

CONSEQUENCES OF TECHNOLOGICAL CHANGES IN THE AUTOMOTIVE INDUSTRY – PERSPECTIVES OF THE CENTRAL EUROPEAN REGION AS PART OF THE GLOBAL VALUE CHAINS¹

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Abstract: *Technological change is on the way in the automotive industry, which is moving towards electromobilitization. This process raises two important questions. Firstly, what will the global value chain look like after replacing internal combustion powertrains? Secondly, what role will play the countries involved in the ‘traditional’ automotive production in the changed value chain? The main goal of this study is to examine the impacts of the current technological change on the automotive value chain and its effects on the Central European (the Czech Republic, Hungary, Poland and Slovakia) production. The problem is well illustrated by the fact that the Central European countries have significant powertrain production and they have a net production surplus of internal combustion engines compared to their car production. The most important finding of the study is that despite positive improvements related to the technological transition, currently the role of the Central European countries as an assembler is determined by being part of the production of the conventional internal combustion engine powered vehicles. The technological change in the Central European automotive production is based on conventional vehicle assembly. On the other hand, outlook of the region’s development is dependent on corporate strategies, how they manage the technological change i.e. how they solve their battery pack production. This also includes a strategy of the automotive manufacturers that defines the spatial pattern of simultaneous production of conventional and electric models.*

Keywords: *automotive industry, operations and production management, global value chain, Central Europe, technological change, electric vehicles*

1. Introduction

From the mid-nineties on, car manufacturers started to reduce emissions in vehicle use (Wells & Orsato, 2004) and therefore developed new technologies to replace internal combustion engine (ICE) cars with pure battery-electric drive vehicles (EV). The first attempts remained only concept cars (e.g. GM Impact, BMW E1, Honda EVX) and

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carmakers focused on Powertrain Control Module (PCM) development instead in order to enhance the efficiency of existing internal combustion engines and reduce fuel consumption. As the Volkswagen emissions scandal highlighted in September 2015, progress in reducing emissions in the context of the current (internal combustion) powertrain technologies remains limited. Also, stricter environmental laws and regulations specify product development directions (i.e., the technological substance of the final product) that influence the individual elements and the structure of the industry's vertical integration.

This technological transformation is underway now, with changes not only in the built-in components of vehicles (powertrain, transmission, batteries etc.), but also in the structure of the industry's vertical integration, i.e., in the value chain (Klug, 2013, 2014; Ciarapica et al., 2014; Slowik et al., 2016). Regarding the transformation of the value chain, there are changes in the relationship and also in the ownership structure. Some production tasks can be outsourced, others can be integrated into in-house production. In the case of electric car manufacturers, regarding the integration alternatives of battery production – which is a crucial part of electric cars – Wang and Kimble (2010, 2011) provide four possible scenarios. These are: vertical integration of a battery producer and an automobile manufacturer in a single company; the acquisition of a battery producer by a car manufacturer; the expansion of a battery producer into car production, and the cooperation of electric car manufacturers with local and foreign battery suppliers.

The technological change will transform the logistics coordination across dispersed plants in the cases of the production of batteries, electric motors and transmissions (Klug, 2013). This evolution based on technological change might lead to the erosion of the current linkages within the trinity of suppliers, Original Equipment Manufacturers (OEMs) and OEM's subsidiaries. Because of the introduction of advanced car technologies, production of previous technologies (e.g., transmissions, internal combustion engines) will gradually decline. Production of new generations of main parts like electric motors, batteries or other power generation units (fuel cells, solar panels) also change the role and scope of suppliers and OEM's subsidiaries. New technologies and technological transformation create an increasing role for e-drive development companies. Because of this there are newly joined independent firms involved in electric powertrains production or drive control development. This process affects intra-firm relationships in the automotive value chain with an overall impact on the evolution of their governance structures.

Scholars usually pay less attention to the value chain consequences of ongoing technological change. This question is pertinent in the sense that the Central European countries (the Czech Republic, Hungary Poland and Slovakia) have been deeply integrated into this international production network as part of the global vehicle production. Technological transformation raises the question of the long-term sustainability of current production capacities in the automotive-related export-based Central European economies. The economic and social costs of the transformation can be a shock, with layoffs as well as export decline, that threaten the economic development of these countries.

