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Ildikó Ritzlné Kazimir

(Hungarian Central Statistical Office)

Klaudia Máténé Bella

(Hungarian Central Statistical Office)

Tímea Cseh

(Hungarian Central Statistical Office)

András Pinkasz

(Hungarian Central Statistical Office)

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Analysis of the development of the automotive cluster by network analyses methods and its impact on employment between 2015 and 2019

Ritzlné Kazimir, Ildikó - Máténé Bella, Klaudia - Cseh, Tímea, PhD - Pinkasz, András
(Hungarian Central Statistical Office)

Corresponding author: ildiko.ritzlne@ksh.hu

The multinational enterprises' (MNE) activity influences the receiving economies differently depending on the division and position in the global value chain and their ownership (domestic or foreign). The divisions operate by different labour and capital (physical capital or intellectual property) intensive technology. Moreover, the enterprises in the different levels of global value chain can be characterized by different labour intensive production.

It is particularly interesting from point of view of income and wealth distribution in the case when the MNE has foreign ownership. Therefore, it is important to analyse which is the proportion of wages and salaries and operating surplus in the gross value added (GVA) from income side. If the employment of MNEs is significant, then the wages and salaries increase the domestic consumption and saving. We have the assumption that the labour intensity grows moving down in the supplier chain. Therefore, the MNEs decisions influence the GVA and the employment differently depending from their supplier chain and technology. This hypothesis is proved in our research for the Hungarian automotive supplier chain.

To test this hypothesis, we applied the next method and data. From the VAT databases, we detect the supplier chain of Hungarian automotive industry, we identify the OEMs, the TIER1 and TIER2 enterprises and their suppliers. We analyse these enterprises from network aspect, identify the important nodes from point of view of GVA and employment. The embeddedness and the inventory management method determine the impact of OEM's decision on supplier chain relating to speed of spread and measure of effect.

The effects of exogenous shocks on employment which are arisen by the decision of OEMs, can be forecasted by network analyses method. Our latest research focused on the spread of exogenous shock in Hungarian automotive industry relating to GVA. We drew an analogy between the spread of diseases in society and spread of economic shocks in economic transactions. In this paper, we extend the developed model for automotive network to employment.

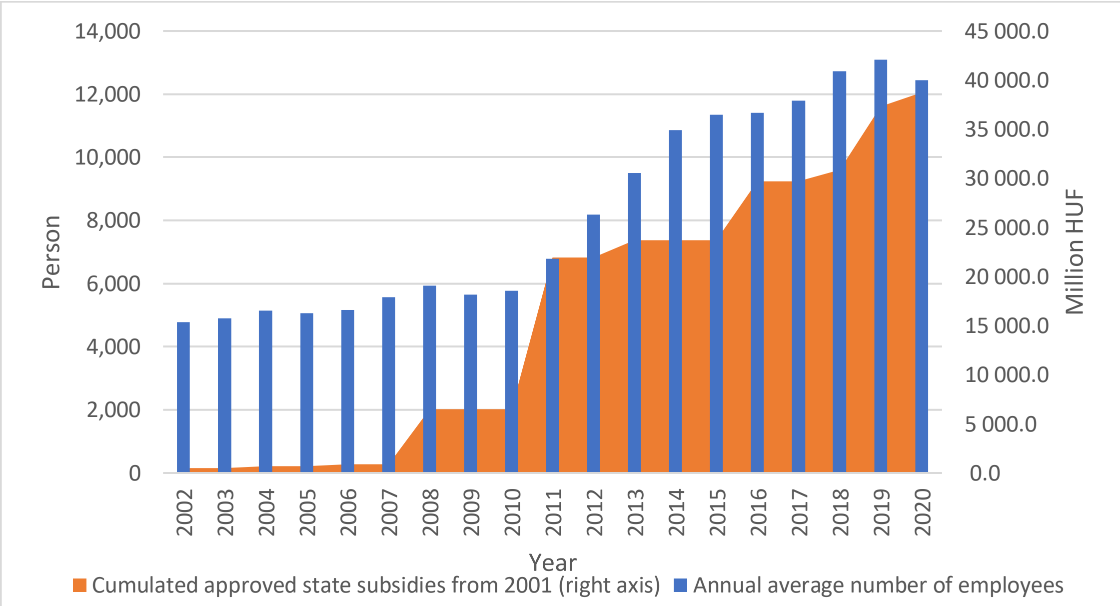
The exogenous shock has a greater impact on employment than GVA in Hungarian automotive industry. It is important because the change of income through employment cause a different adjustment process, as the level shift in GDP. The main objective with this project is to improve the knowledge about the large automotive companies and their value chains in order to understand and forecast their complex effects on national accounts, which is particularly important nowadays, when the automotive industry faces a turning point of global trends and new technological challenges.

1. Introduction

OEMs play an important role in Hungary. Audi (Audi Hungaria Motor Kft., from 2017 Audi Hungaria Zrt.) was established in 1993 in Hungary, in town Győr. Corporate headquarter selection was influenced by various tax benefits and government subsidies.

Audi has received state subsidies on a number of occasions based on individual government decisions. A significant part of the subsidies was related to new investments which caused an increase in employment. The following figure illustrates the development of average annual number of employees and the cumulated state subsidies from 2001. Subsidies were allocated to the year in which the budget was approved by the government.

