia and neighbouring countries; thus, they are called dependent market economies (Nölke and Vliegenthart, 2009). This dependence limits the value capture and control by the domestic countries and makes economies reliant on foreign technologies (Smith et al., 2014).

Although there are many papers on economic transition and the role of foreign trade in Central European economies (see above), studies that use the ECI or PCI are rare. For instance Gabrielczak and Serwach (2019) examined the impact of Slovak EU accession on its export complexity, and Stojkoski and Kocarev (2017) found that economic complexity is a significant explanatory variable of growth for Central and Southeastern European economies. To our best knowledge, there are no other papers elaborating on Czechia or Central European countries using the complexity approach and our paper thus brings novelty in this area of research.

## 2. Data and Methodology

In this paper, we combine the macro and micro-level approaches. First, we identify prospective sectors based on country-level export data. Then, we map existing capabilities in the identified prospective sectors and highly related sectors based on Czech company-level data.

The empirical analysis of the paper is based on the product space and proximity methodology, which enables us to assess the current position of Czechia in the product space and identify potential export diversification. The initial position of a country within the product space determines potential diversification possibilities. Countries can diversify their exports either by taking a big leap towards distant products or shifting their production towards

products lying close to their current export basket. When analysing export opportunities, we will focus on the latter path, because it requires less effort from the country undergoing such a diversification process.

Export data are taken from the Atlas of Economic Complexity published at the Center for International Development at Harvard University. The database provides cleaned export data, retrieved from UN Comtrade, at a highly aggregated level. In our analysis, we use 4-digit SITC rev. 2<sup>2</sup> export data<sup>3</sup>. One of the limitations is the fact that export data do not reflect domestic value added, which is often lower for countries highly integrated into GVCs such as Czechia. Nonetheless, trade in value-added datasets is only available at a sectoral level, which disables identification of prospective products. Furthermore, by using the economic (and product) complexity approach based on a country's production capabilities, we overcome possible biases stemming from the use of income levels of exporters common to previous measures of product sophistication (e.g., Lall et al., 2006; Hausmann et al., 2007).

We employ this dataset to predict export data time series until 2023, using ARMA/ARIMA models<sup>4</sup>. ARMA/ARIMA forecasts are based solely on the past development of the time series. Calculations are made using the R *forecast* package (Hyndman R. et al., 2019; Hyndman and Khandakar, 2008).

We use a three-year temporal mean to smooth potential single-year trend deviations: 2011–2013, 2016–2018 and 2021–2023. The time periods are hereinafter referred to as *past*, *present* and *future*. Variables that use the *future* period data are marked with a superscript <sup>F</sup>, variables that use the *past* period data are marked with a superscript <sup>P</sup>.

2 SITC rev. 2 stands for Standard International Trade Classification Revision 2. The first SITC version was published in 1950; since then, there have been four revisions. Because of data continuity, many databases employ rev. 2 or rev. 3 and not necessarily the latest one, rev. 4.

3 For Czechia, data are available for the period 1993–2017. For the other economies, data are available for up to 1962–2017. For methodological reasons (forecasting using ARMA/ARIMA models), we use the maximum available time series length for each economy. The time series are at first forecast for each economy; world export data are then the aggregation of the individually forecast time series.

4 The forecast was made as follows. The KPSS test was used to decide on the presence or absence of a unit root in the time series. Subsequently, for the original time series (if the unit root was not found by the KPSS test) or for the differenced time series (if a unit root was found by the KPSS test), all the possible ARMA/ARIMA models satisfying the following restrictions were considered. The maximum AR and MA orders could be equal to 3 and the sum of these orders could be equal to at most 4. From these many models, the model with the lowest value of the adjusted Akaike information criterion was then selected and this was used to predict the time series.

Obtained data are employed in the following four steps:

### A. Identification of Czechia's current comparative advantages and disadvantages

We calculate the revealed comparative advantages (RCA) for Czech exports. We employ the Balassa index to calculate the RCA (Equation 1). The index is defined as a compound fraction where the relative share of the 4-digit SITC category on the country's total export is in the numerator and the relative share of the same category on total world's exports in a given year is in the denominator:

$$RCA_{ij} = \frac{\frac{x_{ij}}{\sum_j x_{ij}}}{\frac{\sum_i x_{ij}}{\sum_i \sum_j x_{ij}}} \quad (1)$$

where  $x_{ij}$  is the export of the product  $j$  by the country  $i$ .

