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Analysis of the development of the Automotive Cluster and its Impact on Economic Growth in Central and Eastern Europe between 2013 and 2018

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Abstract

In Central and Eastern Europe (CEE), a closely linked automotive cluster has evolved since the regime change in 1989. The production network mainly includes V4 countries (Czech Republic, Hungary, Poland, Slovakia) and Romania. EU membership has further increased the concentration of this network. Following the crisis in 2008, the automotive value chain has undergone further changes that is experienced as a reindustrialization of the region.

Nevertheless, the evaluation of the region's participation in the automotive value chain is ambiguous. First, the capital intensive production in CEE generally does not need highly skilled labour. The assembly activities are common, and it results a relatively low value added ratio. However, the volume of production is high, therefore its proportion in GDP is significant, and its impact on economic growth is remarkable. Second, automotive industry through its foreign direct investment inflows has been determining for post-socialist countries. Despite of the great amount of FDI stock, these firms' integration into the domestic economies is still weak. The import ratio of the production is very high and domestic suppliers are typically foreign controlled multinational enterprises. The export ratio of the industry is extremely high compared to almost any other industries.

In this paper, a two-level analysis is made. First, a comprehensive picture from the region is got through aggregate data. It is focused on how the global automotive industry's relocation to CEE has changed the value chain and the form of dependence in the region since the slight recovery in 2013. This change is investigated through the countries' exposure to export and import, the influence on GDP and the amount of both profit outflows and FDI stock change. Second, Hungarian automotive cluster is analysed deeper through microdata in order to detect the relationship with other automotive enterprises in CEE. It is based on the interpretation of transaction-level data for the years 2015 and 2018. Due to this method, Hungarian producers can be fully identified and the actors in CEE who have transactions with Hungarian companies can be detected. Through microdata, it is possible to identify the Hungarian enterprises' positions in the hierarchical structure of the value chains. Moreover, many other indicators (GVA, ITGS/ITSS, IFATS, balance of payments) and company's annual reports are used in order to draw consequences on the opportunities and the risks of the particular CEE model on the economic growth.

According to this research, the concentration of the automotive cluster has increased between the four years, and the intensity of trade among the countries has also grown. At the same time, due to the saturation in the European vehicle market, Asian sales opportunities have become more valuable which enhanced indirectly the dependence of the analysed countries. The developed methodology could also be implemented on micro-level data of V4 countries and Romania, and the results, in addition to helping to understand the nature of the region's economic growth, can be used for forecasting purposes later on, as well. The main objective with this project is to improve the knowledge about the large automotive companies and their value chains in order to understand and forecast their complex effects on national accounts.

Keywords: automotive industry, network analysis, MNEs, global value chain, economic shock

1. Introduction

The world economy has been increasingly globalized since 1980s. Multinational enterprises (MNEs) have been integrated to global value chains (GVCs) and outsourced many of their activities to either other companies or newly founded foreign subsidiaries (Gereffi and Korzeniewicz 1994; Feenstra 1998). Eastern European countries rapidly joined this process after the collapse of the socialist integration – Council for Mutual Economic Assistance (Comecon) – at the beginning of the 1990s. A spectacular and well-known example of this process can be traced in the automotive industry (Gerőcs and Pinkasz 2019). The accession of the CEE countries to the European Union (EU) in 2004 and 2007 has further increased the concentration of this production network. Although the financial and economic crisis in 2008 temporary stopped the process, from 2010/2011 European automotive value chains were strongly reorganized: a significant amount of manufacturing activities was relocated to Eastern Europe. On the one hand, it contributes to the GDP growth of these countries, on the other hand, it results a serious dependency on a cycle-sensitive industry.

The extension of the automotive industry is gone beyond the manufacturing of motor vehicles, namely NACE 29. Ritzlné Kazimir et al. (2016) investigated it through an Input-Output table and its Leontief-inverse matrix on Hungarian data. They found that due to the disembedded nature of automotive industry, the actors directly connect rather to foreign partners, than to national firms. There are two limits of this approach. First, the Input-Output tables are available in Hungary only for every five years (2005, 2010, 2015). This time delay prevents the more accurate mapping of the effects of rapid economic changes. Second, it could not deal with all actors of a GVC. Input-output table could not handle those actors who are not in NACE 29 and does not produce directly to Hungarian companies of that industry.

Pinkasz and Ritzlné Kazimir (2019) aim was to avoid the limits of the IOT analysis. They built a database that can be a basis of a network analysis. The authors made a method for identifying the main actors of the global automotive value chains in Hungary. First, they used international lists about OEMs and Tier-1 companies, and identified their Hungarian subsidiaries through IFATS (inward foreign affiliates statistics) and EGR (EuroGroups Register). Second, they supplement the database with their partners through VAT data. This administrative data was also suitable to identify the actors position in the value chain. Furthermore, due to its monthly and quarterly nature, it assures an almost up-to-date information about the relationship and the trade between the actors of the value chain.

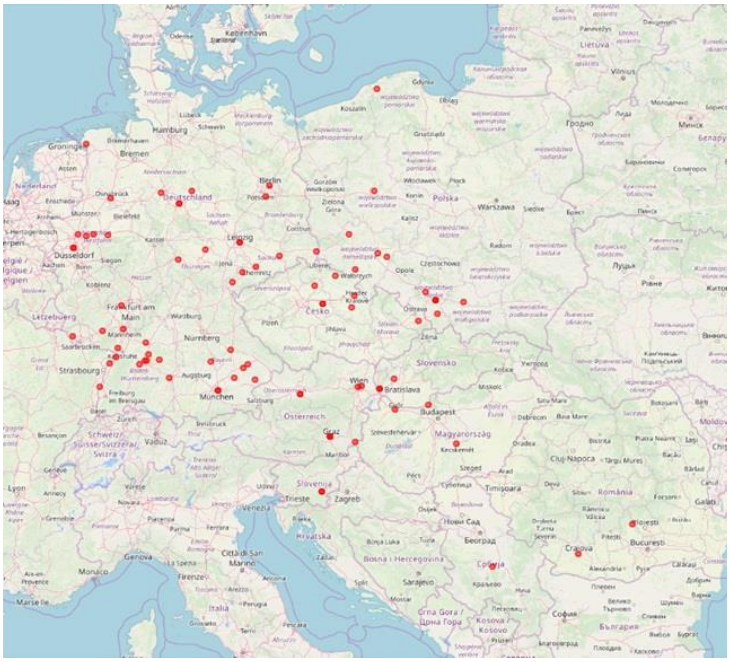
Recent paper utilizes the results of Pinkasz and Ritzlné Kazimir (2019) and supplements it by the using of network analyses methodology. One of the greatest advantages of network analysis is its ability to model the spread of an eventual economic shock. This paper overviews the development of automotive industry in Central and Eastern European countries, from point of view of the gross value added and analyses the development of sales of lead firms (so called Original Equipment Manufacturers, OEMs) in this region. In the second part of the research a model is drawn up, which is appropriate to describe the spread of exogenous shocks in automotive industry. This model is built on the analogy between the spread of epidemics on population and spread of exogenous shocks in value chain.

2. Data

The automotive value chain has a significant presence in CEE countries. As Figure 1 shows, there are many factories of OEMs in the region, and due to strategies of follow sourcing (parts are supplied by the same company in different locations) (Humphrey and Memedovic 2003), these factories are surrounded by a plenty of Tier-1 companies.