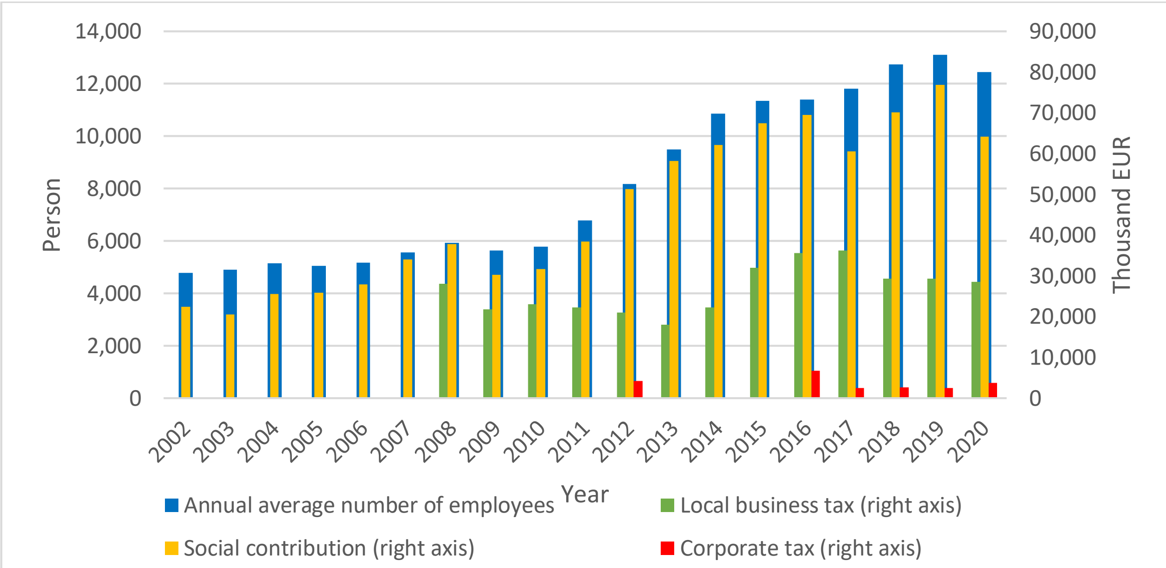
Figure 1: The development of average annual number of employees of Audi and the received, cumulated state subsidies



source: own elaboration, annual reports of AUDI

The company was exempt from paying corporation tax until 31 December 2011, but after 2011, based on the different allowances, the effective payable corporate tax was low. Between 1993 and 2007, it did not have to pay local business tax and building tax. Between 2007 and 2014, it was able to offer a certain proportion of business tax to sports and cultural associations in the city, as well as sports, cultural and public cultural, health and educational institutions, and for environmental purposes. After 2007, the business local tax became a significant financial source of the municipality of Győr. Relating to the increase of employment, Audi was a significant contributor to the budget through the payment of social contributions.

Figure 2: The development of the main contribution of Audi to the budget

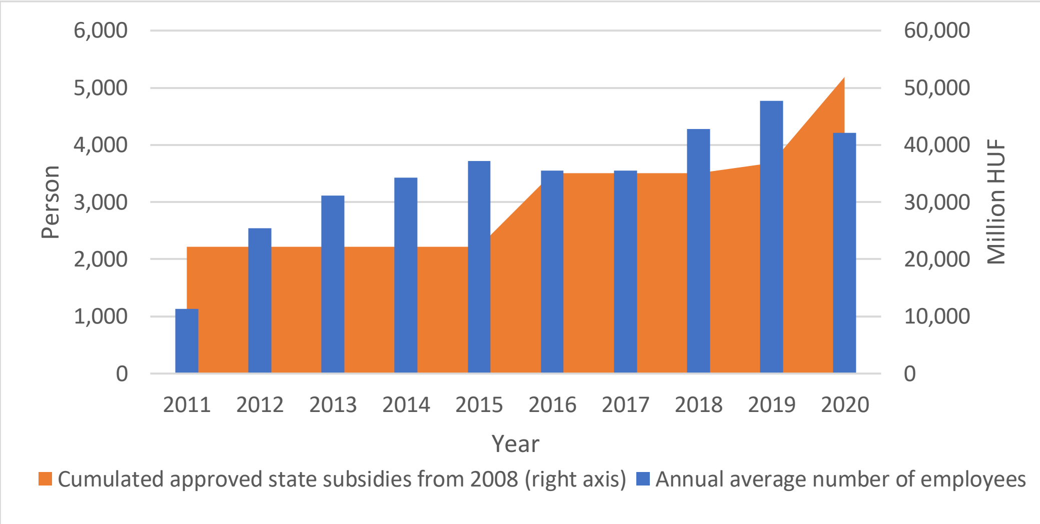


Sorce: own elaborations, annual reports of AUDI

Based on the figures above, we can conclude that the employment increased 2.6 times between 2002 and 2020. Máténé Bella and Ritzlné Kazimir (2021) investigated using a structural equation model the relative development of counties in Hungary between 1994 and 2016. They argued that the employment is an important indicator which influences the relative development of a region. The infrastructure, the cultural and sport facilities are also important factors influencing well-being of a region which can be financed from local business tax. The county of north-western Hungary, Győr-Moson-Sopron was ranked 6th in the Hungarian counties, while in 2016 it was already ranked 3nd based on the latent variable of SEM.

Another important OEM, Mercedes (Mercedes-Benz Manufacturing Kft.) was established in 2008, but the production started only in 2012. The company received state subsidies in 2008, 2016 and 2020 relating to new investments. The average number of employees was approximately 4000 in 2020 which made it a key employer in the region, in the county Bács-Kiskun. Unfortunately, we could not collect data regarding local business tax paid in the corporate headquarter, in town Kecskemét, but similar to the Audi, we can realise a significant improvement in the relative development of this county. According to Máténé Bella and Ritzlné Kazimir (2021), Mercedes could change the relative advantage of the region as much as Audi. The county Bács-Kiskun was ranked 8th in the Hungarian counties, while in 2016 it was already ranked 6nd based on the latent variable of SEM.

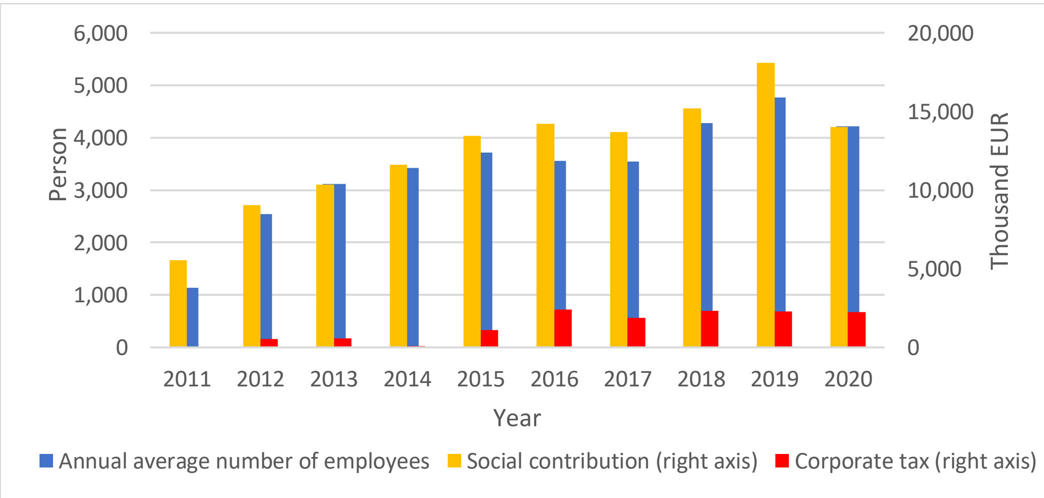
Figure 3: The development of average annual number of employees of Mercedes and the received, cumulated state subsidies



Sorce: own elaborations, annual reports of Mercedes

However, the Mercedes received the approximately similar amount of subsidies as the Audi, it do not have similar number of employees. This can contribute to the above mentioned effect on the relative development. The Figure 4 shows the development of employees of Mercedes and its contribution to the budget. Similarly to the Audi, the Mercedes contributed also at low level to the state budget by the Corporate tax. The both companies contributed significantly to the state budget according to the Social contribution based on the wages and salaries.

