

The Motor Vehicles Industry in Slovakia, 2005 – 2015¹

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Abstract

This paper examines the evolution of the Slovak motor vehicles sector during 2005 – 2015, drawing on the latest update (December 2018) of OECD's Inter-Country Input-Output (ICIO) model database. The review takes a global value chain (GVC) approach and looks at the linkages from the gross production and value-added perspectives. The overall contribution of the motor vehicles sector to Slovakia's gross production and domestic value added increased twofold during the reference period. There was an ongoing change in the structure of the GVC linkages. The reliance on domestically-sourced inputs increased over the years. The (indirect) value added created in the production of domestically-sourced inputs gradually approached the level of the (direct) value added generated within the motor vehicles sector. Subsequent to the global financial crisis, the share of intermediate goods in exports, the forward linkage of the GVC, and the upstreamness of the production process were all on a rising trend. The sourcing pattern of imports of intermediate inputs and the market for exports steadily shifted away from the euro area towards non-EU countries. It is estimated that a hypothetical 10 percent negative shock to global final demand for motor vehicles would lower Slovak GDP growth by 1 percentage point.

Keywords: backward linkage, forward linkage, GVC participation rate, length of GVC, position in GVC

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Introduction

Over the past two decades, the Slovak automotive industry has steadily grown to become one of the key industries in the Slovak economy and an important global player. It currently comprises of four major car manufacturers and more than 350 automotive parts suppliers, including both first tier global suppliers with a local presence and lower tier purely local suppliers (SARIO, 2022).² The industry is characterized by a complex value chain. The automotive components segment has expanded over time along with the increase in car production. The car manufacturers as well as automotive parts suppliers operating in the country rely on a mix of domestic and imported intermediate inputs. The automotive parts suppliers not only provide components for the domestic assembly of cars but also produce for external markets. The cars manufactured in Slovakia are mostly exported.

This paper provides and synthesizes new empirical evidence on the Slovak automotive industry. The main aim is to examine the evolution of the “Motor vehicles, trailers and semi-trailers” sector (Sector D29; motor vehicles sector hereafter) in Slovakia during 2005 – 2015, using input-output data from the December 2018 update of OECD’s Inter-Country Input-Output (ICIO) model database.³ The review takes a global value chain (GVC) approach and looks at the linkages from the gross production as well as value added perspectives. It identifies the trends in the sourcing pattern of intermediate inputs, geographical origins of imported inputs and destinations of exports. The paper also examines how the GVC participation of the motor vehicles industry, the length of the value chain and distance to final demand have unfolded over time.⁴ Finally, building on these findings, the paper assesses the potential impact of a negative demand shock in the motor vehicles industry on Slovakia’s GDP.

1. Background

The growth of the automotive industry in Slovakia is well documented. The Slovak Investment and Trade Development Agency monitors developments in the automotive industry and prepares overviews on a regular basis (e.g., SARIO,

² The four major car manufacturers include Volkswagen Slovakia (production started in February 1992), PSA Peugeot Citroën Slovakia (production started in June 2006), Kia Motors Slovakia (production started in December 2006), and Jaguar Land Rover (production started in October 2018).

³ See <<http://oe.cd/icio>>.

⁴ These concepts are defined in later parts of the paper, and are well documented in the GVC literature (e.g., see De Backer and Miroudot, 2013; Kowalski et al., 2015; and OECD, 2019).

2012; 2020; 2022). Numerous reports provide descriptive and qualitative assessments based on publicly available data sources and automotive industry studies and surveys (e.g., Ceeweb.org, 2017; GLOBSEC, 2021; Jakubiak et al., 2008). An exception is the study by Luptáček et al. (2013) that takes into account the interdependencies of industries in the Slovak economy using input-output tables and quantifies the direct, indirect and induced effects generated by the automotive industry.

Jakubiak et al. (2008) and Kureková (2018) note that foreign direct investment has been a key driver of the Slovak automotive industry and instrumental in its participation in the global value chain. Various factors encouraged the entry and continuation of foreign direct investment flows by major worldwide known automotive companies: a tradition of automotive production during the pre-transition period; availability of a skilled labour force; favourable productivity-adjusted wage differentials compared with other European Union-member states; European Union membership; geographical location; and investment incentives.⁵

Car production picked up pace substantially following the start of production by PSA Peugeot Citroën Slovakia and Kia Motors Slovakia in 2006 and subsequent expansion of capacity by all car manufacturers and the start of production by Jaguar Land Rover in 2018. Thus, annual car production increased five-fold from about 218 thousand in 2005 to over one million in 2019, putting Slovakia among the 20 biggest car producers in the world (SARIO, 2012 and 2022). With the domestic market size of Slovakia being rather limited, the automotive industry is highly export oriented.⁶

Besides the four main car manufacturers, a supply chain network of producers of car parts comprise an integral segment of the automotive industry in Slovakia. The various types of suppliers are divided according to level (Tier 1 to Tier 3), functionality and specialization.⁷ The top tier suppliers are typically global entities with a local presence whereas lower tier suppliers are typically pure local entities. The creation of a supply chain started hand in hand with the arrival of Volkswagen in the early 1990s, and production of this segment of the automotive sector is estimated to have increased at a faster pace than the output of the final

⁵ Investment incentives can have different forms. See SARIO (2022, p. 13) and Ceeweb.org (2017, pp. 8 – 9) for the currently prevailing incentives. With EU accession, Slovakia is required to comply with the EU rules on the provision of state aid. However, exemptions can be granted to large investment projects, mostly when such projects significantly contribute to regional development and are based on the European Commission's cohesion policy.

⁶ GLOBSEC (2021, p. 5) report that car manufacturing in Slovakia accounts for 33 percent of the country's industrial exports.

⁷ The structure and linkages of the supply network are presented in SARIO (2012, p. 7) and a grouping by functionality and specialization is presented in Ceeweb.org (2017, pp. 9 – 10) and SARIO (2022, pp. 9 – 10).

car producers in the initial years (Jakubiak et al., 2008, p. 36). Luptáčík et al. (2013, p. 14) estimate that the share of indirectly generated production in total production in the automotive industry averaged around 29 percent during 2008 – 2012. Available data indicate that the number of automotive suppliers increased from 18 in 1998 to 49 in 2004, 274 in 2012, and more than 350 in 2017 (Jakubiak et al., 2008, p. 36; SARIO, 2012, p. 5; SARIO, 2022, p. 8). The producers of car parts also export a sizeable proportion of their output (Jakubiak et al., 2008; Luptáčík et al., 2013; SARIO, 2022), a reflection of the Slovak automotive industry's integration into GVCs.

A study by De Backer and Miroudot (2013, pp. 24 – 28) shows that already in 2009 the automotive industry in Slovakia was highly integrated into GVCs and a larger portion of the value chain was international. The participation of the industry in GVCs was strongly driven by the importance of imported intermediates in exports, an indication of the predominance of assembly activities in car production. The automotive industry in Slovakia also had a higher “distance to final demand” index compared with most other countries in their sample, implying that a larger proportion of intermediates produced by the supplier networks in Slovakia were exported to other countries and included there in more downstream production activities.