Figure 1

The distribution of OEMs in Central and Eastern Europe



Source: OpenStreetMap, ACEA and own editing.

In order to have a comprehensive picture about the motor vehicle industry (NACE 29) in CEE, we collected the following macro data:

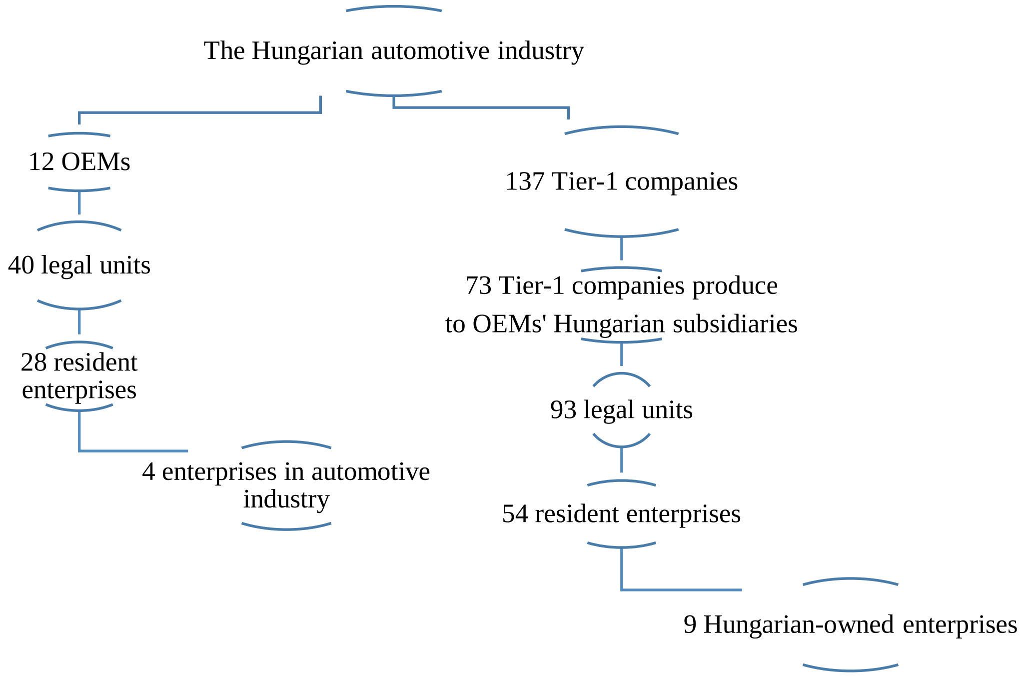
- gross value added (GVA) of total economy in constant prices (chain linked volumes (2005), million euro) in national account concept;
- GVA of NACE 29 in constant prices (chain linked volumes (2005), million euro) in national account concept;
- export of goods and services in current prices;
- net sales data (total, regional), deliveries of cars by regions (annual reports of selected OEMs)

This data show us a picture about the worldwide development of sales in automotive industry. In addition, the effects of production value on gross value added can be analysed as well.

After having a broad picture of the region, we analyze deeply the Hungarian parts of the global automotive value chain through micro data. The research is based on a database of OEMs and Tier-1 companies located in Hungary. The main sources of the database were the VAT data, the IFATS and EGR data. The compilation of the database had three steps. First, we detected the Tier-1 suppliers and OEMs in Hungary. Second, the transactions to OEMs were selected from VAT data. Finally, those enterprises were erased from the database, who had transactions with the OEMs, however we did not consider them as a Tier-1 company. See the detailed method of that database in Pinkasz and Ritzlné Kazimir (2019). Figure 2 shows the structure of the Hungarian automotive industry in 2017. Our recent research focuses on the network of four OEMs' subsidiaries and the Tier-1 suppliers.

Figure 2

The structure of automotive industry in Hungary in 2017



Source: Pinkasz and Ritzlné Kazimir (2019).

Through the transactions of the firms, it is possible to identify the Hungarian enterprises' positions in the hierarchical structure of the value chains. Due to this database, Hungarian producers can be fully identified, and we argue that it would be worth to creating similar databases in each country of CEE in order to understand the national automotive network and the connections among networks of all countries of CEE.

3. Method

As a first step, we examined the role of automotive industry and development of sales of OEMs in order to understand the main process in this field of economy in previous years. For this purpose, time series analyses was used. As a second step, network analysis is selected as a good mathematical model which can aid in the understanding of the nature of the automotive network and the spread of economic shocks. In the framework of network analysis, first is the key concept explained, then epidemic modelling is described to present the spread of economic shocks through a network. We argue that there is a clear analogy between the spread of epidemics and economic shocks.

3.1. Analysis of the importance of motor vehicle industry in CEE

We calculate the strength of the relationship between total gross value added and gross value added of automotive industry (NACE 29) by linear regression in the analyzed CEE countries. The purpose of this analysis is to gain information about the impact of the automotive industry on the total GVA. The t-statistic is used to test the significance of the coefficient.

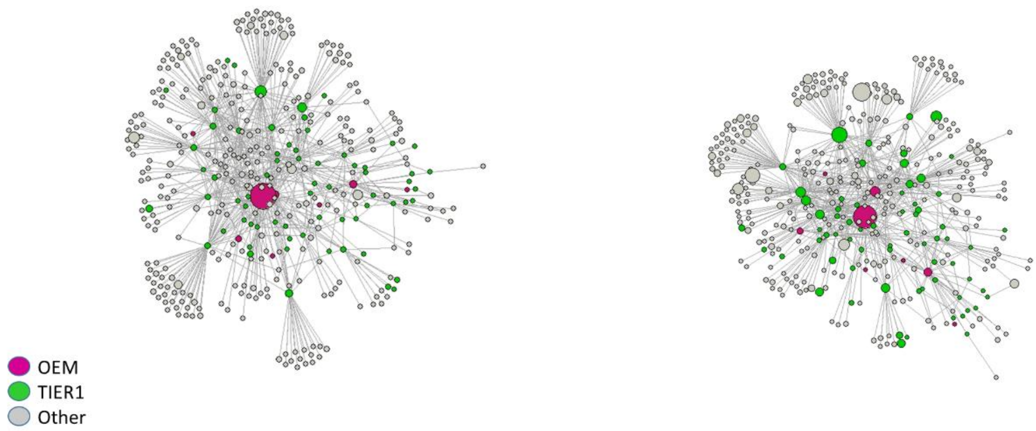
Then we choose some OEMs from those countries where we found the industry significant and analyze their annual reports. We make time series from their sales and export data in order to detect the possible risks.
of some OEMs were collected to create time series to detect the possible risks in sales and export. We argue this is a very important step because without it we cannot infer what economic exposures exist.

3.2. Network topology

If you want to understand a complex system, you need to know some basic concept. This part is based on the book of Barabási (2016). First, the connection diagram should be written. As an example, the Figure 3 is shown as connection diagram of Hungarian automotive industry (OEMs, Tier-1 and their suppliers) in 2017.

Figure 3

Network of Hungarian automotive industry in 2017
(size of nodes by GVA on left side and by employment on right side)



Source: own editing.

A network consists of nodes (vertices) and edges (links). The number of nodes is denoted by N, and the number of connections (edges, links) is marked by L. The edges of a network can be **directed** or **non-directed**. In non-directed networks, the links are two way connections.