The Balassa index reaches values from zero to infinity. RCA values greater than one denote comparative advantage, and vice versa, values below 1 show that a country has no comparative advantage. Various modifications of the original index can be found in the literature (e.g., Ballance et al., 1987; Memedovic, 1994; Vollrath, 1991); however, as we are not examining RCA development across time, nor space, the original Balassa index is suitable for our purpose (Sejkora and Sankot, 2017).

Let the temporal mean of the Balassa index in the *present* period (2016–2018) identify the current comparative advantages of Czechia. All manufacturing products are subsequently split into two groups, based on whether  $RCA_{ij}$  is above or below  $\overline{RCA_i}$ . Since we are interested in the opportunities of Czechia, we consider only commodities with RCA below the country's mean (Equation 2):

$$RCA_{ij} < \overline{RCA_i} \quad (2)$$

### B. Identification of products with high PCI and export prospects

We evaluate the PCI and export development. Namely, we identify products with higher PCI than the PCI of Czechia's current comparative advantages. We calculate the PCI for all 4-digit SITC export categories for Czechia using the R package Economiccomplexity (Vargas, 2022),

employing the *method of reflections* (for details see Hidalgo and Hausmann, 2009)<sup>5</sup>. Now, let the PCI temporal mean of products in which Czechia currently (2016–2018) demonstrates an above-average comparative advantage  $\overline{PCI}_i | (RCA_{ij} > \overline{RCA}_i)$  determine the threshold that splits Czechia's exports in the future period (2021–2023) into two groups. Opportunities for Czechia are searched for within the group of commodities that demonstrate higher PCI than the commodities currently produced at above-average comparative advantage (Equation 3).

$$PCI_{ij}^F > \overline{PCI}_i | (RCA_{ij} > \overline{RCA}_i) \quad (3)$$

Simultaneously, we evaluate the development of exports on the world market by comparing the export temporal mean of a = commodity  $j$  in the future period<sup>6</sup> and the past period<sup>7</sup> (Equation 4).

$$\Delta \sum_i x_{ij} = \sum_i x_{ij}^F - \sum_i x_{ij}^P \quad (4)$$

As the global export volumes demonstrate a decrease on average, let the opportunities of Czechia be found within the group of commodities that exhibit export growth (Equation 5).

$$\Delta \sum_i x_{ij} > 0 \quad (5)$$

### C. Selection of prospective products for Czechia: ones that Czechia does not produce at comparative advantage and simultaneously demonstrate high PCI and growth prospects

We identify the prospective products as the intersection of opportunities in terms of PCI, export development and current comparative disadvantage for Czechia (Equation 6).

$$\{RCA_{ij} < \overline{RCA}_i\} \cap \{PCI_{ij}^F > \overline{PCI}_i | (RCA_{ij} > \overline{RCA}_i)\} \cap \{\Delta \sum_i x_{ij} > 0\} \quad (6)$$

5 The method of reflection is one of the methods to calculate economic complexity indicators, among others the PCI. Our selection of this method is based on its usage in the seminal paper by Hidalgo and Hausmann (2009).

6  $\sum_i x_{ij}^F = (\sum_i x_{ij}^{2021} + \sum_i x_{ij}^{2022} + \sum_i x_{ij}^{2023}) / 3$

7  $\sum_i x_{ij}^P = (\sum_i x_{ij}^{2011} + \sum_i x_{ij}^{2012} + \sum_i x_{ij}^{2013}) / 3$

#### D. Assessment of similarity of prospective products with ones Czechia currently produces at comparative advantage

We compute the product relatedness and create the product space. The results of the Balassa index are transformed into a binary system where 0 corresponds to comparative disadvantage ( $RCA_{ij} < 1$ ) and 1 to comparative advantage ( $RCA_{ij} > 1$ ). Subsequently, we construct a proximity matrix for products stemming from the Jaccard similarity index (J), a statistical measure to identify similarity of sets. The formula for the Jaccard index is defined as Equation (7) (Bouchard et al., 2013):

$$J_{ji} = \frac{M_{11}}{M_{01} + M_{10} + M_{11}} \quad (7)$$

where in our case:

$M_{11}$  indicates the total number of countries  $j$  that demonstrate a comparative advantage (1) in production of two compared products  $x_i$ ,

$M_{01}$  indicates the total number of countries where the first product is not produced at comparative advantage (0) and the second product is produced at comparative advantage (1),

$M_{10}$  indicates the total number of countries where first product is produced at comparative advantage (1), and the second product is not produced at comparative advantage (0).