Figure 4: The development of the main contribution of Mercedes to the budget



Sorce: own elaborations, annual reports of Mercedes

The main aim of the significant state subsidies was to promote the embedment of the automotive cluster in Hungary. It was supposed, that the OEMs would redound the suppliers of OEMs in Hungary. The embedded part of the automotive global value chain in Hungary will increase the employment and GDP through the direct and indirect effects of its derivative demand.

Nevertheless the automotive network in Hungary is only the part of automotive cluster of Eastern and Central Europe, and this cluster is organically involved in the global automotive value chain. Therefore, the following questions should be investigated.

- How are the multinational companies, which are the part of the automotive value chain, connected to the enterprises of the domestic economy?
- How does an effect of exogenous shock spread through the economy?
- How does the change of derivative demand influence the employment in Hungary?

An obvious tool to analyse the input requirements of one unit increase in final demand or in output is the models using Input-Output tables. We calculated the input multipliers from the Hungarian Input-Output tables. We argue that this type of modelling is less suitable to answer the above questions. Therefore, we developed a new method based on individual transactions derived from the VAT database, which allows to distinguish the TIER1 companies according to the database developed by us. (Pinkasz, Ritzlné Kazimir, 2019) This method includes the compilation of transaction network database, the calculation of direction of causality and the time series analyses of relations.

2. Literature review

The highly globalized world economy have significant effects on the national economies, as well, however, these effects are hardly quantifiable. Our research started in 2015 in the Hungarian Central Statistical Office (HCSO) focused on quantifying and analysing the automotive industry of Hungary. (Ritzlné et al. 2016) Due to the limitation of the Input-Output tables a development of a new method was started in 2018. The Input-Output tables are available late, in the third year after reference period and they are published only in all five years.

The first step of our research included the compilation of a TIER1 database, which contains the TIER1 corporations operating in Hungary, their parent company, and the country to where the given company is connected. (Pinkasz, Ritzlné Kazimir, 2019)

Using the available individual data, the research aimed at the selection of the best suitable method of network analyses. The model used the epidemic spread model for individual companies was built in 2019 on the basis of the models described by Barabási (Barabási, 2018) and was presented at the Special IARIW-HSE Conference in Moscow. (Máténé Bella et al. 2019)

In this paper the directed transaction network are analysed, where the direction are determined by the causality of the relations. This approach less generalizes the spread of shocks, allows for more accurate analysis.

The diffusion of shocks in a network is analysed in several studies. These shocks can be not only relating to national or global economies, but also other types of network, e.g. ecommerce network.

Carmi et al (2009) analysed the diffusion of demand shocks in an ecommerce recommendation network. The shocks were generated by book review on the Oprah Winfrey Show and in the NYTimes, and the recommendation network is generated by Amazons's copurchase network. They founded a high level of diffusion of exogenous shocks through networks based on calculated measures relating to magnitude of the shocks, the network structure and the link parameters. An average of 40% of neighbours, even 4 clicks showed a statistically significant increase in the demand level.

As result of the increasing trade and globalisation, several studies adopt the network science approach to quantify the shocks on the global economic network.

Peckham (2013) examined the use of contagion as a model for assessing the spread of infection of H1N1 in 2008 and the diffusion of financial shocks in 2007-2008. They argue that this analogising is important for understanding the financial contagions in the interconnected global environment.

Acemoglu et al (2015) developed a framework in order to study the network interactions. They showed, how microeconomic interactions function as a channel for the propagation of different shocks. Based on their results, it is argued that the impact of network structure depends on the properties of the economy's Leontief's matrix corresponding to the underlying interaction network. The Leontief matrix is usually used in analysis of Input-Output tables, but they argue that this matrix can be used for all possible direct and indirect effects of interactions between any pair of agents.

Starnini et al (2019) proposed a model to describe how economic distress propagates between connected countries. The shocks can be driven by different domestic or exogenous factors, such as political instability, fiscal contraction, banking crises, etc. They assumed that shocks cause a reduction on aggregate demand in an epicenter country. They proved that the inter-country propagation dynamics is non-linear. This systemic impact is connected to intra-layer and inter-layer network multipliers that are independent of the magnitude of the initial shock.

Sebestyén and Iloskics (2020) analysed the topological properties of the economic shocks contagion network by pairwise Granger causality between economic outputs of countries. Their results showed that the density of the analysed network moved between 10 and 20% which is relatively high. An average country is exposed to shocks from one sixth of the economies.

They founded that disregarding crisis periods, shock contagion follows show a cycle pattern. The connectedness decreased over the previous decades until the first decade of the 21st century. The authors argue that there is a systematically existing contagion path in 16% of all possible connections. However, they did not find significant association between economic openness and exposure to shock transmission in either direction.

3. Data

In the research individual administrative data and the data of symmetric Input-Output tables (IOTs) are used. In this section the compilation process of database is described, and the main features of data are shown. The data of symmetric IOTs are available at the homepage of HCSO. For the research, the symmetric IOT for domestic output (industry by industry) at basic prices was used. The symmetric IOTs are prepared in Hungary only by five years, therefore the IOT could be downloaded for the reference year 2015.

3.1. Compilation process of dataset

For the research two datasets were compiled. The used data sources included the Business Register of HCSO, the VAT return database, the database of social contribution returns, and the self-developed database about the OEMs and TIER1 enterprises of automotive value chain operating in Hungary. (Pinkasz, Ritzl-Kazimir (2019))

The registration number and the NACE Rev. 2.2 data of individual enterprises were used from the Business Register of HCSO database.