The main goal of this paper is to examine the results of previous research in the Central European region. The paper will demonstrate that the above-mentioned trends have a fundamental impact on the prospects of the Central European region. Therefore, this research analyzes what kind of changes the technological transformation (i.e. introducing new technologies) will cause in the 'conventional' (i.e., vehicles with internal combustion engines) car manufacturers' value chain. In the first part of the paper I will summarize the

latest issues of electromobility. In the second part, the role of the Central European countries in the technological change will be examined. The main question is whether the countries involved in the technological change are ordered in a similar spatial pattern as those in conventional (internal combustion engine, ICE) automotive manufacturing.

2. The rise of alternative drives in the automotive industry and their impact

There are alternatives replacing internal combustion engines, but currently the car's evolution is towards electric drive (EV) vehicles (Deloitte, 2017). Technologies taking over ICE (Spath et al., 2011; Kühn & Glöser, 2013) will completely replace the direct use of fossil fuels in the future. This evolution begins with the *Hybrid Electric Vehicle* (HEV) that is a combination of the ICE and the electric motor/generator. The structure of the *Plug-in Hybrid Electric Vehicle* (PHEV) is the same but due to having a charging possibility a relatively smaller ICE is combined with a larger battery capacity. The difference between *Battery Electric Vehicle* (BEV) and the *Fuel Cell Electric Vehicle* (FCEV) is the storage of electricity. In BEVs mostly Li-ion battery cells store the energy, in the FCEVs the energy cells produce electricity by electrochemical reaction of oxygen and hydrogen.

Over one million EVs were sold in 2017², which amounted to about 1% of the global sales. According to the Bloomberg's EVs timeline (Bloomberg 2016) it will be growing about 35% until 2040. Battery pack³ determines about 75 percent of BEV's power train cost (Wolfram & Lutsey, 2016), and one third of the total cost (UBS 2018 via portfolio.hu⁴), so the propulsion of the electric car is determined by the price of the batteries. Based on related literature (see Berckmans et al., 2017) the technology split is predicted to start from the 2020's with the reduction of battery prices (Bloomberg New Energy Finance 2016). Therefore, the main driving force will be the innovation in battery technology and the Chinese consumption that will account for almost 50% of the global EV market in 2025.⁵ If we go into details the picture is not so 'optimistic', the breakthrough will not be the BEVs but the mixed HEVs (see Figure 1.). The forecast of Berckmans and his co-authors (2017) highlights the uncertainty of the market launch of e-technology.

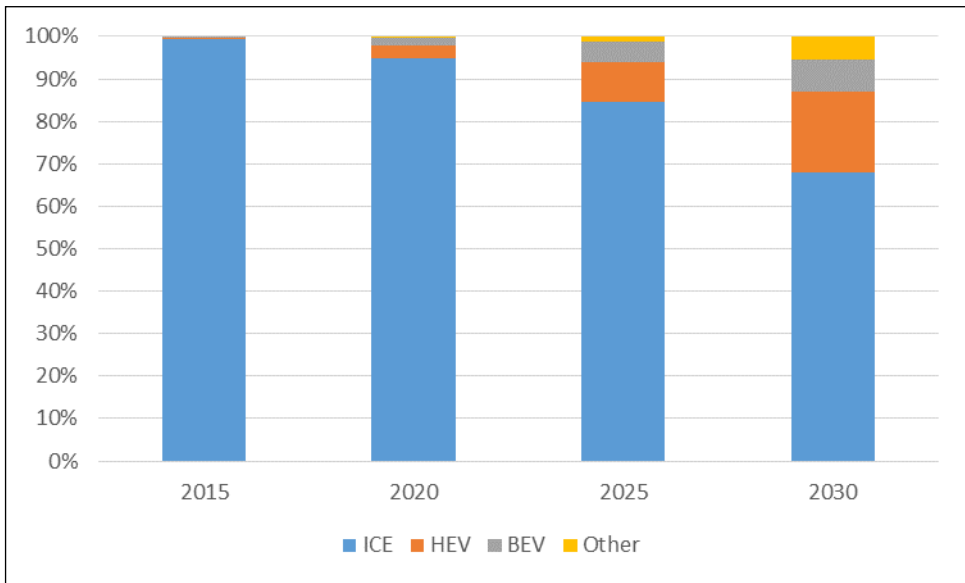
² <https://www.iea.org/gevo2018/>.