The Jaccard similarity index holds values from 0 to 1. Values closer to unity indicate stronger relatedness and vice versa. Let the Jaccard similarity index compare similarity among products Czechia currently exports at comparative advantage ( $RCA_{ij} > \overline{RCA_i}$ ) and prospective products. For reasons of clarity, the above-mentioned methodology is visualized in Figure 2.

We then build the world product space network depicting the mutual relatedness (proximity) of exported products based on similar knowledge and capabilities required to produce them (Hausmann and Hidalgo, 2011; Hausmann et al., 2014). Following Hidalgo et al. (2007), we set the threshold for proximity between products at  $> 0.4$  to eliminate the number of weak connections.

Based on this procedure, we identify the most promising prospective sectors. To further estimate existing capabilities, we proceed to a firm-level analysis. Following the correspondence tables between SITC2 categories and CZ-NACE3 codes, we identify the respective firms in the Amadeus database. We consider firms which reported the respective NACE code as their primary or secondary activity. We focus on companies with turnovers of over 1 million EUR for the last reported year and we also assess their innovativeness in terms of patenting activity. This final step enables a more robust feasibility assessment of the products we identify as prospective in the previous steps.

### 3. Results and Discussion

Czechia has often been characterized as a small, export-oriented economy with a strong industrial tradition (Myant and Drahokoupil, 2012). Within the periods 2011–2013 and 2016–2018, the country increased its share of world exports from 0.73% to 0.86%. Its exports are also highly specialized (Janda et al., 2013). The top five 4-digit SITC export categories account for 27% of total exports (Table 1), while the top ten only account for 35%. Even though the first export group has been slightly losing its share over time, it represents traditionally highly important export products for Czechia, with further export prospects. All top five export categories fall under *Machinery and transport equipment (SITC 7)*. *Passenger motor vehicles (SITC 7810)* represent the largest constantly growing export SITC 7 subcategory contributing to nearly 12% of total exports, followed by *Other parts and accessories for vehicles (SITC 7849)*, accounting for 8%. From the past to present time period *TV, radio and transmitters* replaced *Electrical apparatus for line telephony or line telegraphy* among the top five export categories. Yet, this product category does not perform well either in terms of comparative advantage or complexity. *TV, radio and transmitters* clearly demonstrate a transition from a rather complex product group in 2011–2013 to a group with diminishing, even negative product complexity. The explanation for this trend can be given by a relative decline in the PCI and/or relocation of production to less complex economies. Nevertheless, *TV, radio and transmitters* are estimated to further strengthen their share of total Czechia's exports in the future. These exports are driven by Foxconn, a worldwide producer of electronic devices and the second largest Czech exporter.

**Table 1: Top 5 Czech export categories in 2016–2018**

SITC	SITC description	Export share (%)	RCA	PCI
<b>7810</b>	Passenger motor vehicles (excluding buses)	11.7	2.5	0.69
<b>7849</b>	Other parts and accessories, for vehicles of headings 722, 781-783	8.1	3.4	1.04
<b>7721</b>	Switches, relays, fuses, etc; switchboards and control panels, nes	2.9	2.4	0.57
<b>7523</b>	Complete digital central processing units; digital processors	2.3	5.6	0.79
<b>7643</b>	Television, radio-broadcasting; transmitters, etc	2.3	0.87	−0.21

Source: Authors' calculations based on the Atlas of Economic Complexity data (Center for International Development at Harvard University, 2016).

Note: In our dataset, present PCI reaches values from −3.26 (the lowest complexity) to 2.47 (the highest complexity).