In a network, the most important property of a point is the **degree** which is the number of connections between the point and the other nodes of the network. The degree of *i* point is denoted by k_i . In an undirected network, the number of edges (L) can be calculated as follow (1):

$$L = \frac{1}{2}\sum_{i=1}^{N} k_i \qquad (1)$$

The average degree of the total network $\langle k \rangle$ is another important feature of an undirected network (2):

$$\langle k \rangle = \frac{1}{N}\sum_{i=1}^{N} k_i = \frac{2L}{N} \qquad (2)$$

3.3.Degree distribution function

The degree distribution is the probability that a nodes have *k* links to other nodes. If the network are formed by random process, then the distribution of links follows a Poisson distribution function in large networks, the small networks have binomial distribution. The most real networks are different, they follow scale-free distribution function. The nodes in the real networks are not similar, because there are also several nodes with very many connections. In this case, the degree distribution of the network shows a distribution of power function.

3.4.Assortativity

Networks can be divided according to several aspects. The first point of view is the *assortativity* and *dissasortativity*:

i. *Assortative networks*: In assortative networks, nodes of similar degrees are connected to each other, the centres (high degree nodes) to centres and the low degree nodes to low degree nodes. Social networks (e.g. networks of mobile calls, actors, and scientific cooperation) are of this type. Celebrities, political leaders, company directors know many people, they can be seen as centres. They make effort to build relationship with each other.
ii. *Disassortative networks*: In this type of network, the nodes avoid each other and are connected to low degree nodes. It can be described with a structure of centre and spokes. Good examples are the metabolic and the protein network or the e-mail network.
iii. *Neutral networks*: In neutral networks, nodes are randomly connected to each other. There are few neutral networks in reality, one of them is the power network.

3.5.Degree correlation.

The second aspect of network topology is the degree correlation function which helps determine whether or not there is correlation in the network under investigation. First, the average degree of the nodes adjacent (j) to a given i node should be measured for all i nodes.

$$k_{nn}(k_i) = \frac{1}{k_i}\sum_{j=1}^{N} A_{ij}\, k_j \qquad (3)$$

The degree correlation function can be estimated in two ways:

- Assuming a power function, the degree correlation function can be described in the following way:

  $$k_{nn}(k_i) = ak^{\mu} \qquad (4)$$

  The μ correlation exponent defines the type of degree correlation:

- Assortative networks: μ>0
- Disassortative networks: μ<0
- Neutral networks: μ=0

- Assuming a linear function, the *r* degree correlation coefficient is another measure of the degree correlation. Behind its calculation lies the hypothesis that $k_{nn}(k_i)$ that k can be approximated by a linear function:

  $$k_{nn}(k_i) \sim rk \tag{5}$$

  In this case, r is the Pearson correlation coefficient between degrees at both ends of the same relationship. Its value can range from -1 to 1, in the case of
  - Assortative networks: r>0
  - Disassortative networks: r<0
  - Neutral networks: r=0

Knowing the type of a network is extremely important because of the robustness of the network. In assortative networks, the removal of a centre cause less damage because centres form a "core". In disassortative networks, removing a centre is much more destructive because centres have connections to a lot of low degree nodes which will drop out with the centre.

3.6.Spread of economic shocks

An economic shock has an impact on the automotive industry through the connections among companies. The links between the corporations may appear in different areas of economic activities. In this research we focus on the **supplier chain** between enterprises, and we ignore the other types of connection, for example financial links or ownership relations. Therefore, we analyse the sales to OEMs and proportion of sales to total sales in all case of Tier-1 companies. The analysed network is a **directed** network, because the reactions from the suppliers to the OEMs are not taken into account in our analyses.

We argue that the observed problem is similar to the spread of other phenomenon on a contact network presented in Table 1.

Table 1

Networks

Phenomenon	Distributor	Network
Flu	Pathogens	Social network/Spatial proximity network
Computer viral infection	Virus programs	Internet
Mobile phone viral infection	Mobile phone virus programs	Social network
Bed bug	Parasites	Hotels and travellers network
Economic shock	Corporations	Economic relationship among corporations

Source: Barabási 2016: 396.

To model the spread of epidemics and, by **analogy**, the spread of economic shocks, some concepts need to be clarified. Table 2 presents the main definitions of epidemic modelling (Barabási 2016) and **own adaptation** to economic environment.

Table 2

Stages of an infectious disease

Concept	Definition in epidemic modelling	Definition in economic modelling
Immune	An individual who can't be infected	A corporation that can't be infected because of its activities highly diversified, that is, its sales to on OEM are low within all sales.
S: susceptible	Healthy, not yet in contact with the pathogen	A corporation that has not yet in contact with the companies affected by the economic shock
I: infected	An infected individual who has come into contact with the pathogen and can infect others	A problematic corporation
R: recovered	An individual who was previously infected but recovered from the disease, does not infect	A corporation that has overcome the difficulties, who emerging from the crisis

Source: Barabási 2016: 397; own interpretation.

The condition of homogeneous mixture (everyone has the same chance of getting infected by an infected individual) is generally implied in epidemic modelling. This cannot be applied in sector of non-financial corporations because the chance of getting in connection with an infected company is not the same for all companies. If the proportion of sales to an OEM is high within all sales, then the chance of infection is high also.

There are three basic models of spread of epidemic developed by Pastor-Satorras and Vespignani (2001). Their research is presented in book of Barabási also (2016).

- Susceptible-Infected model (SI model)
- Susceptible-Infected- Susceptible model (SIS model)
- Susceptible -Infected-Recovered model (SIR model)

Which model of epidemic is suitable to describe the spread of an economic shock in the global value chain of the automotive machinery?

We argue that in this automotive industry, the Susceptible-Infected model can be applied as a first step. This model is based on the reasoning, if there is an economic shock, then all companies will be infected finally, but **the impact will not be the same for each company**. This simple model does not take into account the possibility of recovery.

If a pathogen\economic shock spreads through a network, those people\companies who maintain multiple connections are more likely to come into contact with a person\company who has become infected and are more likely to become infected themselves.

Therefore, the degree of each node in mathematics must be treated as an independent variable which can be achieved by degree block approximation: this differentiates the nodes by their degree and assumes that the nodes of the same degree are statistically identical. The ratio of the infected k degree nodes (i_k) can be written as follows:

$$i_k = \frac{I_k}{N_k} \tag{6}$$

where

I_k: Number of infected k degree nodes

N_k: Number of total k degree nodes

The ratio of total infected nodes (i) can be obtained as the sum of the number of infected k degree nodes:

$$i = \sum_k p_k * i_k \tag{7}$$

where p_k is ratio of the k degree nodes to the total number of nodes.

For each k degree can be expressed the SI model with the following equation:

$$\frac{di_k}{dt} = \beta * (1 - i_k) * k * \theta_k \tag{8}$$

where

β: The probability that an infected individual will transmit the disease to a susceptible person within one unit time.

θ_k : The density function shows the infected proportion of neighbours of a k-degree susceptible node.

In the case of the homogenous mixing, θ_k is simply the ratio of the infected nodes i_k. In our case, however, the rate of infected nodes depends on the k degree of a node and on the t time. It follows that each k degree in the network has its own equation separately.