³ See more on: <http://www.samsungsdi.com/column/all/detail/54344.html>.

⁴ <https://www.portfolio.hu/vallalatok/cegauto/darabokra-szedtek-az-uj-teslat-az-eredmeny-megdobbento-es-figyelmeztetes-magyarorszagnak.300200.html>.

⁵ <https://about.bnef.com/electric-vehicle-outlook/>.

Figure 1: The rise of alternative drives in automotive industry



Source: Berckmans *et al.* 2017.

The Bloomberg New Energy Finance analysis (Bloomberg 2016) focused on the total cost of ownership of electric vehicles, and articulated the main points in order to achieve EV's widespread adoption:

1. *Governments must offer incentives to lower the costs;*
2. *Manufacturers must accept extremely low profit margins;*
3. *Customers must be willing to pay more to drive electric;*
4. *The cost of batteries must come down.*

There is a growing number of serial EVs. According to different sources^{6,7} worldwide there are more than three dozen (between 36 and 44) different electric vehicle models made in 2018. Among the electric cars in production, there are more and more cars developed and manufactured in China. Some of these are the result of a cooperation with triad OEMs (e.g. with BMW), others are the development of Chinese companies. A large number of new players are entering the local or regional market. However, the paper focuses on vehicles produced by triads (North America, Europe and Japan) and South Korea. Moreover, the companies present in the European Union's market also come from these regions only.

Table 1 shows the evolution of the mass production of the EVs in the 'triad countries'. Regarding the location of the production, there are three kinds of approaches. First, OEMs locate the production near the market in a 'low-cost country'. Fiat 500E is exclusively produced for the U.S. market, therefore the assembly of the EVs is in the FCA's (Fiat Chrysler Automobiles) Mexican factory. The situation is the same with the Volkswagen e-UP which is produced in Slovakia. Second, the technological cooperation in order to develop an EV can determine the location of the assembly. As a result of the Groupe PSA⁸-Mitsubishi cooperation the city EVs are

⁶ https://en.wikipedia.org/wiki/List_of_modern_production_plug-in_electric_vehicles.

⁷ https://en.wikipedia.org/wiki/List_of_electric_cars_currently_available.

⁸ Groupe PSA or Peugeot S.A. is a French manufacturer of automobiles and motorcycles sold under the Peugeot, Citroën, DS, Opel and Vauxhall brands.

assembled in the Japanese factory of Mitsubishi. Third, the latest developments are produced in the headquarter/home country of the OEMs. BMW's i3 is made in Germany or General Motors's EVs are made in the U.S.

Table 1: Electric vehicles (BEV) of the 'triad brands' in serial production, ranked by the starting time of mass production

OEM	Model	Mass production started	Assembled in
Nissan	Leaf	2010	Japan (Oppama, Yokosuka); USA (Smyrna, Tennessee); United Kingdom (Sunderland)
Mitsubishi; Peugeot; Citroen	Mitsubishi, i-MiEV; Peugeot, iOn; Citroen, C-Zero	2010	Japan (Kurashiki)
Ford	Focus Electric	2011	USA (Wayne, Michigan); Germany (Saarlouis)
Honda	Fit EV	2011-2014	Japan
Renault	Fluence ZE	2011	2011-2014 Turkey (Bursa); 2013- South Korea (Busan)
Renault	ZOE	2012	France (Flins)
Renault	Twizy	2012	Spain (Valladolid); South Korea (Busan)
Tesla	Model S	2012	U.S. (Fremont, CA); Netherlands (Tilburg)
FCA (FIAT)	500e	2013	Mexico (Toluca)
BMW	i3	2013	Germany (Leipzig)
BMW Brilliance Zinoro	1E	2013	China (Shanghai)
Volkswagen	e-Up!	2013	Slovakia (Bratislava)
Kia	Soul EV	2014	South Korea (Gwangju)
Volkswagen	e-Golf	2014	Germany (Wolfsburg)
Daimler	Mercedes-Benz B-Class Electric Drive	2015-2017	Germany (Rastatt)
Tesla	Model X	2015	U.S. (Fremont, CA); Netherlands (Tilburg)
General Motors	Chevrolet Bolt EV/ Opel/Vauxhall Ampera-e	2016	USA (Detroit, Michigan)
Hyundai	Ioniq Electric	2016	South Korea (Ulsan)
Tesla	Model 3	2017	U.S. (Fremont, CA)
Hyundai	Kona Electric	2018	South Korea (Ulsan); India (Chennai)
Jaguar Land Rover	Jaguar I-Pace	2018	Production was outsourced to Magna Steyr in Austria (Graz)

