Disruptions and resilience building in Central European automotive supply chains*

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In this paper, we focus on the disruptions of automotive GSCs and their resilience building in Central Europe where the economic role of the automotive sector and its connected industries is highly significant. We apply a qualitative approach based on interviews to investigate the impacts of the COVID-19 pandemic. Our aim was to discover the measures and strategies the automotive firms adopted to counter the pandemic effects in Hungary and Czechia. Based on the literature, we define the framework of the given CE companies' resilience building techniques. We mapped the measures companies used against the pandemic and analysed the various resilience-building techniques they applied. These measures are similar to those employed in previous local shocks, but we found an increased role of communication and collaboration. We also found some variations according to the firms' position in international networks.

Keywords: global supply chain; Hungary; Czechia, automotive industry, resilience
JEL Codes: F23, L23, M11

Introduction

The COVID-19 pandemic restricted the movement of both people and goods, and global supply chains experienced a sudden fall in deliveries from Asia between 2020 and 2021. Transport disturbances and problems in production, but most of all, semiconductor shortages caused severe disruptions.

Disruptions and resilience of Global Supply Chains (GSCs) have been studied by many scholars. Recent studies have looked into theory building, both in review studies (Adobor 2020; Aldrighetti et al. 2021) and conceptual papers (Azadegan/Dooley 2021; Christopher/Peck 2004; Sarkis 2020). However, in connection with the pandemic, there is still a need for more empirical research that would validate and improve the understanding of the theory and help supply chain executives to build resilient supply chains (van Hoek 2020; Darby/Fu-

* Received: 06.01.22, accepted: 29.10.22, 2 revisions

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gate/Murray 2019). Studies on the COVID-19 pandemic have mostly focused on the food and healthcare industries or on multiple industries (Chowdhury/Paul/Kaisar 2021). We focus on automotive GSCs' disruptions and resilience building in Central Europe (CE). In this article we present the Hungarian and Czech pandemic experiences of the dominantly foreign-owned automotive sector and its supplying industries, which are significant contributors in terms of employment, exports, and value-added. Our study applies a qualitative approach, based on semi-structured interviews conducted on companies in both countries to explore the resilience strategies of the automotive firms. The novelty of our research lies in mapping the effects of a global and unique external shock on automotive GSCs in Central Europe. The previous literature on supply chain disruptions and resilience has examined the consequences of a natural or human disaster happening only in one specific region.

In this article, we verify two major research questions:

RQ1: Do the resilience building techniques of the interviewed CE companies differ from those applied in previous localised disruptions?

RQ2: Do the applied response strategies vary among CE automotive companies and, if yes, in what features?

Our results are among the few to consider post-pandemic resilience strategies in the automotive industry. We found a wide range of resilience tools applied by the automotive firms but not essentially different from those applied in previous disruptions. The global feature of the crisis, however, put collaboration and communication in the foreground. We also found certain differences in these measures, depending on the firms' position in international networks.

The article is structured as follows. In the first part of the article, we provide a literature review on GSCs disruptions and resilience building. The next section is devoted to methodology. In the third part, we provide the findings of our qualitative research and summarise the implications for managers and academia.

Literature review

Disruptions and resilience in GSCs

The pandemic challenged firms' resources and capabilities. The resource-based view theory (RBV), first published by Wernerfelt (1984), claims that the resources owned by a company determine the company's strategic behaviour. Strategic resources (human, physical, and organisational) are valuable, rare, inimitable, and non-substitutable, and they determine the company's competitive advantage (Barney 1991). Later, Barney (2012) would argue that procurement and supply chain management can also be a resource that provides the company with a sustainable competitive advantage. Subsequently, Gligor and Holcomb

(2014) found RBV as a useful theory for examining supply chain agility in connection with firm-specific logistic capabilities. A follow-up concept of dynamic capabilities states that it is not sufficient to build up resources, these must be further developed to retain competitive advantage. Furthermore, this concept emphasises the need for the adaptation, integration, and re-configuration of corporate organisational capabilities (Teece/Pisano/Shuen 1997; Winter 2003) and thus it is well suited for the turbulent situation caused by the pandemic. Fawcett (2011) argues that supply chain collaboration is a dynamic capability, and this area has been strengthened in the COVID-19 crisis. Supply chain resilience is facilitated through dynamic managerial capabilities and their contributions to the organisational supply chain resilience antecedents (Nikookar/Yanadori 2021). The authors found that industry-specific skills (gained through experience in the same firm or industry), rather than generic skills, improve supply chain resilience antecedents.