If a network is not random, but it is scale-free that means the following: if a pathogen infects a centre, the centre can pass it on to many other nodes, so that the pathogen can survive in the population even if it is only slightly contagious. In our cases, if an economic shock influences the centre (OEM), the centre affects the companies connected to it.

The weight of relationship is important: the more time you spend with an infected person, the more likely you are to be infected. The bigger and stronger the economic relationship between the two companies are, the greater the probability is that the economic shock will spread through the network.

4. Result

According to the Figure 1, there are some OEMs in CEE. It is right to ask whether the gross value added of automotive industry has a significant impact on the total gross value added of a country.
Using time series analysis, this relationship is significant in the most analysed countries, which suggests that these countries are exposed to eventual changes in automotive industry. The annual reports of OEMs show that sales have been become dependent more and more on Asian markets from 2008. This fact is an advantage on the one hand and a potential source of risk on the other.
A possible drop in demand in the Asian market or other economic shock have impact on the sales of OEMs and the total automotive network. Because every country in CEE has another position in the GVC, the effect might be different on GDP of one country. To be able to estimate how fast a shock is spreading through network, the total network of a country must be explored. Using microdata and epidemic modelling, we present the Hungarian automotive network and the estimation of how fast an OEM will "infect" their suppliers. According to the results, the "infection" is rapid.

4.1.Analysis of the importance of motor vehicle industry in CEE

First, we assumed that motor vehicle industry has a great impact on GDP in CEE. Using dlog of annual time series (1995-2017) of total GVA and gross value added in 29 industry according to NACE rev. 2 in chain linked prices 2005, linear regressions were fitted for selected countries in CEE and for Germany in EViews. Table 3 shows the results. Coefficient of GVA in 29 industry is significant in the following countries: Germany, Austria, Czech Republic, Hungary, Croatia, Slovenia, Serbia, Latvia and Lithuania because the calculated probabilities are lower than 0.05. In case of regression for Slovakia, Romania, Bulgaria, Poland and Estonia, the probabilities were higher than 0.05, so the coefficients are not significant.
According to t-Statistic, we can accept the hypothesis that the motor vehicle industry has significant impact on GDP in the most countries in CEE.

Table 3

Results of the linear models (with constant) between the total GVA and the GVA of 29 industry according to NACE rev. 2 of selected European countries (without rounding)

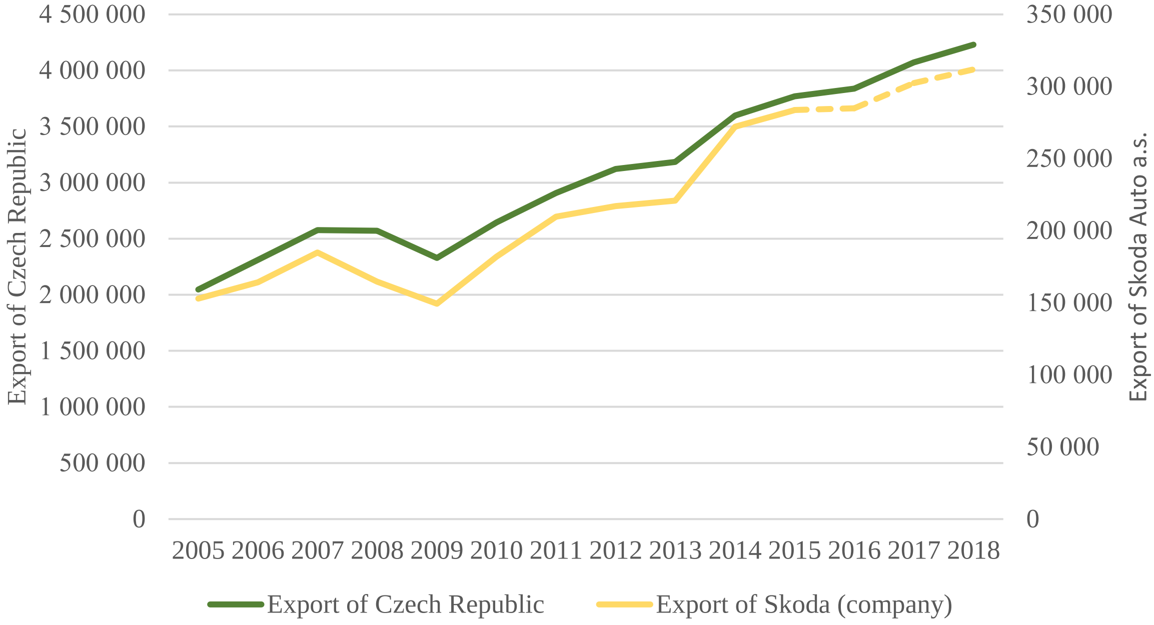
Country	GVA of 29 industry				Main manufacturers
	Coefficient	t-Statistic	Probability	Adjusted R-squared	Type
Germany	0.1397	5.87	0.0000	62.59	OEM
Austria	0.1674	6.76	0.0000	68.05	OEM
Czech Republic	0.1274	4.11	0.0005	43.15	OEM
Slovakia	0.0602	2.03	0.0555	12.99	OEM
Hungary	0.0821	2.45	0.0232	19.37	OEM
Croatia	0.075	2.54	0.0198	21.47	TIER-1
Slovenia	0.1628	2.86	0.0095	25.62	OEM
Serbia	0.8397	12.67	0.0000	88.36	OEM
Romania	0.0838	1.59	0.1262	-	OEM
Bulgaria	-0.0187	-0.41	0.6803	-	-
Poland	0.1679	0.87	0.3951	-	OEM
Estonia	0.0809	1.38	0.1800	-	-
Latvia	0.1123	2.39	0.0311	24.02	TIER-1
Lithuania	0.1245	4.91	0.0001	54.96	TIER-1

Source: Eurostat; own calculation.

Second, we investigated how appeared the sales and export of OEMs in national accounts of countries in CEE. Because of lack of microdata of other countries, our analysis is based on consolidated annual reports.

Figure 4

Export of Czech Republic and Skoda Auto a. s. between 2005 and 2018



Source: annual reports of Skoda; Czech Statistical Office; own calculation.

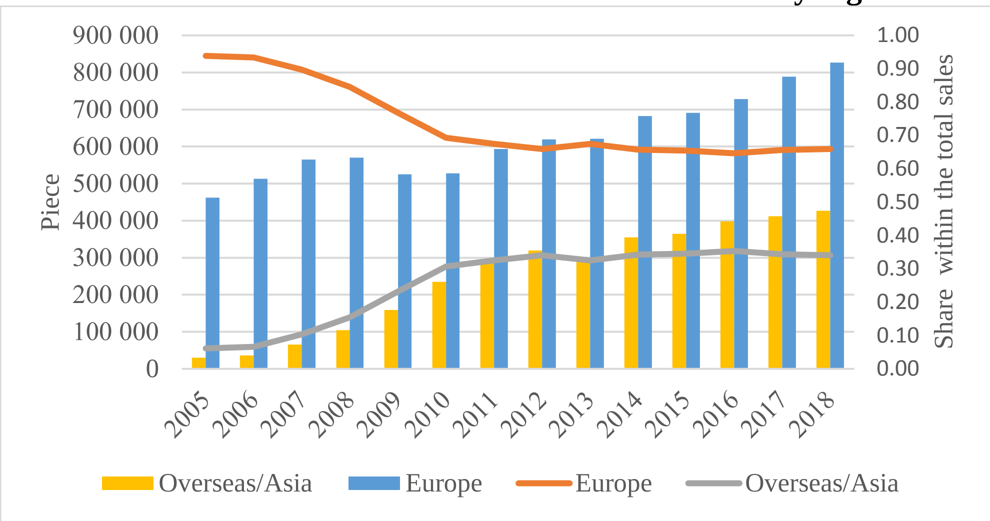
In the period 2005-2014, export of Skoda Auto a. s. had an average share of 7% from the total export of goods and services (calculated in current prices) of Czech Republic, see Figure 4. (The dashed line between 2015 and 2018 shows our forecasted values because the annual reports did not have contain information about export.)