Source: author, based on company reports and press releases.

Going into details of the supply chain, the technological change specifies not only the built-in components of vehicles, but also the structure of the industry's vertical integration, i.e. the supply/value chain (Klug, 2013, 2014; Ciarapica *et al.*, 2014; Slowik *et*

al., 2016). There are consequences of the technological transformation at *product level*. On the one hand, there will be *outdated products* such as the internal combustion engine and transmission. The outdated technology will be phased out in parallel with the evolution of electric vehicles. That means that engine size reduction (downsizing) will be continuing, because of the HEVs (Douba, 2011) and the PHEVs (Green Car Congress, 2012) move forward to electromobility. On the other hand, there are *new components representing new technologies and new features*. Changing of the parts and features of the vehicle redound new suppliers. For instance, the largest Li-ion battery producers are Chinese (Contemporary Amperex Technology, BYD Auto), Japanese (Panasonic) and South Korean (Samsung, LG) companies.

There will be consequences of the technological transformation also at *production level* i.e. at the value chain. The technological moving towards electromobility brings a new situation. Replacing ICE vehicles by EVs *requires three types of knowledge*, i.e. mechanical, chemical and electronic competences, so called a ‘me-chem-tronics’ (McKinsey, 2011). This new situation means that OEMs need new abilities and knowledge that are beyond their traditional competence (Grauers *et al.*, 2017).

As previously mentioned, significant share of the production costs is the price of the battery pack, therefore, all OEMs seek intensive research and development activities for cheaper price together or independently with the battery producers (Sarasini *et al.*, 2013). Establishing this “new knowledge networks” (Sarasini *et al.*, 2013) needs time, among others because OEMs prefer traditional suppliers.

There are integration alternatives for the different product or production phases. OEMs are forced to choose between in-house production and outsourcing or cooperation with the suppliers. In terms of technological development and production, besides new services, the development and production of the powertrain – as a complete system – are also critical points within the value chain. Same as the alternatives provided by Wang and Kimble (2010, 2011), the OEMs have long a tradition and routine regarding in-house production or outsourcing. The question is raised, how the level of outsourcing influences the new or changing structure of the supply chain in the automotive production. Traditionally, the Japanese OEMs are more ‘outsourced’ (Chanaron, 1995), while the European and U.S. firms produce more in-house, since then ‘Western’ (U.S. and European) manufacturers have adopted the Japanese method (Clark & Fujimoto 1991). However, apparently standardizing production management shows several differences. While the European manufacturers were focusing on outsourcing, Japanese manufacturers focused on modularization (Takeishi & Fujimoto, 2001). In addition, during the Japanese outsourcing, the significance of the (grouped) suppliers belonging to the same group of companies cannot be neglected either (Takeishi & Noro, 2017). They shade the picture that emerged from the supply chain of Japanese and ‘Western’ manufacturers.