Disruptions in the supply chain may originate from external sources (e.g. extreme weather events, cybersecurity events, and failures in interstate relations) and internal problems. These events mainly occur rapidly and unexpectedly, resulting in disruptions in logistics, raw materials supply, the assembly of components, or production and product defects. The assessment of disruption probability and effects is difficult. Whereas internal supply chain risks show a significantly higher impact (Thun/Hoenig 2011), an external event such as a global pandemic requires considerable attention, as the occurrence of global events are rare but the impact can be huge and long-lasting.

In GSCs, disruptions can spread, causing ripple effects. These emerge when a disruption at supplier firm level propagates downstream in the GSC and amplifies from stage to stage. Ripple effects can spread globally, and the longer the ripple effect lasts, the larger its devastating impact is on GSCs' functioning. Resilience to disruptions and ripple effects are crucial in GSCs. Resilience is a multidisciplinary topic, transcending a great variety of complex systems of individuals, ecosystems, organisations, communities, supply chains, computer networks, and building infrastructures (Fraccascia/Ilaria/Vito 2018). There are five crucial resilience dimensions associated with these complex systems: (a) Stability refers to the ability to preserve or return to the same equilibrium state when a failure occurs. (b) Robustness means maintaining basic functionality, while (c) vulnerability concerns the sensitivity of the system to threats. (d) Safety is the condition of no or minor damage, involving a defence process. (e) Adaptive capacity involves transformation, learning, self-organisation, and positive feedback (Fraccascia et al. 2018). A widely accepted definition of supply chain resilience is hence '*the adaptive capacity of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function*' (Ponomarov/Holcomb 2009:131).

While recovery refers to regaining lost functions as quickly, cheaply, and efficiently as possible, adaptation refers to the capacity of a system to change and better deal with future threats of a similar nature (Linkov/Trump/Hynes 2019). We can distinguish several types of risk mitigating strategies: short-term vs long-term, or proactive and reactive (Belhadi et al. 2021). Proactive strategies rely mainly on modern technologies (digitalisation, automation) and the reorganisation of sourcing, whereas reactive strategies are based on real-time information, supply chain simulation, and data-driven decision-making. Supply chain resilience is also about controlling the ripple effect. This involves three kinds of risk management actions: avoidance (reducing the probability of risks), actions focusing on the effects; and increasing knowledge and information about risks (Anbumozhi/Kimura/Thangavelu 2020). Preparing for external shocks can occur at the level of individual companies in the supply chain and/or at the level of the whole supply chain. Reducing the vulnerability of individual suppliers is crucial, but the resilience of the entire chain depends on the integrated performance of all companies (Ozdemir et al. 2022).

One of the basic analytical frameworks widely used in the literature, is that of Christopher and Peck (2004). It defines four main areas of resilience building: *Design and supply chain engineering,* high level of *collaborative working* within the chain, *agility and velocity*; and creation of a *risk management culture* in the organisation, which we discuss briefly below.

(1) Design and supply chain engineering (mapping vulnerabilities, risk register, alternative supply source, strategic and selective use of slack) are mainly reflected in the reconsideration of supply strategies. We can see discussions about the shortening of supply chains, backshoring and nearshoring of some production phases, although such solutions can increase vulnerability and lower efficiency (Miroudot 2020; Arriola et al. 2021). The role of standardisation and flexibility in procurement is also stressed (Contractor 2022; Anbumozhi et al. 2020). According to Frederico et al. (2021), management of supplier relations and the sourcing conduction and development phase is of high importance for the supply chain response to the pandemic. This has also been confirmed by van Hoek (2020), who found that 58 % of survey respondents considered moving away from single sourcing, while 47 % considered holding more inventory. Some of the common strategies used involve keeping strategic stock, distributing parts production, establishing a localised supply chain or building a flexible global production system. Such alternatives decrease risks but can also decrease efficiency (Anbumozhi et al. 2020).