Although we could not calculate the accurate GVA of Skoda Auto a. s. based on IFRS annual report, we argue that the average export share of 7 % is very high that should also appear in production.

The direction of sales is important if effects of an eventual economic shock is to be examined. The Figure 5 illustrates that the highest growth of the deliveries of cars to customers was in region Asia (especially China) after the crises in 2008. While in 2005 the proportion within all sales was only 6%, in 2012 it had reached 34% which has been constant since then. We argue that Skoda is exposed to an eventual demand change in Europe and/or in China which will appear in GVA and export figures in national accounts in Czech Republic.

Figure 5

Deliveries of cars to customers of Skoda Auto a. s. by region



Source: annual reports of Skoda Auto a. s.; own compilation.

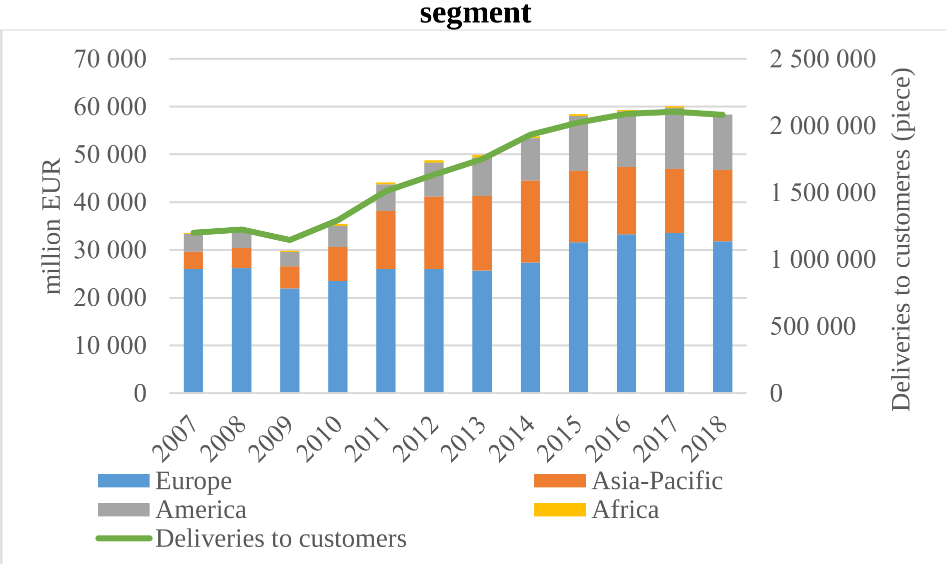
In point of view of Hungarian industry, Audi Group and Daimler Group have an important role. We investigated which regional demand fluctuations can affect the Hungarian economy. It is true for both companies that most of their sales have the direction to Asia (China) and the total growth seems to be stagnate or decrease slightly.

We are aware that the total sales is the sum of all divisions of the OEM, but it was impossible to determine the sales of car production division in regional breakdown. We believe this does not cause a significant distortion in understanding global processes.

According to the Figures 6 and 7, Audi Group and Daimler Group have a strong relationship to the market of Asia and America. Events in these markets influence the performance of the parent company, its subsidiaries together with Tier-1 suppliers in CEE.

Figure 6

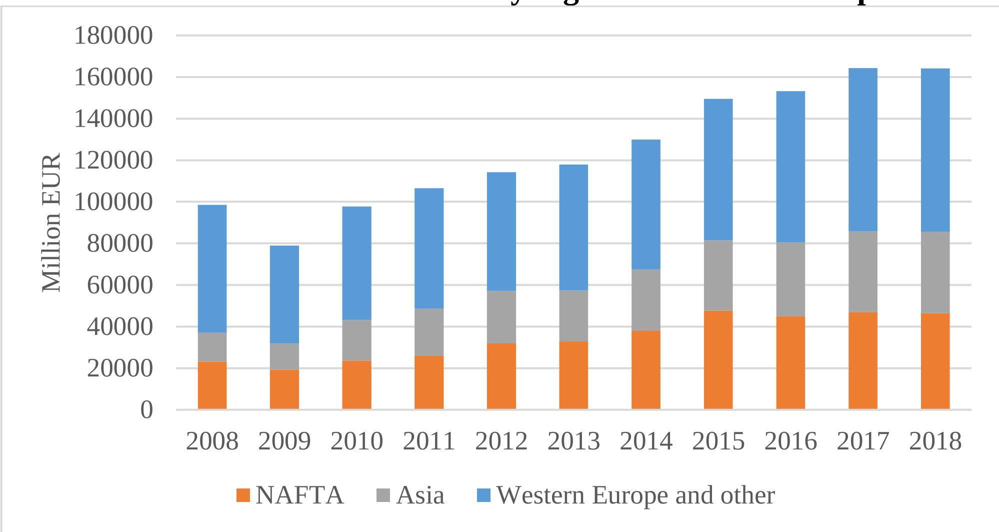
Total sales revenue by region of Audi Group and deliveries to customers in automotive segment



Source: annual report of Audi Group; own compilation.

Figure 7

Total sales revenue by region of Daimler Group



Source: annual report of Daimler Group; own compilation.

We argue that general overview of consolidated annual reports of MNEs is useful to understand the trends. To what extent and how fast can expected effect influence GDP of a country, it is discussed in the following part.

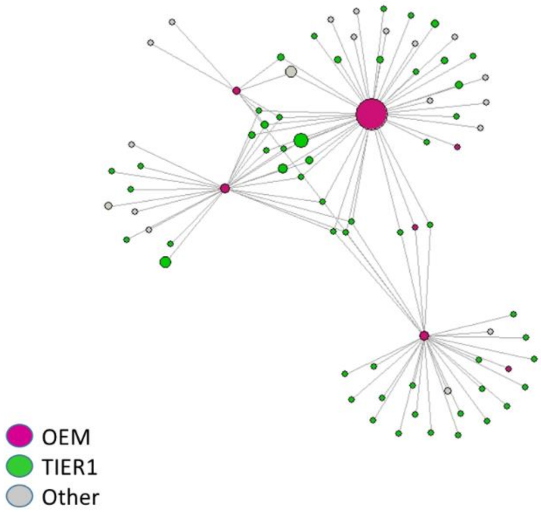
4.2.General overview of the automotive industry network in Hungary

The Hungarian automotive network consists of OEMs, Tier-1 and Tier-2 suppliers and it has connection with other industry such as electronics industry also. However, the detection of Tier-1 suppliers and the compilation of the database took a lot of effort, so the analyses had to be narrowed down to OEMs and Tier-1 suppliers. In the future, we would like to look into an expanded network with Tier-2 suppliers also (Pinkasz and Ritzlné Kazimir, 2019).