For instance, the U.S. automaker Tesla does things differently from the other OEMs in terms of vertical integration. In order to carry out the development of new models efficiently, not just the majority of the development but manufacturing processes are also in-house.⁹ Globalized suppliers react much more slowly to a problem than a company based on a newly developed technology would. In 2016 the Goldman Sachs’ report noted

⁹ <https://evannex.com/blogs/news/vertical-integration-how-elon-musk-employs-an-old-successful-approach-in-american-business-at-tesla>.

that *Tesla* is running about an 80% vertically integrated operation.¹⁰ This high vertical integration of the production is due to mergers of certain production companies.^{11,12,13}

With the spread of technology, conventional automakers differed in the issue of outsourcing of certain components. In case of battery and battery pack production, previously, Volkswagen’s electric cars were powered by batteries from suppliers. “This is not one of our core competencies,” – said Matthias Müller former Volkswagen CEO, “others can do it better than we can.”¹⁴ Later on, Volkswagen decided to move forward to enter battery production. In May 2016 Volkswagen’s new Chinese factory opened in Qingdao and besides their new model it will produce battery systems as well.¹⁵ According to press releases, Volkswagen has very ambitious plans (‘Roadmap E’) to move forward to electricity, from 2019 until 2022 on average every month there will be new e-cars introduced.¹⁶ With this strategy, the proportion of in-house production begins to increase which, instead of the supplier-OEM connection, affects the headquarter-subsidiary relationship.

Focusing on battery packs, those companies who buy their batteries from external sources diversify their procurement, *use more suppliers* (see Table 2). Most of the companies are from Japan and South Korea, even the U.S. companies use Japanese suppliers except for General Motors which has a partnership with the A123 Systems, a subsidiary of the Chinese Wanxiang Group. The role of these countries is confirmed by the scientific biometrics, according to which U.S., China, Japan and South Korea are the most active on electrification R&D (Grauers et al., 2017).

Table 2: Four Japanese OEMs and U.S. GM and Ford lithium-ion battery sources

Toyota	Vehicle	Prius α	Prius PHV	EV "eQ"	
	Supplier	PEVE/Panasonic	Panasonic	Panasonic	
Nissan	Vehicle	Leaf	Fuga/Cima HV	Front-wheel drive HV	
	Supplier	AESC	AESC	Hitachi Vehicle Energy	
Honda	Vehicle	Civic HV	Fit EV	CR-Z HV	Accord HV/PHV
	Supplier	Blue Energy	Toshiba	Blue Energy	Blue Energy
Mitsubishi	Vehicle	i-MiEV	MINICAB-MiEV	MINICAB MiEV TRUCK	
	Supplier	LEJ/Toshiba	LEJ/Toshiba	Toshiba	
GM	Vehicle	Chevrolet Volt	eAssist vehicles	Chevrolet Spark EV	
	Supplier	LG Chem	Hitachi Vehicle Energy	A123 Systems	
Ford	Vehicle	Focus EV	C-Max HV/PHV	Fusion HV/PHV	Lincoln MKZ HV
	Supplier	LG Chem	Panasonic	Panasonic	Panasonic

Source: www.marklines.com (https://www.marklines.com/en/report_all/rep1115_201210).

An example for the collaboration model is the Renault-Nissan Alliance that cooperates with the Automotive Energy Supply Corporation in a joint development of

¹⁰ <https://www.valuewalk.com/2016/02/tesla-stock-rallies-after-tough-couple-of-weeks/>.

¹¹ <https://www.autoblog.com/2016/11/08/tesla-buys-german-company-manufacturing/?guccounter=1>.

¹² <https://www.autoblog.com/2015/05/07/teslas-first-acquisition-is-michigan-based-tooling-company-rivi/?guccounter=1>.

¹³ <https://www.cnbc.com/2017/11/08/tesla-buys-perbix-for-factory-automation.html>.

¹⁴ <https://www.bloomberg.com/news/articles/2018-03-13/vw-secures-25-billion-battery-supplies-in-electric-car-surge>.

¹⁵ <https://www.bloomberg.com/news/articles/2018-05-28/volkswagen-to-open-new-china-factories-as-suv-ev-demand-booms>.

¹⁶ https://www.volkswagenag.com/en/news/2018/03/VolkswagenGroup_expand_production.html.

lithium-ion batteries. In the Renault-Nissan-Mitsubishi Alliance¹⁷ the three car manufacturers can share a growing number of links in the supply chain.¹⁸ The major owner of the Automotive Energy Supply Corporation is Nissan, therefore due to the alliance they can share their existing knowledge.