(2) Close collaboration and coordination are necessary, especially in design, production, and logistics. Communication and collaboration are mediating tools to gain increased flexibility (Yu/Lou/Liu 2018), visibility, and joint decision-making (Morgan/Richey/Ellinger 2018). Collaboration in supply chain management

has a positive impact on performance through supply chain relationship quality (Shin/Thai/Yuen 2018), operational collaboration (Yang/Xie/Liu/Duan 2018), logistics performance (Aharonovitz/Vidal Vieira/Suyama 2018), and operating performance (Yu/Luo/Liu 2018). (3) Agility refers to the ability to react quickly, smoothly, and cost-efficiently to unpredictable events, and is confirmed, e.g. by Lotfi and Saghiri (2018). Furthermore, Scavarda et al. (2015) uncovered that a lack of flexibility in different tiers can inhibit resilience. Gligor and Holcomb (2014) argue that firm-specific logistics form important dynamic capabilities helping supply chain agility. In relation to risk management culture (4), Pettit et al. (2019) encourage companies to "move beyond traditional enterprise risk management practices to embrace a culture of resilience." (p. 61), while Herold et al. (2021) recommend companies respond to disruptions quickly and on an operational level.

COVID-19 effects on automotive GSCs

GSCs in the automotive sector differ from other sectors. Production of components are usually concentrated close to final assembly plants to assure rapid delivery, although the lighter and more generic parts can be produced at a distance (Sturgeon/Biesebroeck 2009). Parts and component manufacturers are categorised into tiers, reflecting production capabilities and the distance between a supplier and the assembler, the so-called Original Equipment Manufacturer or OEM (Dowlah 2018). Tier 1 manufacturers are direct suppliers to OEMs, with technological strength and capacities to design, develop, and test components and modules. Tier 2 suppliers supply finished parts and components to Tier 1 suppliers, while Tier 3 suppliers are low-tech manufacturers delivering products to Tier 2 suppliers.

In the automotive sector, ripple effects are especially caused by the 'just-in-time' system, with almost no inventories (Thun/Hoenig 20011) and the single-sourcing nature of operations. The components supplied are often highly specialised and tailored to the needs of the customer. Low inventories require ensuring that stocks will be easily and quickly accessible. A disadvantage of this optimisation method is the need to conclude exclusive agreements with suppliers, foreseeing deliveries within predefined timeframes, which increases risk if one link in this chain is broken (Rudewicz 2021), as there is a limited possibility to find alternative suppliers promptly and efficiently (Bofinger et al. 2020).

Car production was one of the hardest hit sectors during the pandemic also in the CE countries.

The automotive industry accounts for 5 % of GDP in Hungary, and around 10 % in Czechia and directly employs 170,000 people in Hungary and 180,000 in Czechia (Reuters 2021). The automotive sector also represents approximately 20 % of exports in both countries.

The Hungarian automotive industry, a low value-added manufacturing, is assembly-oriented and its operations are dominant in the function-based hierarchy. There are four automotive OEMs in Hungary, and three in Czechia and many global suppliers have operations in both countries, which serve mainly external markets. Domestic suppliers are usually Tier 3 and Tier 2 suppliers, as they often lack the necessary capabilities and capacities to supply components in the required quality and quantity for the Tier 1 level. Switching subcontractors is a complicated and time-consuming process, with identification and validation issues, which require extensive testing and documentation from alternative suppliers.

Due to the pandemic, exports fell in spring 2020 and were quite unpredictable afterwards. Nonetheless, the COVID-19 crisis slightly modified the demand side, so CE countries could benefit from producing mostly smaller and cheaper models popular during economic downturns. On the other hand, demand for electric cars, rarely produced in the CE region, strongly increased even in 2020 (IHS Markit 2021), and car renting and car sharing have also become more popular (Klein et al. 2021).