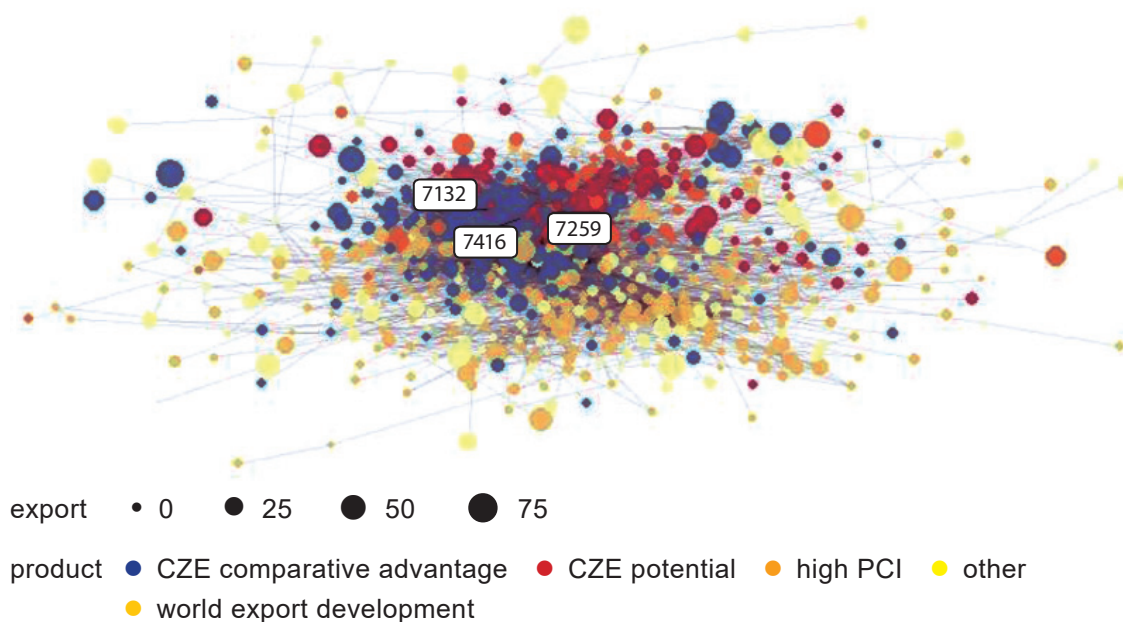
Interestingly, the most complex products contribute only negligibly to the country's total current exports. In terms of complexity, the top five products include *Cellulose acetates* (SITC 5843), *Other machines-tools for working metal or metal carbides* (SITC 7367), *Chemical products and flashlight materials for use in photography* (SITC 8821), *Epoxide resins* (SITC 5826), and *Machinery for specialized industries and parts thereof* (SITC 7284). They correspond to nearly 1% of total exports with a significant contribution of the last product group. Of these, Czechia has comparative advantage only in *Epoxide resins*.

Overall, data reveal that Czechia has experienced a decline in the number of products in which it has a comparative advantage. Between 2011–2013 and 2016–2018, the number of 4-digit SITC products with  $RCA > 1$  fell from 267 to 240 (out of 759 in total). This trend is expected to persist even among the major export categories, including manufactured goods and machinery (SITC 6 and 7). In the past, Czechia's comparative advantage was mainly based on lower labour costs. As labour costs are rising (Procházková et al., 2021), the country will see a decrease and gradual loss in RCA in the long run. Predictions show a further decline to 235 products with RCA in 2021–2023. This development suggests an increasing specialization and transition to fewer but generally more sophisticated products in terms of product complexity. Such a development reflects Czechia's ranking in the Atlas of Economic Complexity (Growth Lab at Harvard University, 2019), where the country has been oscillating around 6<sup>th</sup> and 7<sup>th</sup> place within the past decade in comparison to the 14<sup>th</sup> rank in the mid-1990s. Although the number of exported products with RCA has been declining, Czechia still exports a relatively large variety of products, and its exports have become more sophisticated over time. Thus, both export diversity and less ubiquitous exported products contribute to the country's current ECI ranking.

The demonstrated decline in comparative advantage indicates the need for structural transformation of the economy towards sectors in which Czechia retains or gains comparative advantage. At the same time, global trends (growing and stagnant sectors) must also be considered. A growing barrier to potential structural transformation can be spotted in the overall decline in the similarity of economic sectors. The increase in predicted distances among industries based on the Jaccard coefficients points to a deepening specialization in the world economy. As a result, structural changes in the domestic industry will probably become costlier over time.