The examined network in Hungarian automotive industry in 2017 is presented in Figure 8. We analysed the network for all years of the period 2015-2018, but there was no significance change neither in structure nor in companies. The automotive network in Hungary is **not scale-free**, and there are **one-way links** between the corporations. The OEMs and Tier-1 companies constitute a **disassortative** network because the centres have not direct relationships among them, but they are connected only through Tier-1 companies.

Figure 8

The analysed Hungarian automotive network in 2017 (size of nodes by GVA)

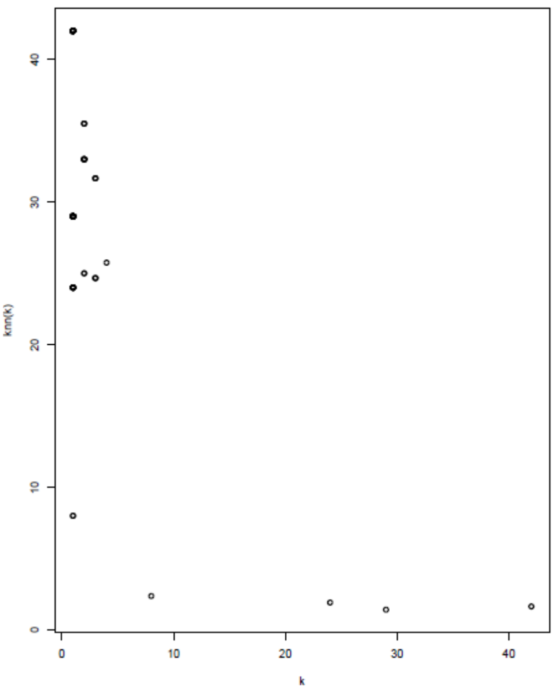


Source: own compilation.

The presence of disassortativity should be tested. Using the assumption (4), the degree correlation function is calculated for our network presented with software R. It can see in Figure 9 that $k_{nn}(k_i)$ is a decreasing function of k, which underlines the nature of the network. According to the assumption (5), the Pearson correlation coefficient is -0.81 that confirms the presence of the strong disassortavity in this network.

Figure 9

Degree correlation function

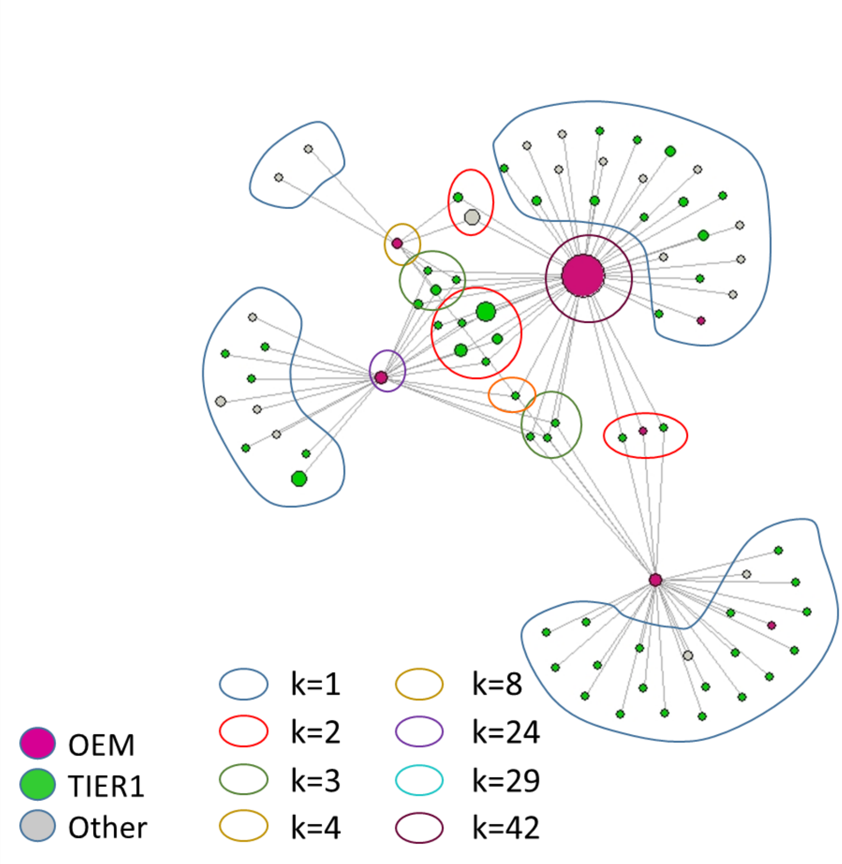


Source: own calculation.

The degree distribution should be analysed also in order to understand the nature of nodes and links. The Figure 10 illustrates with different colours how many links have the nodes, that is, what is the degree of each node. The most Tier-1 companies have only one edge, in this case k=1. Only a few companies are suppliers to two or three OEMs, that is, k=2 or 3. The OEMs have a lot of edges, k is more or equal 8. One of the OEMs in automotive industry has more than forty links (k=42). Figure 11 presents the accurate degree distribution of the automotive network in Hungary in 2017. It can see that the more than 70 percent of the nodes have only one connection (with one OEM).

Figure 10

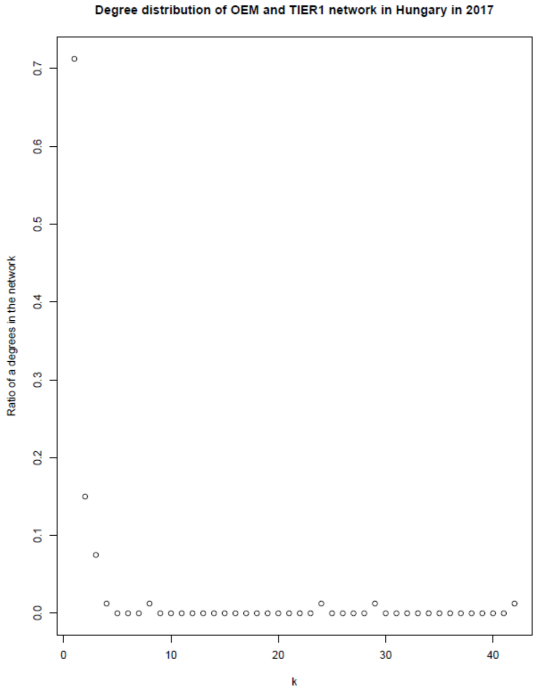
The Hungarian automotive network in 2017



Source: own compilation.

Figure 11

Degree distribution of analysed Hungarian automotive network in 2017



Source: own calculation.

In order to model the spread of an economic shock, the probability of spread β should be determined. As first step, cross-correlation between one OEM and individual Tier-1 suppliers were analysed with software EViews. The value of the delay was determined for each connection. Using the average monthly sales of each company to OEM as weights, the weighted delay for each OEM was calculated.

$$\beta_i = \frac{\sum_{l=1}^{n}(average\ monthly\ sales_l \cdot lag_l)}{\sum_{l=1}^{n} average\ monthly\ sales_l} \tag{9}$$

where l is the number of suppliers of OEM i.

Table 4 presents the calculated β values for each OEM.

Table 4

Calculated β values of OEMs

OEM (Node)	Beta
k=42	0.36
k=24	0.55
k=28	0.95

Source: own calculation.