Methodology

In this paper we apply a two-phase qualitative approach. The first phase focused on the effects of the COVID-19 pandemic, while the second phase's purpose was to gain a deep insight into the resilience approaches adopted by the automotive companies.

Investigating the effects of COVID-19, we interviewed ten automotive companies in each country from March to October 2021. We inquired on how the pandemic affected the companies' operations, what measures were taken, and how the turnover and employees were impacted. Seven of the ten interviewed companies both in Czechia and Hungary were foreign owned. In Hungary, we interviewed five large companies, one OEM, and four Tier 1 – 2 suppliers. In Czechia, we received feedback from Tier 1 – 2 suppliers and one OEM. In Hungary, we also interviewed the secretary general of the Association of the Hungarian Automotive Industry (MAGE). In Czechia, we used a similar interview in the press with the executive director of the Czech Automotive Industry Association (AutoSAP).

In the second phase of our research, we conducted in-depth interviews with five Czech and five Hungarian firms. The aim was to gain insight into supply chain resilience building response strategies. Our interviewees included supply chain managers, marketing directors, HR managers, logistic managers and one CEO. We adopted a multiple case study approach, which provides an in-depth understanding of a particular situation or problem (Mohajan 2018). The COVID-19 pandemic is a new cause of supply chain disruption. Therefore, we found it

essential to analyse company experiences to properly evaluate the pandemic's impacts on automotive companies. Case studies can be used for exploratory, descriptive, and explanatory purposes, with often no clear boundaries (Yin 2017). Apart from using semi-structured interviews, we also analysed the available financial indicators and press information on the given companies. To ensure confidentiality, we indicate the companies by capital letters and country codes. The qualitative data were interpreted through coding and thematic analysis of the interviews (Creswell 2009). The data coding was conducted by two independent researchers in each country. The nodes were structured following the framework of Christopher and Peck (2004) in four main areas (supply chain engineering, collaboration, agility, and risk management).

Results

COVID-19 impact in 2020

We measured the effects of the pandemic using turnover and export development of the firms based on the Orbis database (Orbis 2022). We estimated the difference between 2017–2019 and 2012–2014 average turnover of NACE 29 (automotive) companies with a minimum turnover of 5000 EUR in both countries. We also estimated the change in turnover between 2019 and 2020. We found that the average turnover growth in between 2012–2014 and 2017–2019 reached 79 % in Czechia and 77 % in Hungary, whereas the average decline of turnover between 2020 and 2019 reached -11 % in Czechia and -15 % in Hungary. We compared these results with the turnover growth of our companies under review. We found that most of our 10–10 companies were close to the industry average turnover growth in pre-pandemic times, and that none of the companies witnessed a decline in turnover over the examined period. However, there was bigger variation in turnover decline during 2020 among the interviewed companies in both countries.

All firms in both countries applied antivirus measures, all firms suffered from turnover and revenue decrease – although to varying extent. In Czechia, all auto producers stopped production for several weeks in spring 2020, as did most of their suppliers. The reasons were related to health measures as well as disruption in supply chains (missing components). The situation was similar in Hungary, with OEMs' downtimes. During the first half of 2020, working methods had to be reorganised, layoffs were sometimes necessary and planning employment became insecure. Lockdowns and school closings caused problems for workers with a family. Business meetings and contact decreased, causing some disturbance in collaboration and production organisation. Almost all firms benefitted from governmental aid programmes. Table 1 summarises the results.