2. Methodology

This paper takes a global value chain approach to examining the evolution of the automotive sector in Slovakia during 2005 – 2015. The approach looks at the linkages from the gross production as well as value added perspectives. The empirical basis of the paper is the December 2018 update of OECD's Inter-Country Input-Output (ICIO) model database.⁸

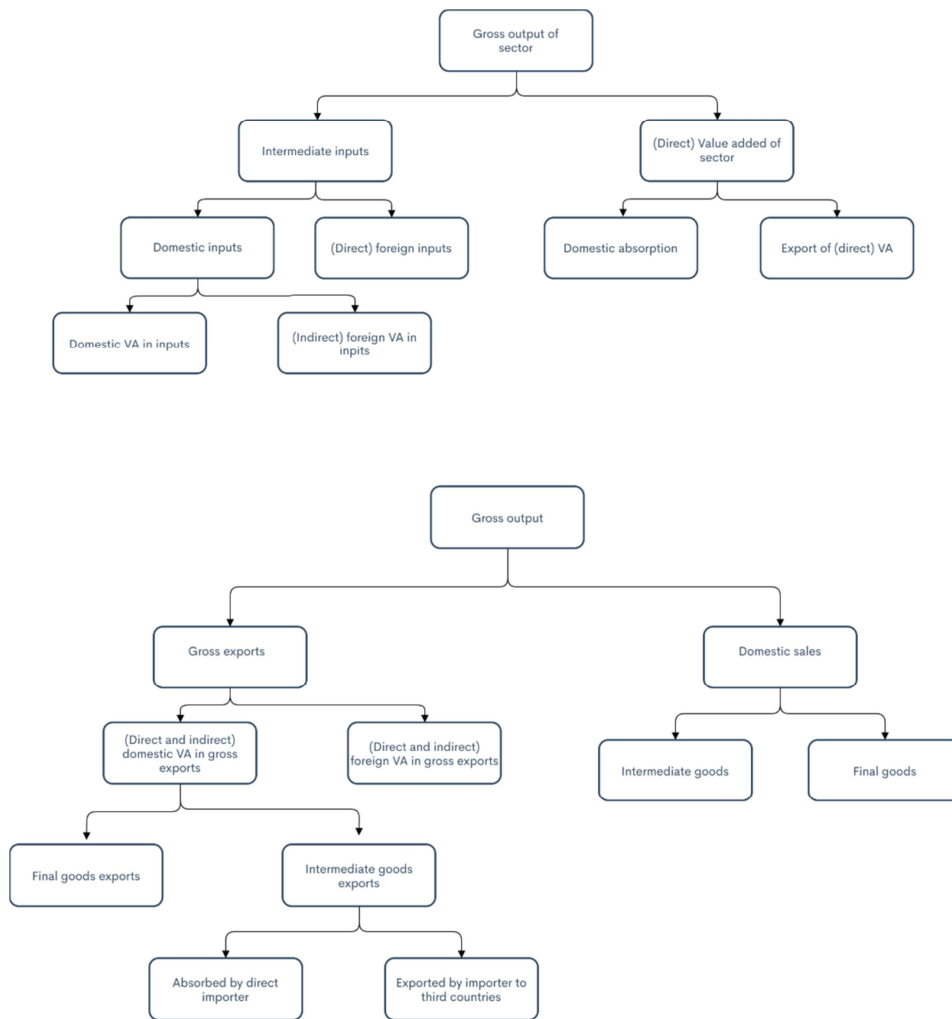
As described in Annex I, domestic input-output coefficient matrix and import input-output coefficient matrix in an inter-country input-output (ICIO) table can be used to distinguish between domestic and foreign factor contents in various production activities, and identify the geographical origins of imported inputs and destinations of exports. The decomposition of production activity or gross output can be carried out from both the supply side and the demand side, as depicted in

⁸ The OECD's ICIO data base provides information on domestic transaction flows of intermediate goods and services across industries, and inter-country flows of intermediates in exports and imports. The ICIO is the principal data source used to produce trade in value added indicators (TiVA; <<http://oe.cd/tiva>>). The December 2018 update of the ICIO database is based on ISIC Revision 4 and the data is available annually for the period 2005 – 2015. Data for the years beyond 2015 are not yet available. An earlier release of the ICIO data base covered the period 1995 – 2011, but the data from this release are not compatible with the data from the 2018 update.

Figure 1. On the basis of such decomposition various concepts and metrics have been proposed in the literature for measuring trade in value added and GVC participation.⁹

Figure 1

GVC Linkages from the Production and Value Added Perspectives



Source: Authors.

⁹ In a seminal paper, Koopman et al. (2014) developed an export decomposition scheme that applied only to aggregate exports. Borin and Mancini (2019) propose an alternative framework for value added accounting of trade flows at the aggregate, bilateral and sectoral levels. Wang et al. (2017a) approach GVC participation from the production perspective instead of the trade perspective. They decompose GDP and final goods production of a country/sector into pure domestic activities and GVC production activities.

From the supply side, gross output of an industry can be decomposed into intermediate inputs and direct value added. The input-output framework allows us to trace the domestic value added embodied in intermediate inputs as well as foreign value added embodied directly and indirectly in intermediate inputs. The direct value added of the industry can be split into one part that is domestically absorbed without involving international trade, and another part that is embodied in exports (see upper panel of Figure 1). An industry's gross output from demand side point of view can be decomposed into gross domestic absorption of intermediate and final goods and gross exports of the industry to the world. The part of exports that originates in the country itself is the domestic content of exports and the remaining part of gross export represents foreign value added (i.e., value added produced in all countries except the domestic exporting country). The domestic component of exports in turn can be split into final goods exports, intermediate goods exports absorbed by direct importer and or re-exported by the importer to third countries (see lower panel of Figure 1).

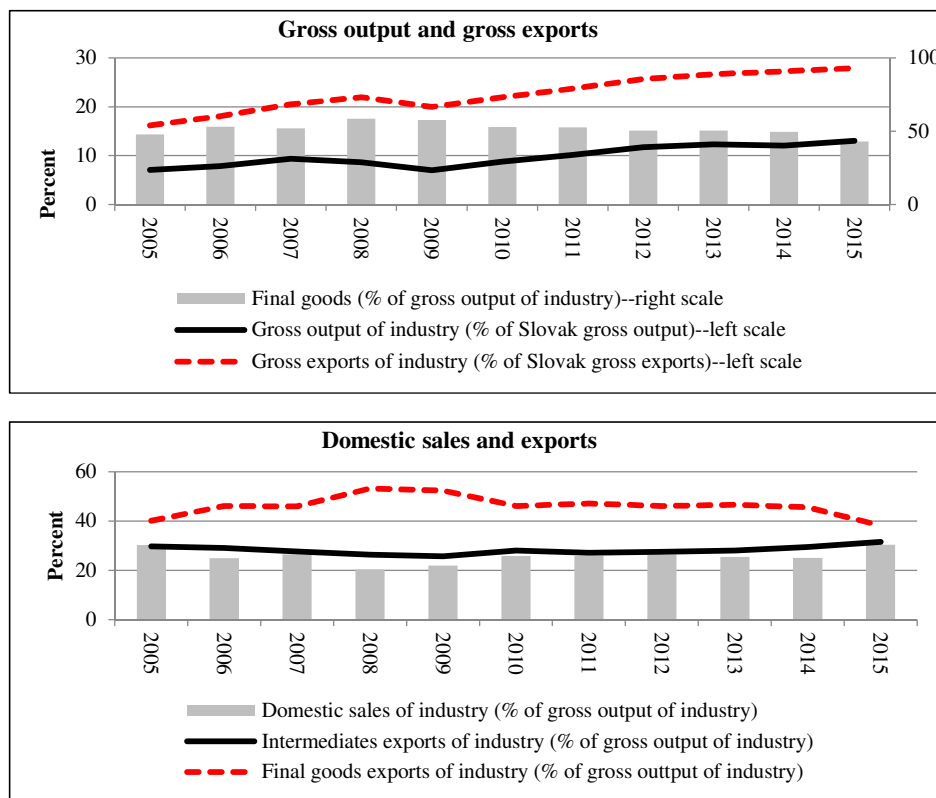
For calculating the indices for the length of global value chains (GVC) and distance to final demand, we follow the methodology proposed by Antràs et al. (2012), Fally (2012) and Wang et al. (2017b), as described in Annex II. The length of GVC reflects the number of stages involved in the entire production process between the primary inputs in a country-sector pair to the final product in another country-sector pair. The distance to final demand indicates the position of the country in the value chain; i.e., it measures the number of stages still left before the goods produced by the industry reach the final consumer. For quantifying the impact on the motor vehicles industry of a shock to final demand, we use the methodology elaborated by Garcia et al. (2020). This is set out in Annex III.