Regarding the VAT return data, the enterprises in Hungary can submit their VAT return data in different frequencies. The main rule is determined according to their turnover data, depending on the turnover the enterprises should be submitted their VAT return data at annually, quarterly, or monthly basis. The enterprises subject to annual or quarterly reporting obligation are relatively small companies in general, but there are also exceptions regarding the VAT law, which allows a quarterly return frequency for companies selling exclusively for export. Large, multinational companies are the ones that can typically take advantage of this opportunity, and such enterprises also occur in the automotive industry. Therefore, quarterly time series were generated for the study.

The data compilation process utilised the data for purchases and sales at individual enterprise level. The sales and purchases data were calculated from the variables of VAT return data because VAT return database was not contained that information directly.

In addition, the Hungarian VAT return data includes information about the transactions between the enterprises. The additional declaration of VAT return must be contained the data about purchases by partner if the purchase exceeds the HUF 100 thousand during the reference period. These data let be determined the transaction network of enterprises involved in the domestic automotive value chain.

The data compilation process also utilised the employment data from the social contribution database. In Hungary, the enterprises must be reported the number, composition of their labour input, and must also declare the data of wages and salaries and social contribution by persons at monthly frequency. Using these data, the quarterly employment data in persons by enterprises were calculated by the average of monthly employment figures.

The automotive value chain is represented on several levels in Hungary. The first step of the data compilation process was the identification of the OEMs (Original Equipment Manufacturer). Their sales and purchase were queried from the VAT data base, and to these data were merged the purchases by domestic partners, the information, which partners included in the TIER1 level of the automotive value chain, and their employment data.

In the second step the suppliers of OEMs were identified and the classification for TIER1 and other enterprises were also available. Using the list of these enterprises the second level of automotive suppliers were identified utilising the transaction level VAT return data. In this step the sales, purchases and employment data were queried to first level of automotive suppliers, in addition to this dataset were merged the purchases from the enterprises at the second level in value chain. Finally, the employment data of enterprises at the second level in the value chain were merged to the dataset.

The merged data are available at individual level. To the further analysis the individual dataset was aggregated by NACE category of suppliers and purchasers, TIER1 classification and year, quarter.

The prepared dataset included data at current prices. Time series analyses should not be prepared on current price data. The appropriate price indices of sales were not available, therefore the implicit price indices of output from the National Accounts database were applied to calculate the data at constant prices.

4. Method

The illustration of connection between industries our paper presents a new, alternative analysis. The connections – network – between enterprises or between industries or products are examined in this paper based on transaction network using administrative data. This analysis allows the development of purchases at high frequency (quarterly) data. To this analysis there are applied a time series model.

The general equilibrium models based on the IOTs also are also appropriate tool to draw the transactions between industries or products. This approach assumed linear relationship in the technology, especially most of the models built on the Leontief technology. The disadvantage of this method is that the required data are compiled for every fifth year in Hungary.

This chapter of the paper described the applied time series model and the linear Input-Output models.

4.1 Network analysis

The research applies the tools of network analysis. A network stays nodes and links. The network can be determined by the list of links between the nodes, this list can be summarized in an adjacency matrix, which is a square matrix used to represent the whole network. Using the list of the links or the adjacency matrix.

In our analysis the nodes are the industries related to direct or indirect links to the automotive industry or automotive value chain. The nodes are connected to each other through the input demand.

4.2 The linear model

The linear model applied on the methodology of Leontief models. The linear models assumed that the production function is a linear Leontief production function in all industries, the substitution is excluded, and the inputs are used in fixed ratio.

The starting point for model is the symmetric IOTs, which include the domestic use matrix, the output vector, the value added section and final demand vector. The element of domestic use matrix x_{ij} means the flow of domestic commodity i to sector j.

The Leontief equation system is described by the following form:

$$Ax + y = x \tag{4.1}$$

where A is the symmetric input-coefficient matrix in order n, its element a_{ij} equals to the ratio of intermediate consumption from industry i in industry j and the domestic output of industry j, $a_{ij} =$

x_{ij}/x_j. The vector x is the column vector of domestic output, while y is the column vector of final uses, which is an exogeneous variable in this system.

The solution of the Leontief equation system is:

$$x = (I - A)^{-1}y \tag{4.2}$$

In the above formula I is the identity matrix of order n. The matrix $(I - A)$ is the Leontief matrix. Its diagonal element $(1 - a_{jj})$ shows the so-called net-output of industry j. The other, non-diagonal elements mean the input requirements. The inverse of Leontief matrix is the Leontief inverse, its elements represent the direct and indirect input requirement of output for final uses.

The output multipliers are calculated from the Leontief inverse by the form $\sum_{i=1}^{n} a_{ij}$. By other words, the input multipliers are sum of direct and indirect input requirements for unit of final use in the given industry.

Using the Leontief inverse the employment multipliers can be calculated by the next form:

$$Z = E(I - A)^{-1} \tag{4.3}$$

where matrix E represents the matrix of input coefficients for labour, and Z includes the direct and indirect requirements for labour. (United Nations, 2018)

The required labour input for producing a unit of output can be calculated by the following formula:

$$R = e(I - A)^{-1} \tag{4.4}$$

where R means the row vector of required labour input by industries for a unit of output, e is the row vector of labour coefficients, whose element is calculated by the following formula as the ratio of employment and output in industry j.

$$e_j = \frac{employment_j}{output_j} \tag{4.5}$$

An Input-Output system describes a network, as well. The industries are the nodes in the network and the elements of Input-Output tables determines the edges between the nodes, so the tables can be used as the adjacency matrices of the network analysis. (Rodrigues et al. 2013) The input coefficients mean the direct connections between the industries. In addition, the indirect connection can be detected using the coefficient matrix. When the coefficient matrix has only non-zero elements, all the industries have direct connections to each other, the tightness of this connection depends on the input requirements though. The Leontief inverse represents the direct and indirect connections between the industries, so the adjacency matrix from the Leontief inverse includes the links which appears at any level of the transaction network.

The value chains in a particular economy cannot be mapped fully using the Input-Output tables, because the Input-Output tables contain the aggregated data, where the different chains and levels are sum up. Due to its static terms, the diffusion of an external shock cannot be followed through the network.