The overall picture of Czechia's present export portfolio is shown in the product space (Figure 1). It is apparent that Czechia is relatively well placed within the network as large numbers of products are placed in the core (typically machinery), which indicates more sophisticated and well-connected export products. The majority of the prospective products (red dots), which can contribute to future complexity of the Czech economy, are also placed closer to the core. Hence, once reached, they are likely to further enhance the country's diversification.

**Figure 1: Czechia in the product space (2016–2018)**



Source: Authors' calculations based on Atlas of Economic Complexity data (Center for International Development at Harvard University, 2016).

Following the steps in the methodology section, we identified 79 product groups with potential for future export diversification (Figure 2). These products meet the following criteria: (1) demonstrate below-average comparative advantage ( $RCA < 1.036$ ), (2) demonstrate higher expected future PCI than products currently produced with a comparative advantage ( $PCI^F > 0.439$ ), and (3) their forecast exports growth rates are positive (export volume of examined products dropped on average by \$198.6 million). Furthermore, we tested their similarity with products currently exported at comparative advantage and considered only those demonstrating a Jaccard similarity index  $> 0.4$ . Finally, we identified 17 products meeting the conditions above. The top ten products are depicted in Table 2 (all the 17 products, including evaluation, are in Appendix 1).

Out of the 17 products, 7 fall into the category *Machinery and transport equipment* (SITC 7), 6 products into *Chemicals and related products* (SITC 5), 3 products into *Manufactured goods* (SITC 6) and one product falls into *Miscellaneous manufactured articles* (SITC 8). After sorting by the highest average ranking reflecting predicted PCI, predicted RCA and number of connections to other products with RCA<sup>8</sup>, we identified the top ten products (Table 2) which reveal high predicted complexity and are simultaneously not very far from the current production portfolio.

8 We normalized the values of the three evaluated categories (number of alternatives, predicted PCI and predicted RCA) so that they reach values from zero to one. Then, we summed up the normalized values to get the point counts based on which the prospective products are sorted.



**Table 2: Top 10 prospective products**

SITC	SITC description	Predicted RCA	Predicted PCI	Number of alternatives with present RCA	Normalized points sum	Predicted share of Czech exports
<b>7284</b>	Machinery for specialized industries and parts thereof, nes	0.91	2.35	3	2.98	0.844%
<b>7281</b>	Machine-tools for specialized industries parts or accessories, nes	0.92	1.41	2	2.01	0.068%
<b>7451</b>	Power hand tools, pneumatic or non-electrically powered, and parts thereof, nes	0.80	1.74	1	1.54	0.042%
<b>5824</b>	Polyamides	0.40	1.56	2	1.50	0.044%
<b>6631</b>	Hand polishing stone, grindstones, grinding wheels, etc.	0.89	1.23	1	1.38	0.027%
<b>5827</b>	Silicones	0.52	1.77	1	1.25	0.023%
<b>7442</b>	Lifting, handling, loading machinery, telfers and conveyors	0.87	0.85	1	1.15	0.258%
<b>7452</b>	Other non-electrically powered machines and parts thereof, nes	0.80	0.72	1	1.01	0.254%
<b>7758</b>	Electro-thermic appliances, nes	0.80	0.72	1	1.01	0.221%
<b>5829</b>	Other condensation, polycondensation or polyaddition products	0.06	1.15	2	0.92	0.005%

Source: Authors' calculations based on Atlas of Economic Complexity data (Center for International Development at Harvard University, 2016)

## 4. Firm-level Analysis

Following our results shown in Table 2, we focus specifically on three 4-digit SITC categories with the highest prospects for Czechia, namely *Machinery for specialized industries and parts thereof (SITC 7284)*, *Machine-tools for specialized industries parts or accessories (SITC 7281)* and *Power hand tools, pneumatic or non-electric, and parts thereof (SITC 7541)*<sup>9</sup>. Czechia

<sup>9</sup> SITC 5824 is also high in ranking, but as there are only few companies producing polyamides, we do not discuss it in detail.

does not have a comparative advantage in producing them yet, but they have high product complexity, their exports are increasing globally and at the same time they require similar capabilities as products where Czechia already has RCA.