3. Empirical Analysis

3.1. Linkages from Gross Production Perspective

The importance of the motor vehicles industry in the Slovak economy has increased steadily over time. The share of this industry in gross output of the entire economy rose from about 7 percent in 2005 to 13 percent in 2015 (Figure 2 and Appendix Table 1). Both intermediate goods and final goods figure prominently in gross output of this industry. However, the share of final goods output has been on a downward trend since the onset of the global financial crisis, falling from a peak of 59 percent in 2008 to 43 percent in 2015. The decline in the share of final goods indicates increasing fragmentation of supply chains in the motor vehicles industry.

Figure 2
Gross Output, Domestic Sales and Export Composition of Motor Vehicles Industry



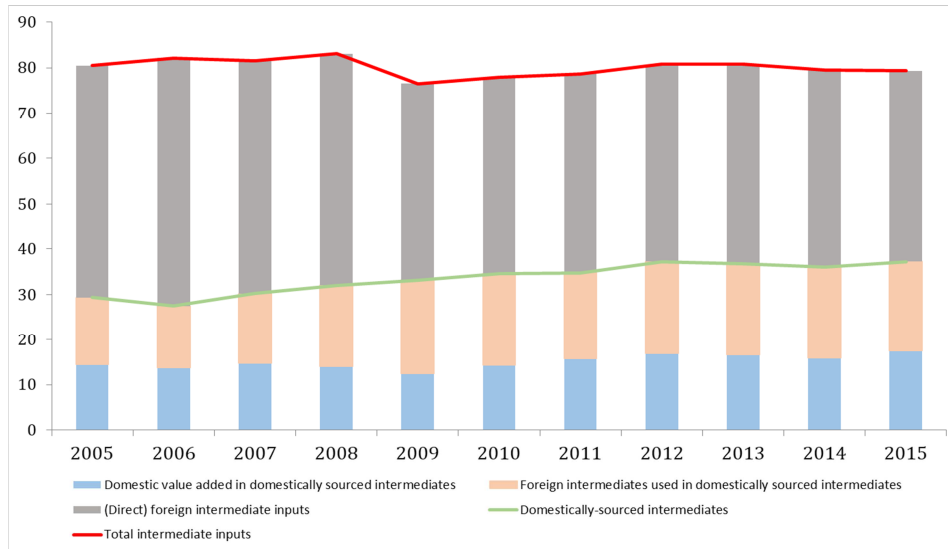
Sources: ICIO 2018; authors' calculations.

The motor vehicles industry is highly export oriented. The export propensity is higher for final goods output than for intermediate goods. On average, 90 per cent of the final goods output and 60 per cent of intermediate goods output were exported annually during 2005 – 2015. Domestic sales comprised primarily of intermediate products, reflecting the importance of linkages between the motor vehicles industry and other industries of the domestic economy. However, the importance of exports of intermediates also was growing from 2009 onwards and could be attributed to the rise of global value chains. In view of the declining share of final goods in gross output as noted above, the share of exports in gross output of the motor vehicles industry was falling. Nevertheless, the export share remained in excess of 70 per cent during the reference period. Although the importance of exports within the industry decreased, the contribution of the motor vehicles industry in total gross exports of Slovakia increased from 16 per cent in 2005 to about 28 per cent in 2015 on account of the rising share of the industry in gross output of the entire Slovak economy.

The motor vehicles industry of Slovakia depends heavily on imported intermediates, but the reliance on domestically produced intermediate inputs has increased over time. The share of direct imports in intermediate inputs of the motor vehicles industry decreased from 64 percent in 2005 to 53 percent in 2015 (Figure 3). The trend is indicative of Slovakia moving up the value chain in the production of motor vehicles, trailers and semi-trailers in the sense of substituting foreign value added by domestic value added in intermediates embodied in gross output. The domestic supply chain has been growing as an increasing number of automotive parts suppliers have been setting up plants in Slovakia. Domestically sourced intermediates in turn have a large import content. Taking these (indirect) imports into account, the combined share of direct and indirect imports has been relatively stable since the global financial crisis at around 75 percent of intermediate inputs involved in the production of motor vehicles, compared with around 80 percent prior to the crisis.

Figure 3

Intermediate Inputs Used in Motor Vehicles Production
(in % of gross output of industry)



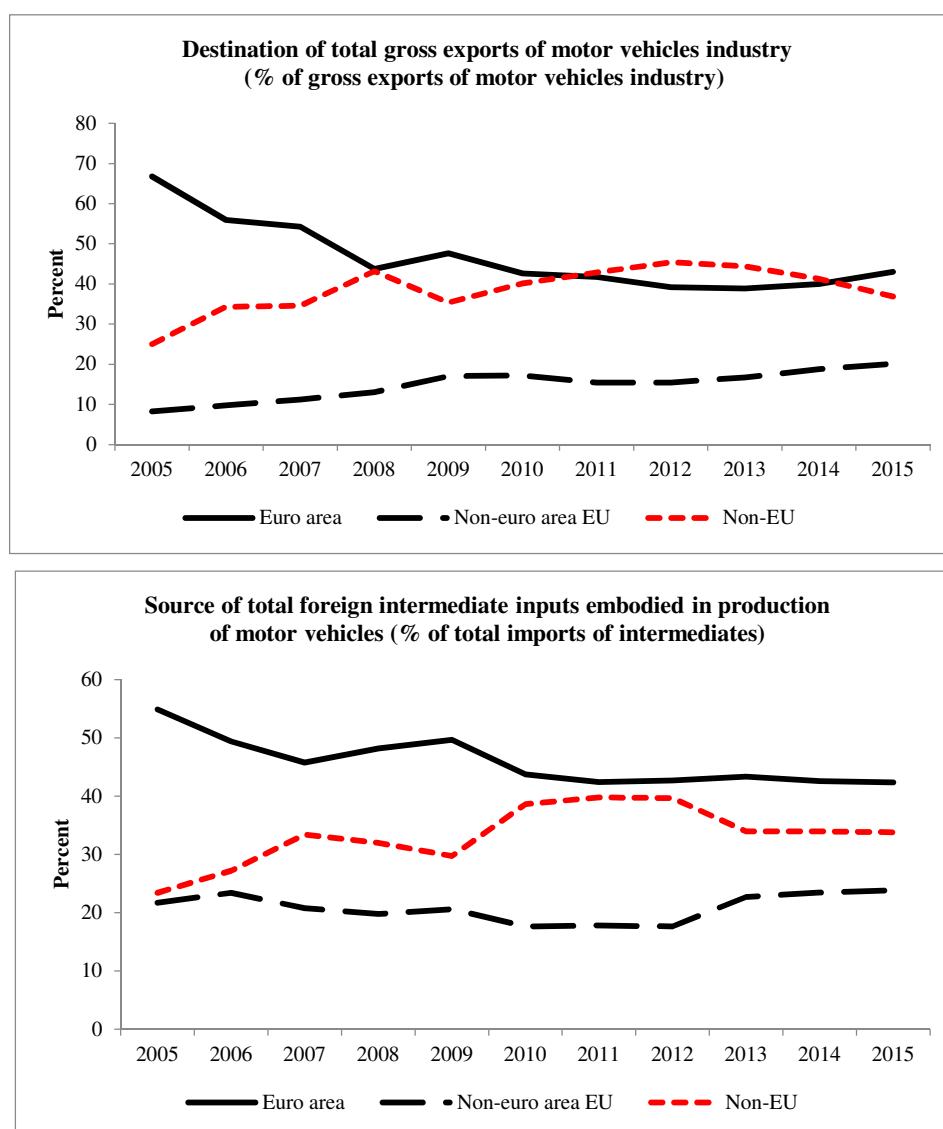
Sources: ICIO 2018; authors' calculations.