3. Perspectives of the Central European Region as part of the Global Value Chains

In order to understand the industry's role in Central Europe we need to study the forces behind the recent evolution of the global value chains. Technology and the governance structure of the automotive value chains are thus the focus of this research. Several low-cost countries joined global production in the 70's and 90's (Humphrey & Memedovic 2003; Friedman, 2005 and others), transforming their global position in the world economy. Global value chains enhance intra-firm linkages; they are complex and ever-changing governance frameworks which have impacts on local economies as well. Moreover, global value chains have an immediate and profound impact on individual states as well. The Central European automotive industry has shown outstanding development in the last 25 years, and it has also incorporated the economies of the region into the global value chains.

Central Europe (the Czech Republic, Hungary, Poland and Slovakia) is still popular among automotive investors. Besides its moderate market potentials, the geographical proximity to the Western markets is also a crucial factor when investing into the Central European countries (Schmitt & Van Biesebroeck, 2013). There were almost three dozen OEMs assembly and production plants in the Central European region¹⁹ at the end of 2017. The output of 3.6 million road vehicles reached 3.7% of the world and 19.3% of the European output in 2017 (OICA, 2018). The potential of the region has not yet been exhausted, additional investments in modernization will result in an increase in production. There are new factories just opening in the second half of 2018 in Slovakia and under development in Hungary.

Almost the whole production of the automotive industry is exported (Túry, 2018) therefore apart from trade relations, export figures also show the structure of the production. Production figures are strongly affected by their parts production (Eurostat ComExt database, 2018). Except the Czech Republic and Slovakia where the export ratios of the assembled vehicles are 54 and 66 percent respectively, the export of components and parts give most of the trade (in Poland 60-, in Hungary 62 percent) in the other two countries in 2017. This is not just the production of suppliers (Humphrey & Memedovic, 2003), but the component and part production of the OEMs' affiliates (Nunnenkamp, 2004; Túry, 2017). For instance, the Czech Republic, Hungary and Poland have significant powertrain productions, in 2017 they produced nearly 4.7 million units that is a net production surplus of engines, compared to the car production of 3.4 million (OICA, 2018). In Hungary Volkswagen (Audi)²⁰ and PSA (Opel)²¹, in Poland Volkswagen²², PSA

¹⁷ <https://www.alliance-2022.com/about-us/>.

¹⁸ <https://www.economist.com/business/2018/03/17/renault-nissan-mitsubishi-has-become-the-worlds-biggest-carmaker>.

¹⁹ 16 in Poland, 8 in the Czech Republic, 4 in Slovakia and 5 in Hungary.

²⁰ <http://audihungaria2017-hu.audiportal.hu/hu/mult#infografika>.

(Opel)²³, Toyota²⁴ and FCA (Fiat Chrysler Automobiles)²⁵ have separate engine production plants, until in the Czech Republic Volkswagen (Škoda), and in Slovakia KIA²⁶ factories have integrated engine production. While in the field of assembly the factories are flexibly adapting to the technological change^{27,28}, stopping production of a major unit, like the powertrain, is a serious financial burden.

If we look at the current production matrix of the Central European countries, on the one hand, we can see that vehicle assembly dominates the activities of the OEMs. On the other hand, in terms of technology change, there are few examples compared to conventional technology (see Table 3). Comparing Table 1 with Table 3 we can sum up, that production of vehicles with alternative drive (HEVs, PHEVs or BEVs) begins in the 'home countries' i.e. for a Chinese company in China, for a Japanese company in Japan. As earlier mentioned, if there is a cooperation between firms' production can be allocated to a partner's country (e.g. in the case of Renault-Nissan-Mitsubishi Alliance).