In the following part, we evaluate whether there are existing capabilities in these product categories in Czechia. We analyse companies operating in the corresponding sectors (see Methodology). We also include examples of successful companies. Table 3 provides a quick overview on how significant the firm coverage of the three SITC categories is. However, a more detailed investigation was necessary, because of firms' inaccuracy in reporting the correct NACE codes. The last column in Table 3 depicts the number of large and highly innovative companies (turnover over 1 million EUR and patented solutions), for which we looked into their portfolio to verify if their production fits into the respective SITC category. In our further comments, we also distinguish between Czech and foreign-owned companies based on the Global Ultimate Owner criteria retrieved from the Amadeus database.

**Machinery for specialized industries and parts thereof (7284)** is the fourth most complex area amongst all SITC 4-digit categories. In 2017, it was the 19<sup>th</sup> most exported Czech product (0.86% of exports) with an RCA of 0.91. This product has a very high Jaccard index with SITC2 5826 (*Epoxide resins*), in which Czechia already has a comparative advantage. Eight different 4-digit NACE sectors are linked to *Machinery for specialized industries and parts thereof* (see Table 3), which signals a wide range of products falling under this category. Below, we focus on the most represented NACE subsectors.

Over 1250 companies report *NACE 2899 (Manufacture of other special-purpose machinery)* either as primary or secondary code. We identified 37 large and highly innovative firms, mostly under domestic ownership. Among the most successful ones there are for instance Aura - Engineering Hranice, s.r.o.<sup>10</sup> producing lines for automated production, assembly and transportation and Atelier Technik, s.r.o. focused on production facilities and test rooms by developing and manufacturing precision machinery and accessories. Nanotechnological Elmarco, s.r.o. is also highly innovative.

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10 The Czech term "s.r.o." is the rough equivalent of "private limited company" and "a.s." is the equivalent of "public limited company". Since we use official names of companies in our paper, we keep the original terms in Czech.

**Table 3: Overview of firm numbers corresponding to SITC 7451, 7284 and 7281**

SITC code	Corresponding NACE codes	Number of firms		
		Primary NACE	Secondary NACE	Firms with at least one patent and turnover over 1 million EUR
<b>7284 - Machinery for specialized industries and parts thereof, nes</b>	2830 - Manufacture of agricultural and forestry machinery	15	69	4
	2891 - Manufacture of machinery for metallurgy	13	8	3
	2892 - Manufacture of machinery for mining, quarrying and construction	69	31	14
	2893 - Manufacture of machinery for food, beverage and tobacco processing	70	33	15
	2894 - Manufacture of machinery for textile, apparel and leather production	43	25	7
	2895 - Manufacture of machinery for paper and paperboard production	13	6	6
	2896 - Manufacture of plastics and rubber machinery	20	15	2
	2899 - Manufacture of other special-purpose machinery n.e.c.	283	980	37
<b>7281 - Machine-tools for specialized industries parts or accessories, nes</b>	2841 - Manufacture of metal forming machinery	99	13	16
	2849 - Manufacture of other machine tools	47	21	9
<b>7451 - Power hand tools, pneumatic or non-electric, and parts thereof, nes</b>	2822 - Manufacture of lifting and handling equipment	300	333	0
	2824 - Manufacture of power-driven hand tools	14	21	4

Source: Amadeus, 2021

Two other relevant sectors are NACE 2892 and 2893. NACE 2892 (*Manufacture of machinery for mining, quarrying and construction*) is represented by 14 large and innovative companies. Out of these, two large foreign-owned companies prevail, each with a turnover of over 100 million EUR, the Slovak Unex, a.s. and the Swiss Ammann Czech Republic, a.s. There are also three companies (Gearworks, a.s., Kobit, s.r.o. and Repax, s.r.o.) with a broader focus on gearboxes, machinery and equipment for construction and maintenance of roadways

or hydraulic systems. NACE 2893 (*Manufacture of machinery for food, beverage and tobacco processing*) is covered by 15 innovative companies. Firms like J 4, s.r.o., Bupospol and Armaturka Koukol, s.r.o. specialize in bakery lines, bakery tunnel ovens and grain dryers.

The remaining NACE subsectors have lower numbers of large and innovative firms (see Table 3). Some relevant examples are the Czech-owned Farmtec, a.s. and Romill, s.r.o., which produce *Agricultural and forestry machinery* (NACE 2830). *Machinery for textile, apparel, and leather production* (NACE 2894) is produced by Rieter CZ, s.r.o., a company focusing on fibre processing lines with a portfolio of 204 patents. Zebr, s.r.o. produces machines for interior and exterior blinds, including software for the machines (falling under NACE 2891).