The market composition of both exports of the motor vehicles industry and imports of intermediate inputs changed noticeably during 2005 – 2015 (Figure 4). The European Union (EU) in the aggregate was the principal market for exports and a major source of imports of intermediate inputs, indicating a strong regional dimension of the supply chain. However, in both exports and imports, non-EU

countries gained market share over time and this occurred at the expense of falling shares of the euro area. Much of the regional realignment occurred during 2005 – 2010, following the start of operations of Kia Motors Slovakia and PSA Peugeot Citroën Slovakia and the introduction of new models by Volkswagen Slovakia.

Figure 4

Market Shares in Total Gross Exports of Motor Vehicles Industry and Total Imports of Intermediate Inputs



Sources: ICIO 2018; authors' calculations.

The loss of market share of the euro area and the gain in market share of non-EU countries were particularly conspicuous in the exports of final goods. In the event, from 2010 onwards, the proportion of final goods exports to non-EU countries was higher than that to the euro area and almost equal to the share of the EU as a whole (see Appendix Table 1). The main non-EU markets were China, United States, and Russia. A majority of the new generation up-market models produced by Volkswagen Slovakia were exported to non-EU markets, especially China and the United States. For Kia Motors Slovakia, Russia was one of the biggest export markets (besides Germany and the United Kingdom). In addition, the Košice plant of Volkswagen Slovakia was also engaged in the exports of semi-knocked-down vehicles to Russia.

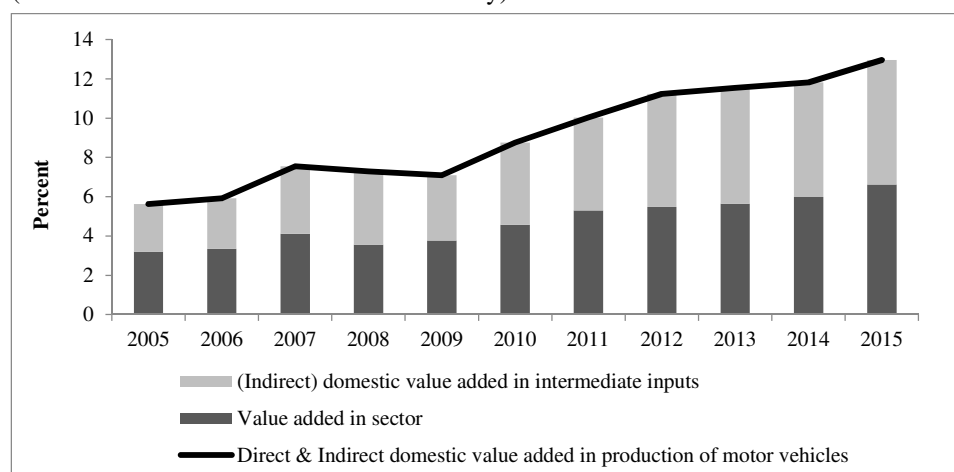
The gain in market share of non-EU countries in intermediate goods exports was minimal. The EU was the main export market for intermediate goods, but there was a shift away from the euro area towards non-euro EU countries. The market share of non-euro EU countries in intermediate goods exports increased while that of euro area countries decreased. A major driving force behind this development was the rising exports of car engines by Kia Motors Slovakia to the sister Hyundai plant in the Czech Republic.

Nearly one third of the imported intermediates originated from non-EU countries in 2015 compared with around one fourth in 2005. There was a slight re-balancing in the sourcing pattern away from non-EU countries towards non-euro area EU members in 2013, and the relative market shares of the three country groupings remained broadly unchanged in the subsequent years.

3.2. Linkages from Value Added Perspective

While the gross production perspective provides some insight into the importance of the motor vehicles for the Slovak economy and an initial assessment of its participation in GVC, a rigorous evaluation of the motor vehicles industry's contribution to growth, its exposure to shocks and GVC participation requires an examination of domestic value added in production and exports. An industry's exposure to shocks in final demand would be smaller if the production process entailed the last stages of the value chain and the production process relied mostly on foreign inputs. The motor vehicles industry in Slovakia is intensive in the use of intermediate inputs. Over the years, value added directly within this industry has typically accounted for only one fifth of gross production. Thus, reflecting the sectoral growth of gross production, the share of direct value added in the motor vehicles industry in total value added generated in the Slovak economy (i.e., Slovak GDP) increased during the reference period from 3.2 percent in 2005 to 6.6 percent in 2015 (Figure 5 and Appendix Table 2).

Figure 5
Direct and Indirect Value Added in Production of Motor Vehicles
 (in % of total value added in Slovak economy)



Sources: ICIO 2018; authors' calculations.

Total domestic value added embedded in gross production of the motor vehicles industry is much higher than the value added directly generated within the industry. It also includes the domestic value added created in the production of domestically-sourced intermediates used in the manufacture of motor vehicles (the so-called indirect value added). Typically, the indirect value added accounted for about one half of the gross amount of domestically-sourced intermediates. In effect, this has meant that the magnitudes of the indirect value added component and the direct value added generated in the motor vehicles sector were broadly similar over the reference period. As a result, the combined share of the direct and indirect value-added components in total value added in the Slovak economy increased from 5.6 percent in 2005 to 13 percent in 2015 – i.e., twice as large as the contribution of the direct value added in the motor vehicles industry. While the higher value-added share is a sign of the maturity of the motor vehicles industry in Slovakia and its agglomeration economies, the multiplier effect on the Slovak economy of any demand shock to the motor vehicles industry would be larger than if Slovakia was merely a processing center of a global supply chain mostly reliant on imported intermediate inputs.