4.1. Granger test

The Granger causality test, which was first proposed by Granger 1969 (Granger, 1969) is a statistical hypotheses test for specifying whether one time series is worth using in forecasting another. Generally, the variable z is the Grager-causes variable y if

$$E(y_t|I_{t-1}) \neq E(y_t|J_{t-1}), \qquad (4.6)$$

where I_{t-1} contains past information on y and z, and J_{t-1} contains information on past y. When (4.1) holds, past values of z are useful for predicting y_t. (Wooldrige, 2014)

A linear model is assumed included pre-determined lags of y in $E(y_t|y_{t-1}, y_{t-2},)$, and the null hypotheses that z does not Granger-cause y is tested.

To be more specific, suppose that y and z are stationary time series. To test the null hypotheses, two steps are necessary. First, the proper lagged values of variable y should be found for univariate autoregression of y.

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_m y_{t-m} + error_t \qquad (4.7)$$

where a_i is the coefficient of lagged value of y_{t-i}, a_0 is the constant value in the equation. In the next step, the autoregression model of y is extended by including lagged values of z, when

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_m y_{t-m} + b_1 z_{t-1} + \cdots + b_q z_{t-q} + error_t \qquad (4.8)$$

where b_i is the coefficient of lagged value of z_{t-i}. All lagged values of z that are individually significant according to their t-statistics, are retained in regression when collectively they add explanatory power to the regression according to an F-test (whose null hypothesis is no explanatory power jointly added by the z's).

It would be remarked that the software Eviews was applied to the recent analyses, and it runs bivariate regressions of the form (according to the User's Guide of Eviews 11):

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_q y_{t-q} + b_1 z_{t-1} + \cdots + b_q z_{t-q} + error_t \quad (4.9)$$

$$z_t = a_0 + a_1 z_{t-1} + a_2 z_{t-2} + \cdots + a_q z_{t-q} + b_1 y_{t-1} + \cdots + b_q y_{t-q} + error_t \quad (4.10)$$

for all possible pairs of (z, y) series in the group. The reported F-statistics are the Wald-statistics for the joint hypothesis: $b_1 = b_2 = \cdots = b_q = 0$ for each equation. The null hypothesis is that z does not Granger-cause y in the first regression and that y does not Granger-cause z in the second regression.

4.3 The time series model

The relationship between time series were examined by the Granger test. If the causality between two series was justified, a time series model was fitted. The equation in this model was described by the following equation.

$$emp_{j,t} = c + \sum_{k=0}^{t-z}(b_k \cdot sales_{ij,t-k}) + dummy_s + ar(p) + ma(q) \quad (4.11)$$

where $emp_{j,t}$ means the number of employees in industry j and quarter t. The coefficient c is the constant, $sales_{ij,t-k}$ means the sales from industry j to the industry at higher level in the transaction network (industry i) at constant prices while $k \geq 0$ is the lag. The variable $dummy_s$ is the seasonal dummy, which has unit value in the quarter s. The order of autoregressive process is p, the order of moving average process is q.

5. Results

In the research in the first step the Leontief inverse and the multipliers were calculated, and there was drawn up a reduced network of domestic economy using input coefficients. The next step the transaction network was determined and analysed as a whole and partitioned by TIER1 classification. The transaction network is available in time series breakdown as well, therefore the Granger causalities were calculated at all possible relation. Finally, time series models were fitted to the relations for which the Granger causality justified the statistically significant relationship.

5.1 The employment effects according to the Input-Output tables

Using the Input-Output tables the employment multipliers were calculated for the year 2015. The input requirements changed compared to the previously published Input-Output tables of 2010. The most important direct suppliers for Manufacture of motor vehicles industry were the same industries, the Manufacture of rubber and plastic products and the Manufacture of fabricated metal products industry according to the Input-Output tables. The Wholesale trade industry has to be mentioned as well, which was the fourth most significant industry among the suppliers. The next table includes derivative demand data for the most significant three industries:

Table 1: The input requirement for a unit output

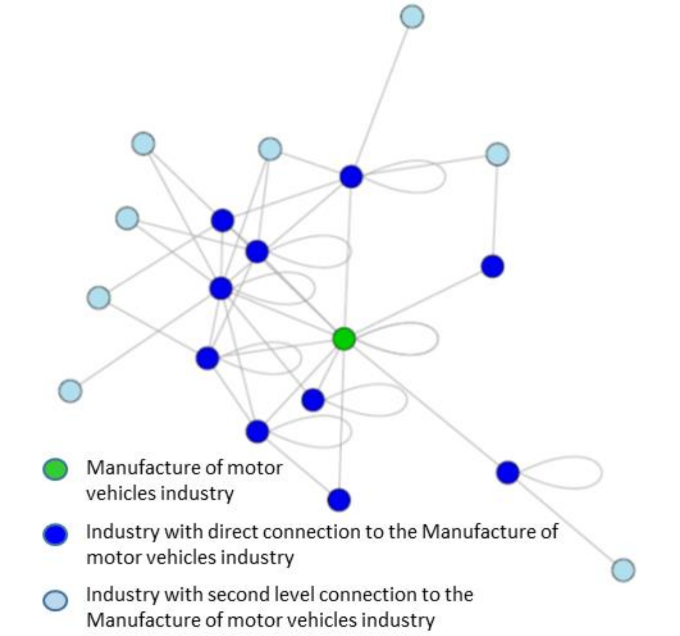
		Manufacture of motor vehicles		Manufacture of rubber and plastic products		Manufacture of fabricated metal products	
		2010	2015	2010	2015	2010	2015
Derivative demand for a unit of output							
Demand for	imports	0.71	0.74	0.54	0.57	0.43	0.47
	labour input (persons)	0.03	0.02	0.07	0.05	0.11	0.08
	fixed capital	0.06	0.06	0.09	0.08	0.07	0.07
	wages	0.11	0.10	0.22	0.20	0.32	0.31
Intermediate consumption / output		0.78	0.82	0.72	0.69	0.66	0.63
Derivative demand for a unit of gross value added (million HUF)							
demand for	imports	3.22	4.03	1.92	1.87	1.25	1.29
	labour input (persons)	0.14	0.12	0.25	0.16	0.33	0.22
	fixed capital	0.28	0.31	0.32	0.25	0.21	0.18
	wages	0.49	0.54	0.78	0.64	0.92	0.84

Source: own calculation, HCSO, Ritzlné et al. 2016

While the requirements of imports and the intermediate consumption ratio to output increased to 2015, the labour input and wages requirements decreased in the same period. Hence the input requirement of gross value added for labour decreased to a greater extent.