**Machine-tools for specialized industries parts or accessories (7281)** has a PCI of 1.54 (40<sup>th</sup> place). Exports in this category are rather low (0.08% of total Czech exports of goods) with an RCA of 0.91. This product category uses similar capabilities as products in which Czechia already has a high RCA: SITC 7373 (*Welding, brazing, cutting, etc. machines and appliances, parts*), SITC 8935 (*Articles of electric lighting of plastic*) and SITC 7753 (*Domestic dishwashing machines*). We identified two relevant NACE codes. NACE 2841 (*Manufacture of metal forming machinery*) is reported by 25 innovative companies, for instance Toshulin a.s., a manufacturer of technologically advanced, multifunctional CNC vertical turning lathes, ŠMT a.s. and TOS Varnsdorf a.s., producers of boring and milling machines, horizontal lathes and rotary tables. The second relevant NACE code is 2849 (*Manufacture of other Machines Tools*), reported by relevant firms as Briklis, s.r.o., producing hydraulic briquetting presses for processing waste, and TOS Svitavy, a.s., producing woodworking machines.

**Power hand tools, pneumatic or non-electric, and parts thereof (7451)** is the last product category we included in our selection of prospective products. While ranking amongst the top 25 products in terms of complexity (PCI 1.85), it is one of the least exported products in Czechia (0.05% share of total Czech exports) with an RCA of 0.89. The highest similarities to existing exports in which Czechia has an RCA are with SITC2 6891 (*Tungsten, molybdenum, tantalum, magnesium, unwrought waste, scrap*), SITC 7784 (*Electro-mechanical hand tools, and parts thereof*) and SITC 7368 (*Work holders, dividing heads for machine-tools, etc tool holders*). Two NACE sectors correspond to SITC 7451, namely NACE 2822 (*Manufacture of lifting and handling equipment*) and to a certain extent NACE 2824 (*Manufacture of power-driven hand tools*). After applying the threshold of a turnover of over 1 million EUR and at least one patent, we identified only 4 firms, amongst them Belgian-owned company, Deprag CZ, a.s., producing air tools and screwdriving tools and Czech-owned Rivet Factory Group, s.r.o. focusing on riveting tools.

The company-level analysis provided further evidence of the feasibility of products we previously identified as prospective. Many of these large and innovative companies are Czech-owned, enhancing the possibility of a successful structural transformation towards more complex products with higher domestic value added. Czech governments have so far been rather reluctant in employing active support to selected economic sectors because of the missing strategic developmental policy, the prevailing *laissez-faire* approach and because of a limited ability to identify prospective sectors capable of delivering structural transformation towards higher domestic value added. With the current developmental model based on relatively cheap, but qualified labour force and geographical proximity to the developed EU economies being exhausted, the government approach to the strategic industrial policy and its role in structural transformation in the Czech economy might change in the future. Our paper contributes factually and methodologically to the related academic debate. By now, the smart specialization policy, which stems from the identification of strategic areas for intervention based both on an analysis of the strengths and potential of the economy, provides a reasonable framework to gradually implement the structural transformation.

Another key observation is that all the identified sectors fall under machinery manufacturing; therefore, labour force qualification is crucial. Already today, many Czech companies call for increased strategic support for technical schools, including the introduction of elements of dual education, as they consistently lack qualified graduates across all educational levels (Hnát et al., 2020). Providing a qualified labour force is therefore a key precondition for successful transformation towards the production and export of more complex products. A more detailed analysis of government policies is beyond the scope of this paper; however, it is important to point out the complexity of such a structural transformation in Czechia.

## 5. Conclusion

Czechia is a highly export-oriented country. Despite being identified as one of the countries with the highest economic complexity, its innovative capabilities are still lower than in the Western European countries. This can be related to the fact that foreign ownership, as well as intermediates originating from other countries, play a significant role in Czech exports. Czechia occupies the core of the so-called product space; thus, its opportunities for diversification related to its current export basket are quite high. The country can therefore benefit from a wide range of existing cognitive knowledge, which can facilitate the implementation of new industrial specializations.