3.3. Participation in the GVC

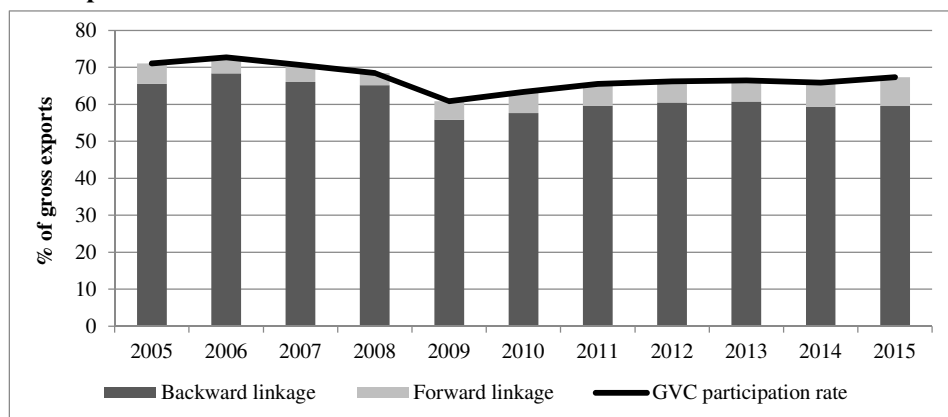
The degree of GVC participation of a country or industry is usually determined by looking at the share of gross exports involved in a vertically fragmented production process. The measure, which is expressed as a percentage of gross exports,

is based on two components: (i) the foreign value added content of intermediate inputs embodied in gross exports (i.e., backward participation) and (ii) the domestic value added embodied in intermediates re-exported by trade partners to third countries (i.e., forward participation). The higher is the backward participation and forward participation, the higher is the participation of a country or industry in the global value chain (see De Backer and Miroudot, 2013).

The Slovak motor vehicles industry is highly integrated in the GVC, with the GVC participation rate standing at about 67 percent of gross exports in 2015. The main channel for integration is backward participation. The forward participation channel has been growing slowly and is relatively weak, with the index measuring 8 percent of gross exports in 2015 (Figure 6).¹⁰ This implies that about four fifths of the domestic value added embodied in exports of final goods and intermediates are absorbed by direct importers.¹¹ Backward participation and, by association, GVC participation fell sharply in 2009 following the onset of the global financial crisis, but rebounded in the subsequent years. Nevertheless, both backward participation and GVC participation indicators in 2015 were lower than the 2005 level. Forward participation also suffered during the crisis but recovered quickly to above the pre-crisis levels.

Figure 6

Participation of the Motor Vehicles Sector in the GVC



Sources: ICIO 2018; authors' calculations.

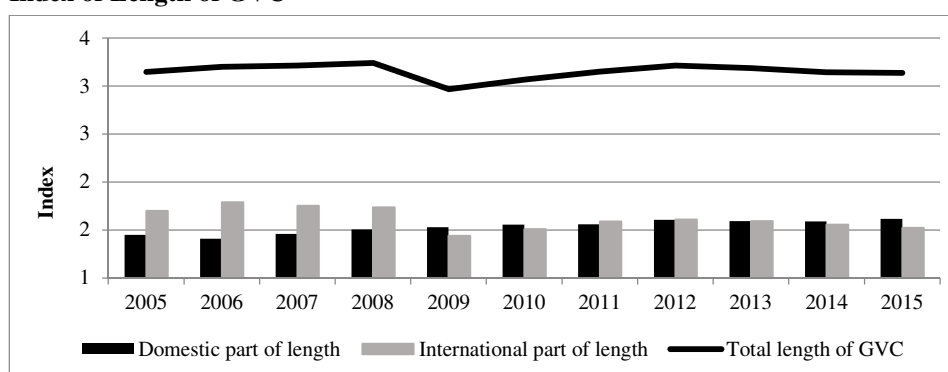
¹⁰ As Guilhoto et al. (2019) note, forward participation generally adjusts more slowly to changing economic conditions than backward linkage.

¹¹ For example, in 2015, the share of foreign value added in gross exports (backward participation) was 59.6 percent, implying that the share of domestic value added in gross exports (commonly known as the VAX ratio) was 40.4 percent. Of this, the share of domestic value added embodied in intermediates re-exported by trade partners to third countries (i.e., forward participation) was 7.8 percent. Thus, domestic value added absorbed by direct importers amounted to 32.6 percent of gross exports, equivalent to four fifths of the VAX ratio.

3.4. The Length of GVC

A complementary measure to the degree of GVC participation is the length of the GVC, which indicates the number of production stages involved in the chain. We follow the methodology proposed by Antràs et al. (2012), Fally (2012) and Wang et al. (2017b) to calculate the index of the length of the GVC and decompose the index according to domestic and foreign production stages (see Annex II). The index takes the value of 1 when no intermediate inputs are used to produce a final good, and the value increases when inputs from the same industry or other industries are used. Since the index is calculated at the aggregate industry level and is not based on plant-level information, the value of the index should not be interpreted as the actual number of production stages but seen as an index of fragmentation. The fragmentation of production in the motor vehicles industry in Slovakia is among the highest in the world.¹² The index of length of GVC was above 3 in all years but one during 2005 – 2015. There was no discernible trend in the intertemporal variation in the index. In other words, there was no significant change in the length of GVC over time. With the financial crisis and trade collapse in 2009, there was a noticeable temporary reduction in the length of the GVC chain. The international part of the chain was the driver of the observed decline which occurred even while there was an increase in the domestic length. The consolidation of the GVC chain in 2009 was cyclical but there was an ongoing structural change in the GVC chain during 2005 – 2015. The international part of the value chain was becoming shorter over time while the domestic part of the chain was lengthening (Figure 7).

Figure 7
Index of Length of GVC



Sources: ICIO 2018; authors' calculations.

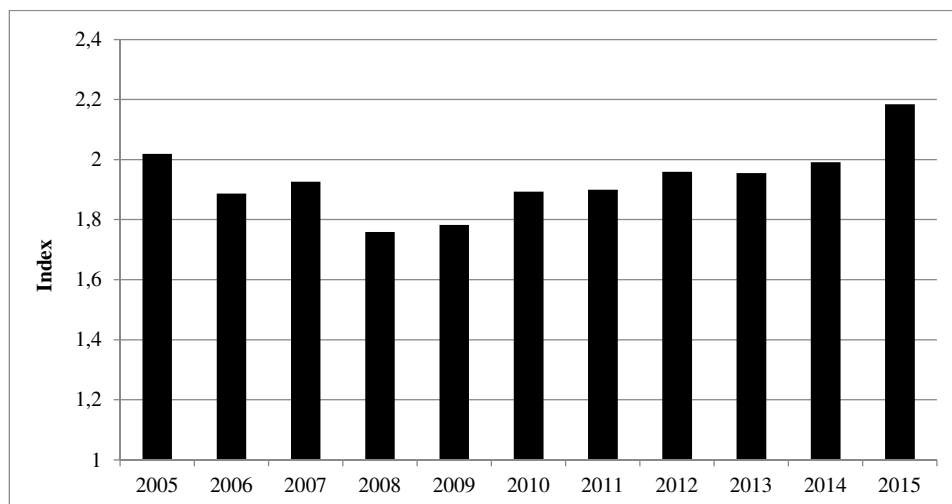
¹² De Backer and Miroudot (2013) found that in 2009 the index of length of GVC for Slovakia's motor vehicles sector was the fifth highest among 51 countries in the sample.