To represent the network according to the Input-Output table there are selected the ten most significant suppliers of Manufacture of motor vehicles industry. For these selected ten industries the input coefficients are higher than 0.003. In the next step the second level of the network was determined by the second level derivative demand of Manufacture of motor vehicles industry, by the form $a_{ij}a_{i29}$, where 29 is the NACE code of Manufacture of motor vehicles. In this case the selected industries have higher input coefficients as 0.001.

Figure 5: The Manufacture of motor vehicles industry and their supplier chain according to the input coefficients, 2015



Source: own calculation, HCSO

The Manufacture of motor vehicles industry due to high direct and indirect requirements for imports is not highly embedded in the domestic economy, as illustrates the above figure.

5.2 The transaction network

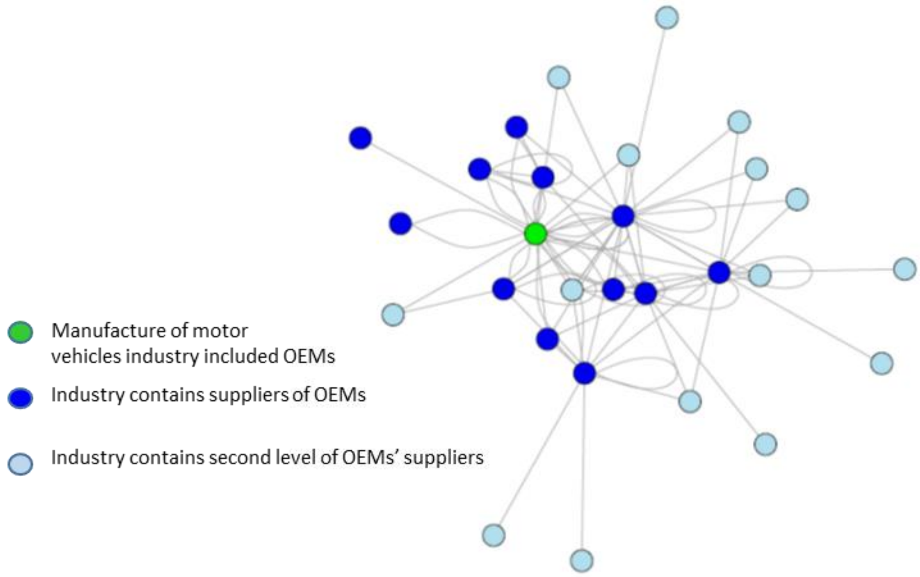
According to the transaction data of the VAT database the map of supplier chain can be drawn. As it was described in the session about data the transaction network of OEMs was compiled. This transaction network differs from the network determined by the Input-Output tables. The main differences are the following:

- The Input-Output tables include the input requirements of the given industry regardless its structure. For example, the Manufacture of motor vehicles industry includes all activities, which are aimed at the producing of motor vehicles or their parts. The companies categorized in this industry are not all OEMs, but they could be at lower level of the supplier chain. Therefore, the network drawn up using the Input-Output tables is not appropriate to illustrate the supplier chain. From this reason a diffusion of a possible exogenous shock in the market of the final product cannot be followed with full accuracy based on the Input-Output tables. However, the transaction network using the individual transaction data draws up the supplier chain starting from the purchases of the OEMs.

- By the concept of National Accounts, the output of the trade activity is the trade margin, the purchase value of goods sold, and the service provided has to be deducted from the turnover. In the compilation process of the transaction network, the purchase value of goods sold and the service provided cannot be handled at all. Therefore, in this network the purchases from the trade industries (wholesale and retail trade, motor vehicle trade) are significantly overrepresented.
- The Input-Output tables are appropriate to examine the presence and role only of industries or products in national economy. The suppliers of the OEMs can take part in the global value chain. The industrial classification of an activity or a company is not enough information about their presence or position in the global value chain. The transaction network using the previously investigated database of TIER1 companies help to distinguish the suppliers integrated in the global value chain and other suppliers.
- The Input-Output tables provides input for a static analysis, the dynamic approach needs more information which are usually not published among the Input-Output tables. The transaction network built on monthly and quarterly data; therefore, it includes time series, and it allows the dynamic analysis.

The following figure shows the transaction network of automotive industry. The OEMs are highlighted by green. The significant suppliers aggregated into industries are selected according to the ratio of sales to the total. Those industries are selected, which sales to OEMs exceed the 0.003 of total. The second level industries of the supplier chain was determined by the sales limit 0.001 in the total.

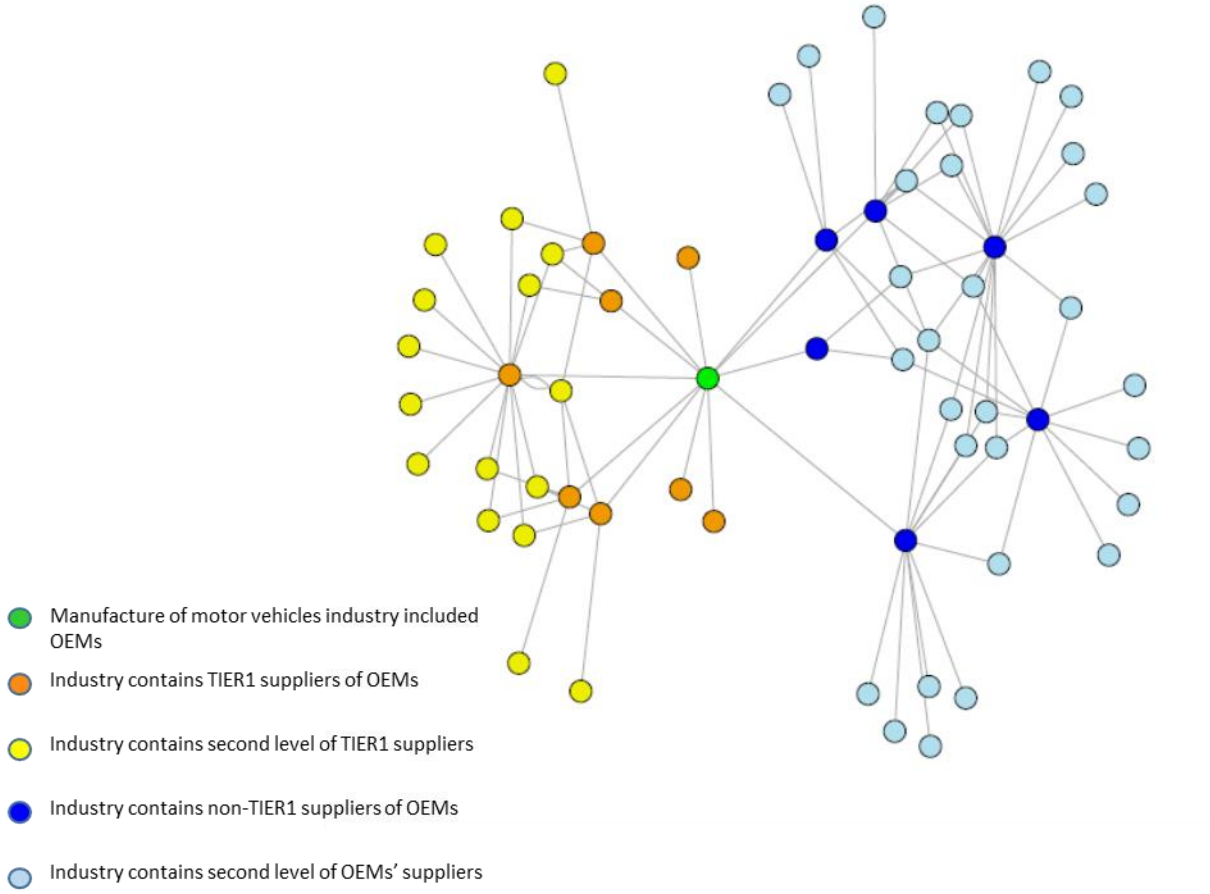
Figure 6: The transaction network of Manufacture of motor vehicle industry, 2018