Table 3: Car production matrix of the automotive OEMs in Central Europe

Country/manufacturer (number of factories, incl. assembly of commercial vehicle)		Vehicle powered by ICE assembly	ICE transmission	ICE powertrain	Starting of EV assembly	Starting of EV components / parts production
Czech Republic	Skoda (3)	x	x	x	2020	2019
	Hyundai (1)	x	x			
	TPCA (1)	x				
Hungary	Audi (1)	x		x		2018
	Daimler (1)	x				
	Suzuki (1)	x				
	PSA (1)		x	x		
Poland	VW (6)	x		x		
	Toyota (1)			x		2018
	PSA (2)	x		x		
	FIAT (1)	x		x		
Slovakia	KIA (1)	x		x		
	VW (4)	x	x		2013	
	PSA (1)	x				
	JLR (1)	x				

Source: author, based on company reports and press releases.

Considering the prospects of the region, there is a large number of companies *continuing old technologies* (i.e. ICE vehicles). In Hungary PSA's Szentgotthárd plant (Opel) continues „normal operation” despite the ownership change (GM sold Opel to the

²¹ <https://autopro.hu/gyartok/Ilyen-autoipari-kornyezetbe-erkezik-a-BMW/26732/>.

²² <https://www.volkswagen-newsroom.com/en/press-releases/volkswagen-motor-polska-sp-z-oo-578>.

²³ Jacobs, A. J. (2017), *Automotive FDI in Emerging Europe: Shifting Locales in the Motor Vehicle Industry*, Springer

²⁴ <https://www.toyotapl.com/about-us.json>.

²⁵ Komisja Konsultacyjna w FCA Powertrain Poland Sp. z o. o., Informator Związkowy 10/2018 <http://www.metalowcy-bielsko.pl/uploaded/Powertrain%2010%202018%20FCA%20Powertrain.pdf>.

²⁶ Kia Motors Slovakia (2018), *Annual Report 2017*, Teplicka nad Vahom: Kia Motors Slovakia s.r.o.

²⁷ <https://www.daimler.com/innovation/case/connectivity/full-flex-plant.html>.

²⁸ <https://www.brand-e.biz/innovation/bmws-first-new-european-plant-in-20-years-builds-evs>.

French PSA), but there are no future plans for the technological change.²⁹ Japanese Suzuki, which has been manufactured in Hungary, plans to change technology with Toyota in a joint production for the Indian market. Even though Suzuki in Europe only has production capacities in Hungary, there is no information about the electromobilization of the Hungarian production. The Hungarian research and development directions of the company are based on traditional technology.³⁰ *New investments can also represent old technology.* While the Indian Tata Motors owned car manufacturer Jaguar Land Rover Automobile move U.K. production of Land Rover Discovery to Slovakia, the British plant will be upgraded for electric models.³¹ On the other hand, electromobilization of the company was outsourced. The first electric model of the company 'I-Pace' is assembled by the supplier company Magna in Austria.³²

At the same time, there are encouraging developments in the *region's connection to new technologies development.* South Korean LG Chem launched Europe's largest Lithium-ion battery factory in Poland in 2018.³³ The main customer is the Renault-Nissan Alliance, but it will be a good opportunity to supply other European manufacturers (among others BMW, Daimler, Volkswagen and Volvo) as well. The capacity is enough for 100 thousand pure electric vehicles.³⁴ Another South Korean producer Samsung SDI launched a serial production of the battery cell in Hungary in 2018. The Hungarian factory is capable of producing battery packs for 50 thousand EVs annually.³⁵

According to the biometric data of the scientific journal publications these four Central European countries are not on the research map (Grauers *et al.*, 2017). Nonetheless, there are R&D activities at the suppliers with which the countries of the region can join the current research and development activities in the automotive production. This is a forward-looking initiative, where not only multinationals but smaller companies can join the international automotive supply chain. In Poland the Japanese Toyota Motor invested in manufacturing a new combustion engine for hybrid vehicles.³⁶ The other EV-related investment, LG Chem gives an opportunity to join the global battery technology R&D through academic research.