This is consistent with the finding reported earlier that the reliance on domestically-sourced intermediate inputs had increased over time. Prior to the global financial crisis, a larger part of the production stages was located abroad. However, during the crisis years and in the later years of the reference period, the domestic length of the chain was longer than the international length implying that a larger part of the production stages was located in Slovakia.

3.5. Position in the GVC

Position in the GVC indicates how far the production process is from final demand. This measure, based on the methodology developed by Antràs et al. (2012), Fally (2012) and Wang et al. (2017b) (see Annex II), shows that the production process in the motor vehicles industry in Slovakia was moving downstream (i.e., the distance to final demand was decreasing) prior to the global financial crisis. However, there was a turnaround subsequent to the crisis with the distance to final demand index exhibiting a rising trend. The distance to final demand index was 2.18 in 2015 compared to 1.76 in 2008 and 2.02 in 2005 (Figure 8). This implies that the production process was moving upstream in the post-crisis period, which is manifested in the growing importance of intermediates in exports (reported in the second Section above) and in the increase in forward participation in the GVC. The U-shaped trend path of the distance to final demand index was strongly correlated with similar trend paths of share of intermediates in exports ($\rho = 0.946$; $p = 0.000$) and forward linkage ($\rho = 0.838$; $p = 0.001$).

Figure 8
Distance to Final Demand



Sources: ICIO 2018; authors' calculations.

3.6. Effect of Negative Demand Shock on Value Added

Given its high export orientation and GVC participation, the Slovak motor vehicles industry is vulnerable to negative shocks to final demand for motor vehicles. Such a shock would result in a fall in the (direct) value added generated in the production of motor vehicles which also would have a negative knock-on effect on the (indirect) value added created in the production of domestically-sourced inputs. The total impact on the Slovak economy would be significant in view of the relatively large contribution of the combined direct and indirect domestic value added embodied in the production of motor vehicles (13 percent of Slovak GDP in 2015).

We calculate the impact on domestic value added of a hypothetical 10 percent negative shock to the final demand for motor vehicles, using the methodology elaborated by Garcia et al. (2020) (see Annex III). The size of the impact is also classified according to the geographical origin of the shock. An underlying assumption of the calculations is that the structure of the global supply chain does not change on account of the negative demand shock. The estimated impact varies linearly with the size of the final demand shock. Thus, a doubling of the demand shock would double the size of the loss in value added.

Table 1

Impact of a Negative 10% Shock in Demand for Cars by Origin of the Shock (in %)

Origin of shock	Change in direct and indirect domestic value added embedded in production of motor vehicles (in percent of combined direct and indirect value added in 2015)	Change in the Slovak GDP (in % of total Slovak GDP in 2015)
Domestic	-0.64	-0.07
European Union (excluding Slovakia)	-3.80	-0.49
Euro area	-2.68	-0.34
Non-euro area EU countries	-1.13	-0.15
Rest of the world	-3.39	-0.44
USA	-1.00	-0.13
China	-0.86	-0.10
Russia	-0.23	-0.02
Total world	-7.81	-0.99

Source: Authors' calculations.

As Table 1 shows, a 10 percent decline in the global final demand for motor vehicles would result in a drop of nearly 8 percent in the direct and indirect domestic value added embodied in the production of motor vehicles in Slovakia. This is equivalent to a fall of about 1 percent in Slovak GDP. A 10 percent negative demand shock emanating from the EU would lower Slovak GDP growth by almost 0.5 percentage point, with the contribution of the shock originating in the euro area being 0.34 percentage point.

The exposure to a shock from non-EU markets in the aggregate is only somewhat smaller than to a shock from the EU, but this market segment is more diverse than the EU. The United States and China are the largest markets outside the EU for Slovak motor vehicles. A 10 percent demand shock originating from these two countries would lower Slovak GDP by 0.13 percent and 0.1 percent, respectively. The impact of a domestic demand shock is assessed to be rather small.

The quantitative estimates of the impact of a hypothetical negative shock noted above may be subject to downward bias, as they are based on data ending in 2015 when there were only 3 car manufacturers in Slovakia. With subsequent capacity expansion and the start of production by Jaguar Land Rover in 2018, the impact of a negative demand shock is likely to be greater as the share of automotive exports in total exports has risen.

However, updated estimates can be provided only once ICIO data for recent periods become available.

Conclusions

The importance of the motor vehicles industry in value added and exports of the Slovak economy has grown over the past two decades. The motor vehicles industry in Slovakia is highly integrated into the GVC, and there has been an ongoing change in the structure of the supply chain. The domestic part of the supply chain has lengthened as the reliance of the industry on domestically-sourced inputs has grown, and the international part of the length of the GVC has shortened. The upstreamness of the production process has been increasing, and the forward linkage in the GVC has slowly crept up. The sourcing of imported inputs and the export market have become more diversified. While the EU remains a major source of imports of intermediate inputs and destination for exports, the market share of non-EU countries in both imports of intermediates and exports of final goods have risen over time.

Given the huge dependence of the motor vehicle sector on exports and the lengthening of the domestic supply chain over time, the vulnerability of the Slovak economy to negative shocks to the demand for motor vehicles originating from abroad has increased.

Although Slovak motor vehicles are exported to many countries, the main export markets for Slovak cars are Germany, China, the United States and Russia. Thus, the sector is particularly exposed to idiosyncratic demand shocks originating from these countries.

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Annex I.

Using the Inter-Country Input-Output (ICIO) model database

In the ICIO model, the relationship between gross output X and final demand Y is given by

$$X = B * Y$$

where B is the well-known (global) Leontief inverse matrix, and the relationship between value added Va and final demand is given by

$$Va = \hat{V} * B * Y$$

where \hat{V} is a diagonal matrix with sectors' value added coefficients in its diagonal.

Matrix $\hat{V} * B$ is crucial in the calculation of the country's origin of value added for variables that are listed in Figure 1 of the main text.

To calculate the origin of the Va in inputs of the Slovak automotive sector we use the matrix

$$\hat{V} * B * INP$$

where INP is a diagonal matrix with inputs to Slovak automotive sector from all domestic and foreign sectors on its diagonal.

Calculation of origin of the Va of exports of the automotive sector rests on the matrix

$$\hat{V} * B * EXP$$

where EXP is a diagonal matrix with total export of each domestic and foreign sector on its diagonal.

The origin of the Va of the Slovak automotive sector's final demand can be determined from the matrix

$$\hat{V} * B * Y$$

Annex II.

Measuring the length of GVC and distance to final demand

This annex sets out the methodology for the calculation of the indices for the length of global value chains (GVC) and distance to final demand. The length of GVC reflects the number of stages involved in the entire production process between the primary inputs in a country-sector pair to the final product in another country-sector pair. The distance to final demand indicates the position of the country in the value chain; i.e., it measures the number of stages still left before the goods produced by the industry reach the final consumer. We follow the methodology proposed by Antràs et al. (2012), Fally (2012) and Wang et al. (2017b).

The accounting framework

The average production length of value added from sector i of country s to the final product of sector j in country r can be computed from the matrix

$$PLvy = \frac{\hat{V} * B * B * \hat{Y}}{\hat{V} * B * \hat{Y}}$$

where B is the well-known (global) Leontief inverse matrix, and \hat{V} and \hat{Y} are diagonal matrices with sectors' value added coefficients and final demand, respectively, in their diagonals.