Source: own calculation, HCSO

The previously developed TIER1 database allows to differentiate the supplier chain into TIER1 and other companies. The classified companies in the transaction network are aggregated by TIER1 classification and NACE categories. The next figure illustrates the classified network where the orange nodes show the TIER1 industries, the yellows are their supplier industries. The dark blue nodes are the industries which do not includes TIER1 suppliers, while the light blues are their supplier industries.

Figure 7: The transaction network participation according to TIER1 classification, 2018



Source: own calculation, HCSO

The selection criteria of the industries were the same as previously. On the above figure the number of industries which are included TIER1 companies are higher than the number of industries included other, non-TIER1 companies. But links of these companies are much higher to the second level. This suggests that the TIER1 companies are less embedded in the domestic economy as the other, non-TIER1 companies. The second level of the transaction network has different structure from the point of view of TIER1 classification. More industries at the second level are connected to more than one first level industries in case of non-TIER1 part of graph. By other words, this part of graph is less radial pattern as the TIER1 part. The interconnectivity of nodes decreases the vulnerability of a network. (Barabási, 2018) In case of low level of interconnectivity, the disappearance of a node can result in collapse of the network.

5.3 The employment effects according to the transaction network – Granger causality

The main aim of this research is to estimate the effects of external shocks on the employment through the supplier chain. The spread of the external shocks has to be modelled in order to this calculation. The modelling includes the determination of direction of diffusion through the network.

The direction of diffusion is defined in our approach as the causality between the employment and sales to the higher level in network of a given industry. In this framework the sales mean the link between the industries (nodes), the sales considered as the demand in our analysis. The employment is the observed input of the technology, this input is considered as the indicator of possible supply. The direction can be the following according to the causality:

- The demand effects the supply, for example the OEMs affected shock influences directly the supplier at the first level of the supplier chain.
- The supply influences the higher level of the supplier chain.
- There is not statistically significant relationship between the levels of the supplier chain.

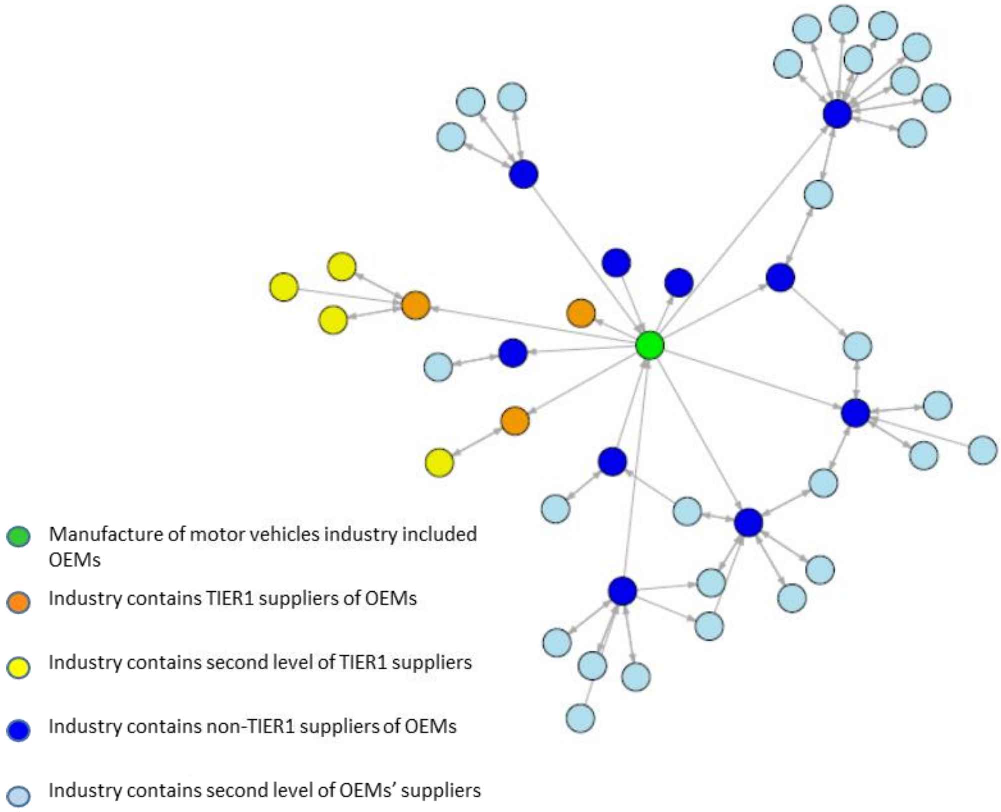
The direction of connection in our network was defined by the Granger causality as it was suggested by Sebestyén and Iloskics (2020).

The time series were available for industries and at TIER1 classification. Before the prepare of Granger causality tests all sales time series was deflated by the implicit price indices of output from the National Accounts, and the sales times series at constant prices were calculated. The reference year was 2015 for this calculation.