As already mentioned, it must be considered how immune a company is. Immunity depends on the percentage of sales that a company makes to an OEM. If this ratio is high, that supplier is more exposed to the effects of OEM sales. These ratios can be considered as the probability of infection that is the empirical density function. If this ratio is considered to be nearly constant over short period.

4.3.Spread of economic shock

The main question is for a country or a region to what extent an economic shock of an OEM will affect the GDP through the network?

The role of β is very important, because probability that an infected individual will transmit the disease to a susceptible person within one unit time depends on the type of the infection. Some example illustrates in the Table 5 that different infectious diseases have different reproduction basic numbers (R_o) which gives the average number of people infected over a period of time by a person while being high infectious. R_o is directly proportional to the probability of spread β.

Table 5

The reproduction basic number for several diseases

Disease	$\boldsymbol{R_o}$
Measles	12-18
Whooping cough	12-17
Diphtheria	6-7
Black pox	5-7
Polio	5-7
Roseola	5-7
Mumps	4-7
HIV/AIDS	2-5
SARS	2-5
Flu	2-3

Source: Barabási 2016: 401.

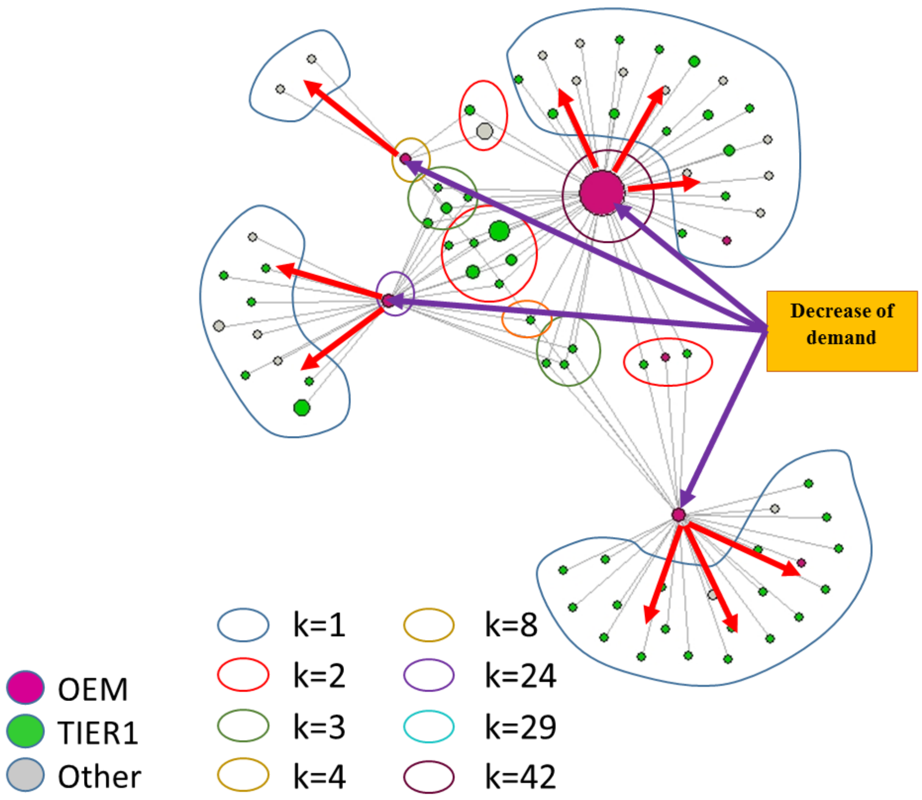
By analogy to diseases, we can argue that different shock effects have different probability of spread β. **Four types of threatening concrete "diseases"** are distinguished that can affect the above presented network of OEMs and Tier-1 enterprises in Hungary.

1. General crises – Decrease in demand
2. Change of product structure e. g. caused by the regulation of carbon dioxide emissions
3. Introduction of new products e.g. hybrid and electric cars with the effect on appearance of new suppliers and on change of the network
4. Restructuring of global value chain with the impacts on regional markets

These are just basic “diseases”, but it can occur the combination of these types, see the Diesel scandal in Volkswagen Group in 2015. This event caused in long run a change in product structure and in short term, a decline in demand due to changes in regulation and consumer preferences.

Figure 12

Illustration for spread of a potential economic shock in the Hungarian automotive network



Source: own compilation.

Diesel scandal in Volkswagen Group in 2015 is mentioned as a complex “disease”. Let’s go through this case step by step in order to understand this event and its effects!

On 21 September 2015, Volkswagen attacked by the American Environmental Protection Agency admitted to manipulating the engine software of some its diesel cars. The software produced much more favourable emission figures during tests than in real use. The trick affected all types produced by the Volkswagen Group, including Audi and Seat. Half a million of the counterfeit Audi engines were made at the factory in Győr, in Hungary. Martin Winterkorn, the leader of Volkswagen, and about then other high-level employees fell into the scandal which affected 11 million cars. The vast majority are in traffic in Europe. Volkswagen undertook the repair at his own expense.

GVA effect: One of most interesting question by an economic change is the impact on the affected industries, sectors and the total economy. In the most simplified analysis, the effect on GVA can be calculated by the following steps.

Effect on own GVA: The direct effect of change of OEMs sales to their input demand and their GVA can be calculated utilizing by the assumption, that the technology is constant in short term, and the inputs cannot be substituted by each other. The above production function allows the calculation of production coefficients by the next formulas:

$$effect_i^{GVA} = \frac{output_i}{totalsales_i} \cdot \frac{GVA_i}{output_i} \tag{10}$$

Effect on GVA of suppliers

$$effect_i^{inputdemand} = \frac{output_i}{totalsales_i} \cdot \frac{IC_i}{output_i} \cdot \frac{domesticpurchases_i}{totalpurchases_i} \tag{11a}$$

$$effect_l^{GVA} = effect_i^{inputdemand} \cdot \frac{salestoOEM_l}{GVA_l} \tag{11b}$$

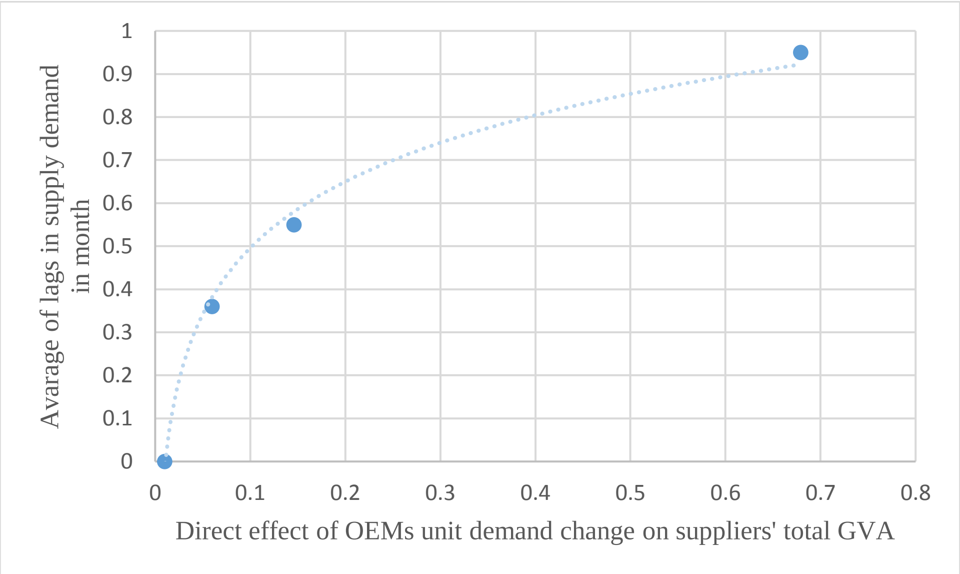
where i means the OEM, the l is the supplier, IC is the intermediate consumption. The ratio $effect_i^{GVA}$ is the effect of unit change of OEM's sales on the own GVA. The ratio $effect_i^{inputdemand}$ shows the results of unit change of OEM's sales on its input demand, while the $effect_l^{GVA}$ means the impact of unit change of OEM's (i) sales on the supplier's (l) GVA.