Table 1: Experiences of automotive suppliers with COVID-19 in 2020

	Hungary	Czechia
Antivirus measures	Preventive measures, PCR tests, disinfection, contact research, plastic barriers.	Preventive measures (face masks, disinfection, people from different shifts not meeting), antigen/PCR tests. Health protection standards adopted independently from government measures to react fast and protect employees. These measures increased operational costs.
Problems with employment, solutions	Home-office, part-time work (4 and 6 hours, deleting one shift) Layoffs, varying from 10 people to 100, depending on the company. Some firms applied compulsory leave. Closing of schools and nurseries was a problem. Psychological effects and frustrated workers. Less available and more expensive external service and maintenance workers. Employees' presence was not predictable. Planned increase of employees in the future: with transporting workers, guest workers, and strengthening dual education.	Frequent remote work for administrative employees. Many workers were quarantined. Women often stayed at home nursing, with some of them misusing the situation. People in quarantine and those who stayed at home with children under the age of 13 and later 10 (when all schools were closed) had the right to 70 % of their salary. Distorted labour market due to COVID-19 programmes. Before the pandemic, there was a great shortage on the labour market. During the pandemic, it got even worse. Foreign employees left the country and did not come back. HR management became challenging in terms of keeping labour in times with less work for times when company production is full.
Revenue loss, in 2020	Largest revenue loss in Q2 2020: 9.4 – 60 % Capacities fell in 2020. Average turnover loss in 2020: 9–25 % However, there were generally no financing problems.	Largest revenue loss in Q2 2020. It dropped by almost 70 %. Capacities fell in 2020 and most companies were behind the plan. Average turnover loss in 2020: 10 %, ranging from 7 %-55 %.
Production problems during lockdowns	Personal contact was restricted, travel was cancelled and developing business became very difficult. Due to missing workers and supplies, and the constant reorganisation of production, there was less efficiency. Supply chain disruptions, the closing of borders and workers' illness caused problems. Forecasts could not be trusted on demand. Less flexibility.	Less contact and less travel caused difficulties. Transport was disrupted. Planning became more difficult. There was extended time for R&D, as the possibilities for testing were limited.

Govt assistance in 2020	Yes, aid for employment in reduced working time, for retaining jobs, wage support, loans for mitigating losses, and HIPA's (investment agency) Competitiveness Improving Subsidy scheme. Some mentioned that more R&D support is needed in the future.	Antivirus programme – for firms whose employees have been quarantined or isolated (reimbursement of 80 % of wage costs).
COVID-19 induced changes in activity	Automation, efficiency growth, and capacity development. Gaining new domestic markets and introducing new products.	Automation in some and efficiency growth. One domestic automotive supplier reoriented its production towards producing sophisticated face masks in spring 2020. Some domestic companies strengthened their effort to go beyond automotive (e.g. healthcare). Most companies take it as an opportunity. The pandemic sped up changes (in IT infrastructure).
Markets, competition	Mixed opinions: competition on the market has become more intensive/decreased/did not change.	Market competition sometimes increased, but not significantly.

The secretary general of the MAGE pointed out that the epidemic gave a further push to automation in the firms, although it was already largely implemented before the pandemic because of the shortage of labour. Hungarian SMEs were still not prepared enough and have difficulty with automation, the biggest problem being the outdated machine parks. Equipping machines, coordinating logistics, finance, and product analytics is a long process, even if the government provides financial support. In Czechia, the executive director of AutoSAP warned that apart from the people directly employed in the automotive sector, COVID-19 has also affected workers in related areas, and that market supply would be affected (Forbes 2021).

Resilience measures

As mentioned in the literature review, all resources in the RBV concept were affected by the crisis, with human resources feeling the most immediate impact. The pandemic also had long-term, indirect effects on GSCs' physical resources too, as a shortage of materials and logistical problems persisted. Tables 2a and 2b illustrate the experiences and measures of five Hungarian and Czech firms in the field of organisational resources mentioned by Barney (1991), i.e. controlling, reporting, planning, and coordination.

Companies interviewed in Hungary and Czechia reported a shortage of semiconductors and a challenge in securing other supplies as well (e.g. plastic granules and aluminium products). All companies were affected by the production disruptions at OEMs, and all but one in our sample faced a profit decline in the period 2019–2020 compared to 2017–2018, a pre-covid-19 period (Orbis 2022).

The first area of resilience building in the framework of Christopher and Peck (2004) is supply chain engineering. Here firms tried to find alternative suppliers, which is not easy. Their responses are summarised below.

'Due to the supply-chain disruptions, we also tried to find alternative suppliers. The problem was that the new partners were also not able to provide raw materials, because no one had access to these goods (B-HU).