The examined period covered the quarters between 2018q1 and 2021q1. The available time series need to be differentiated according to the unit root test, and due to their exponential pattern, they were logarithmized.

The Granger causality was calculated for all links that were observed in the transaction network. The next figure includes only these links, for which the null hypothesis of Granger causality test was rejected, that is the relationship was statistically significant. The arrows indicate the direction of the connection.

Figure 8: The directed network of the automotive industry in Hungary between 2018 and 2021.



Source: own calculation, HCSO

On the above figure the industry included OEMs are highlighted by green. The industries included TIER1 companies are oranges, and they affected by the demand of OEMs. Their suppliers are the yellow nodes. The industries included non-TIER1 companies are the dark blues, while their suppliers are the light blue nodes.

The industries included the TIER1 companies have less links to the OEMs than in the network were based on the sales ratios (see Figure 7). The high sales ratios do not mean that the statistical relationship can be observed among these data. The less nodes connected the OEMs based on the Granger causality compared to the approach of sales ratios could have the reason that the TIER1 companies are deeply embedded in the global value chain, therefore their connections to the OEMs outside the domestic economy could be also significant. The network of TIER1 and OEMs are not limited to the domestic economy obviously but production chain can be analysed in a wider geographical area, even globally. The causality, statistical relationship may be stronger globally analysed, the effects do not prevail in such a small economy through the domestic connections.

The effects of the external shocks on global value chains cannot be interpreted within the boundaries of national economies. From point of view of official statistics, such effects are hardly estimated.

The industries included TIER1 companies have less links at the second level of the supplier network according to the Granger causality than the suppliers of industries which include non-TIER1 companies. This part of transaction network is deeper embedded in the domestic economy. According to this result, the automotive network has a part containing companies that are not part of the global value chain but have strong relation to the domestic automotive network. An external shock can spread through this part of the transaction network.

5.4 The employment effects according to time series models

The time series which show significant relationships between the nodes according to the Granger causality can have utilized in time series models. The industries included TIER1 companies were examined. Time series models were fitted for the link of were illustrated on the Figure 8, but not all links could be built a statistically acceptable model.

The number of employees of industries included TIER1 companies was the dependent variable, while the sales to the OEMs at constant prices are the explanatory variables. The data were logarithmized and then calculated their first difference (Hence, the models were fitted on the growth rates of employment and sales at constant prices.) The time series were analysed related to ARMA terms, seasonal pattern, and outliers, as well. There was not needed to apply any ARMA term, outlier, or seasonal adjustment in these models. The next table shows the data of fitted models:

Table 2: The coefficients of fitted time series models

		Sales to OEMs in Manufacture of motor vehicle industry	Sales to OEMs in Manufacture of motor vehicle industry, lag=(-3)
Number of employees	Manufacture of rubber and plastic products	0.806	
	Manufacture of fabricated metal products, except machinery and equipment		2.507
	Manufacture of motor vehicle industry	0.369	
	Wholesale and retail trade and repair of motor vehicles and motorcycles	1.699	

Source: own calculation

The structure of the fitted models shows that the relationship between growth rate of employment and sales to OEMs are simultaneous in case of Manufacture of rubber and plastic products, Manufacture of motor vehicle industry, and Wholesale and retail trade of motor vehicles. Only in case of Manufacture of fabricated metal products industry has a third lag relation between the variables. This type of relationship can indicate a longer production or inventory process.

The time series models show, that the growth rate of sales has the highest impact on the growth rate of employment in Manufacture of fabricated metal products industry (2.507). On the contrary the growth rate of sales in case of Manufacture of motor vehicle industry has the lower effect on the growth rate of employment among the examined industries.

There were also fitted models on the second level of this part of transaction network. In this case sales at constant prices to the industries included TIER1 companies were the explanatory variables while the employment of the industries includes their suppliers was the dependent variable. In this case the logarithms and first differences were calculated, too. The results of models are included in the next table:

Table 3: The coefficients of time series models fitted for the second level of supplier chain

		Sales to TIER1			
		Manufacture of rubber and plastic products	Manufacture of fabricated metal products, except machinery and equipment	Manufacture of motor vehicle industry	Wholesale and retail trade and repair of motor vehicles and motorcycles
Number of employees at second level of the supplier chain	Manufacture of rubber and plastic products	0.47		0.589	
	Manufacture of fabricated metal products, except machinery and equipment	1.023			
	Manufacture of machinery and equipment				0.837
	Manufacture of motor vehicle industry		0.491		
	Wholesale trade		0.698	0.989	1.239
	Warehousing and support activities for transportation				0.709

Source: own calculation

According to the above table the simultaneous relationship is characterized the nodes between the TIER1 and second level of the transaction network. The ARMA terms, outliers and seasonal pattern were not statistically significant in the models. The highest effect (1.239) has the sales of companies in second level of the supplier chain in industry Wholesale trade to TIER1 companies in industry Wholesale and retail trade and repair of motor vehicles on the growth rate of employment, while the lowest ratio (0.47) is estimated in case of the sales from Manufacture of rubber and plastic products to the same industry.

6. Conclusion

The research quantified the effects of exogenous shocks through the automotive supplier chain. In the first step the network related Manufacturing of motor vehicle industry was drawn up using different model approaches. The first approach was based on the Input-Output tables. The output multipliers for employment was calculated and compared to the multipliers calculated from previously published Input-Output tables. In this case, the input coefficients determine the structure of network. We argue that this method is not appropriate for the analysing of the supplier chain of OEMs because of the delimitation problems of this particular network and the late availability of the required data.

The second used approach is the diffusion model based on the transaction network compiled from individual quarterly VAT data and calculated Granger causality, which allows to analyse the relationships between the industries included suppliers of OEMs. We distinguished the TIER1 and other, non-TIER1 companies and the second level of supplier chain. Finally, we built time series models according the statistically significant relationships.

Our results show that this part of the automotive network, which are stronger related to the global value chain (included TIER1 companies and their suppliers) have less significant relationships with the OEMs operating in Hungary. Moreover, they have less statistically significant relations to the domestic economy than this part of the supplier network which are built on non-TIER1 companies.

We prepared time series models in order to analyse sales and employment. The relationship was significant between the growth rate of sales and growth rate of employment in case of examined industries. The proved that the short term data show the same significant relationship as the Leontief model between industries, nevertheless the time series models suggested exponential relationship.

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