The result spreads between 0.1 and 0.33 according to OEMs' input demand and the GVA effect between 0.07 and 0.6. In the paper of Ritzlné et al. [2016], it was shown that the demand ratio for total domestic supply of motor vehicles industry was 13% in 2010 according to the Input-Output tables for Hungary. This result may prove the applicability of VAT data.

The following figure includes the average lags and the total GVA effect on suppliers GVA.

Figure 13

Relation between the average lag in production and direct effect of demand on GVA of Tier-1 companies



Source: own editing.

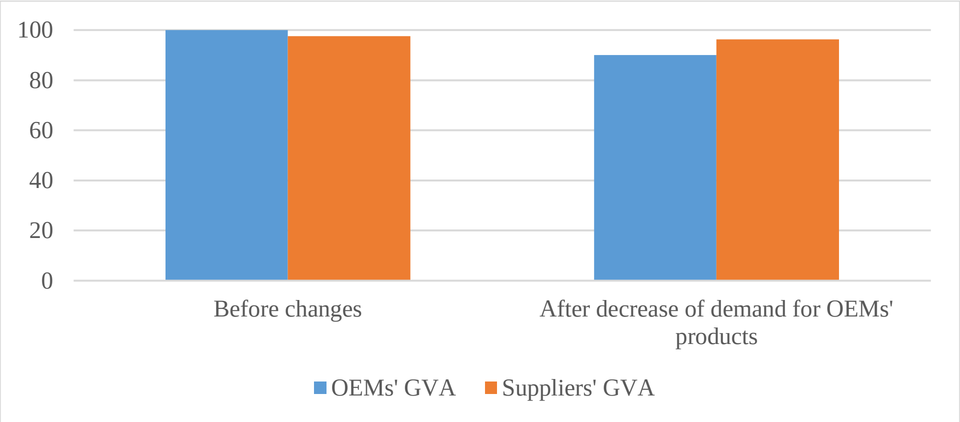
In the Figure 13, the strong relationship can be assumed between the average lag in supply chain and the total direct effect of OEMs' unit demand change on suppliers' total GVA. This phenomena can occur because of the different levels of embeddedness in the domestic economy and therefore, because of the different strategies for purchases. The lower part of above curve on Figure 13 refers to a just-in-time production and inventory management method.

The connection between time in month and GVA is not worth to been analysed, because the most changes occur in the same month, the potential crisis spreads of immediately. The GVA of OEMs' suppliers decrease at smaller extent than in case of OEMs. Therefore the shocks have larger effect on OEMs than on their suppliers. This phenomenon is shown in the Figure 14, the example includes the effect of 10% decrease in final demand of OEMs on GVA in Hungary.

Figure 14

The effect of 10% decrease in final demand of OEMs on GVA

(OEMs' GVA before changes = 100)



Source: own calculation.

5. Discussion

In the analyses of Hungarian automotive industry emerged several questions about the spread of economic shocks. The following list includes the most significant among them which can be focused in next researches.

1. Can the disassortativity be a measure of competition intensity?
2. How disassortative is the network in other countries or markets?
3. How can affect the economic shocks on other areas than gross value added, can it be transmitted through decrease of employment to other industries (e.g. retail trade or personal services)?
4. How can spread an economic shock in different levels of supplier chain relating to employment?
5. How does the automotive cluster differ in other countries of Central and Eastern Europe from the Hungarian structure?

6. Conclusion

In our analysis, we detected of the OEMs and their significant suppliers in the Hungarian part of the global automotive value chain. The graph of their relationships helped us to understand the structure of industry. The analysis of the strength of their relations and the detection of lags promoted the understanding of spread of economic shocks.

We drew an analogy between the spread of diseases in society and spread of economic shocks in economic transactions. We found that the spread depends on the topology of network, the probability of disease in unit time. We calculated the reaction time between the change in final demand of OEMs and their suppliers' sales, in addition, the effect of change on GVA in both level.

We analyzed also the market risks of the significant OEMs in Central and Eastern Europe in the last years in order to detect potential exposure to a crisis. These companies are strongly connected to the world market relating to sales, especially to European, Asian, and North-American markets. We realized a significant shift in sales toward the Asian and North-American markets after the financial and economic crisis in 2008/10. The growth rate of the sales decreased slightly and turned in stagnation in the last two years, so a potential – and we think forthcoming – crisis might be induced from the demand side of OEMs.

Our future plan includes the extension of the network with the next levels of the supplier chain (Tier-2, Tier-3). In addition, we plan to continue the formalization and the extension of epidemic spread model to extended automotive network. Finally, the shocks have different impact on GVA and employment as it is illustrated in Figure 3, because the smaller companies have relative higher share in employment than in GVA. Therefore, a potential crisis decreases lesser the GVA than the employment. So, the indirect effects of crisis in automotive industry may cause larger decrease in GDP through decrease of consumption.

References

Barabási, Albert-László (2016): *A hálózatok tudománya*. Libri. [In English: Idem (2018): *Network science.* Cambridge University Press.]

Feenstra, Robert C. (1998): Integration of Trade and Disintegration of Production in the Global Economy. In: *Journal of Economic Perspectives*, 12(4): 31–50.

Gereffi, Gary and Miguel Korzeniewicz (eds) (1994): *Commodity Chains and Global Capitalism.* Praeger.

Gerőcs, Tamás and András Pinkasz (2019): Relocation, Standardization and Vertical Specialization: Core–Periphery Relations in the European Automotive Value Chain. In: *Society and Economy*, 41(2): 171–192.

Humphrey, John and Olga Memedovic (2003): *The Global Automotive Industry Value Chain: What Prospects for Upgrading by Developing Countries.* UNIDO.

Pastor-Satorras, Romualdo and Alessandro Vespignani (2001): Epidemic Spreading in Scale-Free Networks. In: *Physical Review Letters*, 86(14): 3200–3203.

Pinkasz, András and Ildikó Ritzlné Kazimir (2019): Profiling of the Hungarian Participation in the Global Automotive Value Chain. Paper presented in Group of Experts on National Accounts: Measuring Global Production, Geneva, 11 April 2019. Available: https://www.unece.org/fileadmin/DAM/stats/documents/ece/ces/ge.20/2019/mtg1/Hungary.pdf.

Ritzlné Kazimir, Ildikó, Bálint Murai, Klára Anwar, Anikó Száraz and Anikó Salamon (2016): Analysis of Productivity Trends in 'Manufacture of Motor Vehicles' Industry in Hungary Between 1995 and 2014. Paper presented in IARIW 34th General Conference, Dresden, 21–27 August 2016. Available: http://www.iariw.org/dresden/kazimir.pdf.