The elements of the matrix $PLvy$ are

$$plvy_{ij}^{sr} = \frac{v_i^s \sum_{tk} b_{ik}^{st} b_{kj}^{tr} y_j^r}{v_i^s b_{ij}^{sr} y_j^r}$$

The numerator $v_i^s \sum_{tk} b_{ik}^{st} b_{kj}^{tr} y_j^r$ is the total output generated by the production chain from sector i 's value added in country s and finally absorbed by the final product of sector j in country r . The denominator $v_i^s b_{ij}^{sr} y_j^r$ is the total (direct and indirect) value added of sector i in country s embodied in the final product produced by sector j of country r .

Thus, the length of a production chain $plvy_{ij}^{sr}$ signifies the number of times a value added is counted as output in the production chain, from the first time it is used as the primary input of a country/sector (s, i) until it is absorbed by a final product of a country/sector (r, j).

The matrix $PLvy$ enables us to construct the indices for the length of GVC and distance to final demand.

Measuring the length of GVC index

Aggregating matrix $PLvy$ along the column (r, j) over value-added from all sectors i of country s that have contributed to the final goods and services produced by sector j of country r , we obtain the average production length measure of sector j in country $r - D_j^r$, based on backward linkage. By matrix manipulation, it can be shown that D_j^r is the sum of elements on the column (r, j) of Leontief inverse matrix B :

$$D_j^r = \sum_{si} b_{ij}^{sr}$$

The sum along the columns of the Leontief inverse matrix equals the total value of inputs generated by a unit of final product produced in a particular sector. Therefore, index D measures total intermediate inputs generated by a unit value of a particular final product throughout all upstream sectors in the economy, which the literature usually refers to as the footprint of final goods and services. The longer is the production chain, the greater is the number of upstream production stages that a particular final product has in the economy.

Measuring the distance to final demand index

Aggregating matrix $PLvy$ along the row (s, i) over all products j of country r , we obtain the total average production length of value added generated in sector i of country s , i.e., the average production length measure of sector i in country $s - U_i^s$, based on forward linkage. By matrix manipulation, it can be shown that U_i^s is the sum of elements on the row (s, i) of a matrix $G = \hat{X}^{-1} * B * \hat{X}$ (called Ghosh inverse¹³):

$$U_j^r = \sum_{ij} g_{ij}^{sr}$$

It is the sum along the rows of the Ghosh inverse matrix, which equals the total value of gross outputs that are related to one unit of value added created by primary inputs from a particular sector. Thus, the index U measures total gross outputs generated by one unit of value added at the sector level, which are the footprints of each sector's value added in the economy as a whole. The longer is the production chain, the greater is the number of downstream production stages that a sector's value added is counted as gross output in the economy.

¹³ GHOSH, A. (1958): Input-output Approach in an Allocation System. *Economica*, 25, pp. 58 – 64.

Annex III.

Quantifying the impact on the motor vehicles sector of a shock to final demand

Assuming that the structure of the global supply chain remains unchanged, the impact of a shock to final demand for cars by consumers across the world on the (direct and indirect) domestic value added embodied in the production of motor vehicles can be computed as follows:

$$\Delta Va = \hat{V} * B * (Y_{t=shock,WR}^{cars} - Y_{2015,WR}^{cars})$$

where Va is the (direct and indirect) domestic value added; \hat{V} is a diagonal matrix with sectors' value added coefficients in its diagonal; B is the well-known (global) Leontief inverse matrix; and $Y_{2015,WR}^{cars}$ denotes the demand for cars in 2015 by specified world regions (individual countries, EA, EU, world).

Appendix

Table 1

Selected Indicators from the Gross Production Perspective for the Slovak Motor Vehicles Industry

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gross output of motor vehicles industry (in % of gross output of entire Slovak economy)	7.1	7.9	9.4	8.7	7.0	8.8	10.2	11.7	12.3	12.0	13.1
Share of intermediate goods in gross output of motor vehicles industry (%)	52.2	47.0	48.1	41.4	42.4	47.2	47.5	49.7	49.6	50.5	57.0
Share of final goods in gross output of motor vehicles industry (%)	47.8	53.0	51.9	58.6	57.6	52.8	52.5	50.3	50.4	49.5	43.0
Domestic sales of motor vehicles industry (in % of gross output of motor vehicles industry)	30.3	24.9	26.4	20.4	22.0	25.8	25.8	26.3	25.4	25.0	30.3
<i>of which:</i>											
Intermediate goods	22.5	18.0	20.5	15.1	16.8	19.1	20.4	22.1	21.6	21.0	25.4
Final goods	7.7	6.9	6.0	5.3	5.2	6.7	5.5	4.2	3.8	4.0	4.9
Gross exports of motor vehicles industry (in % of gross output of motor vehicles industry)	69.7	75.1	73.6	79.6	78.0	74.2	74.2	73.7	74.6	75.0	69.7
<i>of which:</i>											
Intermediate goods	29.7	29.0	27.6	26.3	25.7	28.1	27.1	27.6	28.0	29.5	31.5
Final goods	40.0	46.1	46.0	53.3	52.4	46.1	47.1	46.1	46.6	45.5	38.2
Gross exports of motor vehicles industry (in % of total gross exports of Slovakia)	16.2	18.0	20.5	21.9	20.0	21.9	23.7	25.6	26.6	27.3	27.9
Intermediate inputs used to produce motor vehicles (in % of gross output of motor vehicles industry)	80.4	82.1	81.5	83.0	76.5	77.9	78.7	80.8	80.8	79.5	79.3
<i>of which:</i>											
Domestically-sourced intermediate inputs	29.4	27.5	30.2	32.0	33.2	34.6	34.8	37.2	36.7	36.0	37.2
(Direct) Foreign intermediate inputs	51.1	54.7	51.3	51.0	43.4	43.3	43.9	43.6	44.1	43.5	42.1
(Indirect) Foreign intermediate inputs used to produce domestically-sourced intermediates (in % of gross output of motor vehicles industry)	14.5	13.7	14.8	14.1	12.5	14.3	15.8	16.9	16.7	15.9	17.4
Total Foreign intermediate inputs (direct & indirect) embodied in production of motor vehicles (in % of gross output of motor vehicles industry)	65.6	68.4	66.0	65.1	55.9	57.6	59.7	60.5	60.8	59.4	59.6
(continued)											