There are good examples in Hungary as well. The German Audi AG is preparing to launch the serial production of electric cars 'e-tron' as early as 2019, which will coincide with the start of production of electric motors at the Hungarian plant. There is a good practice for research cooperation within the private and the state sector. A research consortium from Budapest University of Technology and Economics, Institute for Computer Science and Control (Hungarian Academy of Sciences), Bosch, a Knorr-Bremse and Continental for autonomous vehicle development. The German Thyssenkrupp also

²⁹ https://hvg.hu/cegauto/20180321_megmenekult_a_szentgotthardi_Opelgyar.

³⁰ <https://www.suzuki.hu/corporate/hu/vallalat/palyazatok/elindult-a-magyar-suzuki-zrt-altal-vezetett-4-eves-konzorcialis-kutatas-fejlesztési-projekt>.

³¹ <https://www.theguardian.com/business/2018/jun/11/jaguar-land-rover-to-move-production-of-discovery-from-uk-to-slovakia-jobs-solihull>.

³² <https://www.magna.com/company/newsroom/releases/release/2018/03/02/news-release---first-ever-all-electric-jaguar-unveiled-at-magna>.

³³ <https://www.reuters.com/article/us-lgchem-factory-poland/lg-to-open-europes-biggest-car-battery-factory-next-year-idUSKBN1CH21W>.

³⁴ <https://electrek.co/2017/10/12/lg-production-electric-cars-new-battery-factory/>.

³⁵ <http://www.samsungsdi.com/sdi-news/1642.html>

³⁶ <https://www.reuters.com/article/us-toyota-strategy-poland/toyota-to-invest-113-mln-in-hybrid-car-engine-factory-in-poland-idUSKBN1DT174>

carries out research in autonomous vehicle development in the center of R&D in Hungary.³⁷

In the Czech Republic Škoda has a unique position although Škoda's in-house research and development activities would be transferred to Volkswagen's centre in Germany, only design activities remaining at the Czech company (Pavlínek, 2015). Together with the other companies in the Volkswagen group, Škoda also makes significant moves towards electromobility. Škoda 'Vision E' being the basis of an electric car will be launched by 2020 (Škoda, 2018). They do not only produce electric motors and electrical components but also a purely electric-drive vehicle at the Mladá Boleslav and Kvasiny plants to cover the needs of Škoda and the Group as a whole.

4. Conclusion

Technological transformation is underway now in the automotive industry, with changes not only in the built-in components of vehicles, but also in the structure of the industry's vertical integration, i.e., in the value chain. It is not only about outdated and new components, but the geographical pattern of the production. Central European countries are deeply integrated into the global automotive value chain. Moreover, production of powertrains has a surplus compared to car assembly. Therefore, the evolution in the EV development, including production of ICE for hybrid vehicles or electric motor has a significant impact on the output of the countries in the region. There are positive improvements related to the technological transition, but currently the role of the Central European countries as an assembler is determined by being part of the production of the conventional ICE powered vehicles. This is also supported by the examples of mass production of the EVs and the production portfolio of the local affiliates. Therefore, the basis of the technological change is the conventional car assembly.

Besides, there are good examples how central Europe can link to the changing automotive value chain. Production of the battery pack which is one-third of the cost is a key question. There are several examples how OEMs organize the production. Tesla is the leader in development, closely allied with Panasonic, building up the whole supply chain in the U.S. Others like GM diversify its procurement, using more suppliers. The main question is how the Central European countries will be involved in powertrain and battery pack manufacturing. There are good examples in Poland and Hungary for building a battery factory. These two 'independent' factories can produce battery packs for more than 150 thousand pure EVs.

On the other hand, the main goal is that as technology changes, countries in the region can absorb as many new technologies as possible. There are good initiatives to link to the main R&D activities. The biggest suppliers started to invest in the development of autonomous driving technology at their Central European affiliates.

Future is open for several reasons. As it is shown in the examples automotive companies have different strategies regarding battery manufacturing. This also includes a strategy that defines the spatial pattern of simultaneous production of conventional and electric models. On the other hand, the ongoing labour shortage of the Central European

³⁷ <https://www.thyssenkrupp.hu/en/component/content/article/16-news/422-sneak-peek-into-the-future-of-steering-press-day-in-hungary>

countries sets a limit on the replacement of the traditional technology, even though using industrial robots is becoming more common in the industry.

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