Based on similarities in existing productive knowledge (exported products in which Czechia has comparative advantage), we identified 17 product categories which have high complexity, are expected to grow in trade volume in the future and are close to the production capabilities present in Czechia. Specifically, we considered three product groups to be highly prospective for Czechia: machinery for specialized industries, machine-tools for specialized industries and pneumatic or non-electrically powered hand tools. This is because they have been manufactured by several large, highly innovative firms in the country. Whereas *Machinery for specialized industries and parts thereof (SITC 7284)* is quite established in terms of exports and the number of domestically-owned large and innovative firms, *Machine-tools for specialized industries parts or accessories (SITC 7281)* and *Power hand tools, pneumatic or non-electric, and parts thereof (SITC 7541)* have lower predicted shares of total exports and a lower number of firms.

Yet, our firm-level feasibility analysis confirmed that Czechia does possess the necessary knowledge to be able to undergo structural transformation towards these three prospective product categories. Despite not including value-added content, the product categories we identified as prospective belong to machinery, which is a less fragmented sector in contrast to automotive or electronics. Furthermore, we identified many large innovative and, above all, Czech-owned companies, which could contribute to an increase in the domestic value-added share of Czech exports. However, in order to shift production factors (especially labour), it will be necessary to make greater efforts on the part of employees and expend higher costs on the part of the state and companies (retraining and on-the-job training). Additionally, changes at all levels of the educational system are crucial for a successful transformation.

Although we were able to determine an optimal diversification path for Czechia, our analysis faces several limitations. We did not include value-added data nor data on the service sector as they are only available at a highly aggregated level. Furthermore, the COVID-19 pandemic might alter the trends in world trade. Future research thus provides a wide array of amplification such as setting these products into regional value chains.

## Data availability statement

The data that support the findings of this study are openly available in VŠE Publication Repository at <http://doi.org/10.18267/datasets.rep.1.1038>

**Appendix 1: Prospective products of Czechia**

	SITC	SITC description	Predicted RCA	Predicted PCI	Number of alternatives with present RCA	Norm. points - alternatives	Norm. points - PCI	Norm. points - RCA	Normalized points sum
1	7284	Machinery for specialized industries and parts thereof, nes	0.91	2.35	3	1.0	1.00	0.98	2.98
2	7281	Machine-tools for specialized industries parts or accessories, nes	0.92	1.41	2	0.5	0.51	1.00	2.01
3	7451	Power hand tools, pneumatic or non-electric, and parts thereof, nes	0.80	1.74	1	0.0	0.68	0.87	1.54
4	5824	Polyamides	0.40	1.56	2	0.5	0.58	0.42	1.50
5	6631	Hand polishing stone, grindstones, grinding wheels, etc	0.89	1.23	1	0.0	0.41	0.96	1.38
6	5827	Silicones	0.52	1.77	1	0.0	0.69	0.56	1.25
7	7442	Lifting, handling, loading machinery, telfers and conveyors	0.87	0.85	1	0.0	0.22	0.94	1.15
8	7452	Other non-electrical machines and parts thereof, nes	0.80	0.72	1	0.0	0.15	0.87	1.01
9	7758	Electro-thermic appliances, nes	0.80	0.72	1	0.0	0.14	0.86	1.01
10	5829	Other condensation, polycondensation or polyaddition products	0.06	1.15	2	0.5	0.37	0.05	0.92
11	6842	Aluminium and aluminium alloys, worked	0.84	0.44	1	0.0	0.00	0.91	0.91
12	6571	Felt, articles of felt, nes, whether or not impregnated or coated	0.60	0.78	1	0.0	0.18	0.65	0.83
13	8749	Parts, nes, and accessories of headings 873, 8743, 87454 or 8748	0.74	0.49	1	0.0	0.02	0.80	0.82
14	7712	Other electric power machinery, parts, nes	0.62	0.69	1	0.0	0.13	0.67	0.80
15	5839	Other polymerization and co-polymerization products	0.33	1.12	1	0.0	0.36	0.35	0.71
16	5838	Ion exchangers of the polymerization or copolymerization type	0.01	1.57	1	0.0	0.59	0.00	0.59
17	5416	Glycosides, glands, antisera, vaccines and similar products	0.12	1.30	1	0.0	0.45	0.12	0.57

Source: authors' calculations

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