Table 1

Selected Indicators from the Gross Production Perspective for the Slovak Motor Vehicles Industry (continued)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Destination of total gross exports of motor vehicles industry (in % of gross exports of motor vehicles industry)											
Euro area	66.8	55.9	54.2	43.8	47.7	42.6	41.7	39.2	38.9	40.0	43.0
Non-euro area EU	8.2	9.8	11.2	13.0	17.0	17.2	15.4	15.4	16.7	18.8	20.1
Non EU	25.0	34.3	34.6	43.2	35.3	40.2	42.8	45.4	44.4	41.2	36.9
<i>of which:</i>											
United States	11.7	15.5	10.4	6.7	3.2	4.8	4.7	5.5	5.4	6.3	8.8
China	1.0	2.8	4.9	5.9	6.9	10.2	16.9	16.8	15.4	14.9	10.0
Destination of intermediate gross exports of motor vehicles industry (in % of gross exports of motor vehicles industry)											
Euro area	29.3	22.9	20.7	14.9	16.0	18.4	16.8	16.4	15.9	16.9	22.4
Non-euro area EU	3.8	4.2	4.6	5.0	8.2	8.9	8.1	8.3	9.0	10.0	11.3
Non EU	9.4	11.5	12.2	13.2	8.7	10.6	11.6	12.7	12.6	12.4	11.6
<i>of which:</i>											
United States	5.3	5.9	5.3	2.6	1.3	1.8	1.8	1.9	1.4	1.9	1.5
China	0.5	1.3	2.3	2.2	2.4	2.7	4.7	4.9	4.7	4.8	3.7
Destination of final goods gross exports of motor vehicles industry (in % of total gross exports of motor vehicles industry)											
Euro area	37.5	33.0	33.6	28.8	31.7	24.2	24.9	22.8	23.0	23.1	20.6
Non-euro area EU	4.4	5.5	6.6	8.1	8.8	8.3	7.3	7.1	7.7	8.7	8.8
Non EU	15.6	22.8	22.3	30.0	26.7	29.5	31.2	32.7	31.8	28.8	25.3
<i>of which:</i>											
United States	6.4	9.6	5.2	4.1	1.9	3.0	2.9	3.5	4.0	4.4	7.3
China	0.5	1.5	2.6	3.6	4.4	7.5	12.3	11.9	10.7	10.1	6.3
Source of total (direct&indirect) foreign intermediate inputs embodied in production of motor vehicles (in % of total imports of intermediates)											
Euro area	54.9	49.4	45.8	48.2	49.7	43.7	42.4	42.7	43.4	42.6	42.3
Non-euro area EU	21.7	23.4	20.8	19.8	20.6	17.6	17.8	17.6	22.7	23.4	23.8
Non EU	23.4	27.2	33.4	32.0	29.7	38.7	39.8	39.7	33.9	34.0	33.8

Source: OECD ICIO Model database; authors' calculations.

Table 2
Selected Indicators from the Value Added Perspective for the Slovak Motor Vehicles Industry

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
(Direct) value added in motor vehicles industry (in % of gross output of motor vehicles industry)	19.6	17.9	18.5	17.0	23.5	22.1	21.3	19.2	19.2	20.5	20.7
(Direct) value added in motor vehicles industry (in % of total value added in Slovak economy)	3.2	3.3	4.1	3.6	3.8	4.6	5.3	5.5	5.6	6.0	6.6
(Indirect) domestic value added in intermediate inputs used in production of motor vehicles (in % of gross output of motor vehicles industry)	14.9	13.8	15.4	17.9	20.7	20.3	19.0	20.2	20.0	20.1	19.8
(Indirect) domestic value added in intermediate inputs used in production of motor vehicles (in % of domestic intermediate inputs used in production of motor vehicles)	50.7	50.1	51.1	55.9	62.4	58.7	54.7	54.4	54.5	55.8	53.1
(Indirect) domestic value added in intermediate inputs used in production of motor vehicles (in % of total value added in Slovak economy)	2.4	2.6	3.4	3.7	3.3	4.2	4.7	5.8	5.9	5.8	6.3
Direct & Indirect value added in production of motor vehicles (in % of total value added in Slovak economy)	5.6	5.9	7.6	7.3	7.1	8.8	10.0	11.2	11.5	11.8	13.0
Backward linkage (Foreign value added in exports in % of gross exports of motor vehicles)	65.6	68.4	66.0	65.1	55.9	57.6	59.7	60.5	60.8	59.4	59.6
Forward linkage (Export value added used in third countries in % of gross exports of motor vehicles)	5.5	4.3	4.6	3.3	5.0	5.8	5.9	5.7	5.7	6.4	7.8
GVC participation index (in % of gross exports of motor vehicles)	71.1	72.7	70.6	68.5	60.9	63.4	65.5	66.2	66.5	65.8	67.3
Length of GVC_Total	3.1	3.2	3.2	3.2	3.0	3.1	3.2	3.2	3.2	3.1	3.1
Domestic part of length of GVC	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6
International part of length of GVC	1.7	1.8	1.8	1.7	1.4	1.5	1.6	1.6	1.6	1.6	1.5
Distance to final demand_Total	2.0	1.9	1.9	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.2

Source: OECD ICIO Model database; authors' calculations.

Table 3
Regressions on Time Trends in Selected Indicators of the Slovak Motor Vehicles Industry

Dependent variable	Constant		TIME		TIMESQ		Adjusted R-Squared	F statistic	
Gross output of motor vehicles industry (in % of gross output of entire Slovak economy)	6.2955 (0.6465)	***	0.5887 (0.0953)	***			0.7879	38.15	***
Share of final goods in gross output of motor vehicles industry (%)	46.0271 (2.5783)	***	3.5844 (0.9875)	***	-0.3467 (0.0802)	***	0.7000	12.67	***
Domestic sales of motor vehicles industry (in % of gross output of motor vehicles industry)	30.6407 (2.5752)	***	-2.4970 (0.9863)	**	0.2182 (0.0801)	**	0.3639	3.86	*
Gross exports of motor vehicles industry (in % of total gross exports of Slovakia)	15.8817 (0.6296)	***	1.1363 (0.0928)	***			0.9370	149.85	***
Gross exports of intermediate goods (in % of gross output of motor vehicles industry)	31.3979 (0.7880)	***	-1.7387 (0.3018)	***	0.1571 (0.0245)	***	0.8139	22.87	***
Domestically-sourced intermediate inputs used to produce motor vehicles (in % of gross output of motor vehicles industry)	25.9780 (1.1815)	***	1.7911 (0.4525)	***	-0.0698 (0.0367)	*	0.8980	45.03	***
(Indirect) domestic value added in intermediate inputs used in production of motor vehicles (in % of total value added in Slovak economy)	1.9105 (0.2196)	***	0.4130 (0.0324)	***			0.9418	162.74	***
Direct & Indirect value added in production of motor vehicles (in % of total value added in Slovak economy)	4.5471 (0.3699)	***	0.7552 (0.0545)	***			0.9502	191.80	***
GVC participation index (in % of gross exports of motor vehicles)	76.1007 (2.6222)	***	-3.1990 (1.0043)	**	0.2222 (0.0815)	**	0.5215	6.45	**
Backward linkage (Foreign value added in exports in % of gross exports of motor vehicles)	70.8960 (3.0795)	***	-2.8480 (1.1795)	**	0.1712 (0.0957)		0.5000	6.00	**
Forward linkage (Export value added used in third countries in % of gross exports of motor vehicles)	5.2047 (0.7470)	***	-0.3510 (0.2861)		0.0510 (0.0232)	*	0.6557	10.52	***
Length of GVC_Total	3.1650 (0.0529)	***	-0.0021 (0.0078)				-0.1024	0.07	
Domestic part of length of GVC	1.4156 (0.0156)	***	0.0198 (0.0023)	***			0.8789	73.56	***
International part of length of GVC	1.7494 (0.0586)	***	-0.0218 (0.0086)	**			0.3504	6.39	**
Distance to final demand_Total	2.0757 (0.0628)	***	-0.0959 (0.0240)	***	0.0094 (0.0020)	***	0.7539	16.32	***

Note: Figures in parentheses are standard errors. ***, **, * denote significance at 1%, 5% and 10% level, respectively.

Source: Own estimations.