'Manufacturing is a complex, multi-step process, the turnaround time for a change takes years. Most supplier contracts are 10–15 years long and include joint product development. Therefore, looking for alternative suppliers is not really an option for us' (A-HU).

'We did search for new suppliers of raw materials, but it was a big problem' (H-CZ).

'Certain steps can be achieved after the agreement with the OEM, but in general, in automotive, employing a new supplier is very difficult' (F-CZ).

Another critical aspect of manufacturing operations is inventory management. Some firms increased inventories, but some could not because they lacked storage capacity and because of associated additional expenses. All companies that had already managed to increase their profits in 2021 reported temporary changes in their inventory policy in terms of increased stock of critical components and materials that included actively searching for alternative suppliers. Companies that suffered losses in 2021 presented their inventory policy as unchanged.

Based on the interviews, we think that the shortage of materials, semiconductors, and containers can have two kinds of consequences on managerial and employees' behaviour. As one manager said '*one has to be very innovative to get the necessary supply of components*' (E-HU). This is a kind of positive effect of the shortage, encouraging creativity. When errors and problems are treated as useful information, they can force the development of new ways of thinking. This was particularly evident in the financial crisis of 2008 that also had an innovation-enhancing effect on several companies (see Archibugi/Filipetti/Frenz 2013). Another effect is an increasing individualism instead of cooperation.

'There is no world level market for exchange: I give you this part, you give me that one. There are predatory dealers and producers, there is cheating and individualism. It is like the gold diggers in Alaska. 40 % of our procurers quit because of the stress and pressure, and they chose another job' (C-HU, also confirmed by G-CZ).

The increased individualism contradicts the findings of Scholten and Schilder (2015). Collaboration is thus another pillar of resilience building. Increased external cooperation with suppliers and corporation organisation units, increased

production flexibility, and the timely information flows were described by all companies independently from nationality, size or performance levels. More often we found growing cooperation among production partners instead of individualism.

The pandemic suppressed any possible reluctance of managers to information sharing (often present at the firms, see Fawcett et al. 2011). The Hungarian affiliate (B-HU) cooperates, for example, with the Czech affiliate of the same mother company, sharing excess materials. Consultations have become more frequent among customers, producers, and suppliers. We found the same experience in the Czech companies, where information was shared among the organisation units. Information sharing has already been highlighted in the research by Scholten and Schilder (2015), but their study does not cover information sharing amongst corporation units. Collaboration with suppliers resulted in daily to weekly reporting and joint production and supplies planning. On the other hand, the situation did not change the extent of information sharing and transparency achieved via EDI. Communication and information sharing among the organisation units increased significantly at the affiliates of global companies. This is the area where capabilities had to develop dynamically, and it shows the global reach of the pandemic.

Agility as the third area of resilience (Christopher/Peck 2004), is manifested mainly in reorganising logistics and transport methods. Two Hungarian companies have reported problems with organising transport. High creativity resulted in finding exceptional transportation solutions (e.g. a shared charter flight). In general, the strategy of transport selection did not change, but air freight increased to cover the outage in supplies. The switch to air freight and partial shipments caused increased operating expenses. Agility in production has been achieved by work during weekends, production replanning, flexible production planning, and shifting employees to different positions in production. This resulted in increased labour inefficiencies, underutilisation of machines, and other operational inefficiencies. Besides the agility expenses, all companies were facing increasing transportation costs due to the market development. In some cases, the replanning of product development also took place, adjusting development time and components to needs and availability.

All sample companies' operating profit margins dropped in 2020 (Orbis 2022) and later those with increasing operating profit margin from 2020 to 2021 had made efforts to increase agility at the cost of increased expenses. Besides other measures, they reported the use of air transport and partial shipments to secure production. It seems that the increased expenses were worth it, given the robustness and functionality of operations. In accordance with the theory, the ability to secure supply chains flows and create capacity to recover is an important part of the resilience concept (Frederico et al. 2021).

Finally, risk management has also developed, introducing daily risk evaluations, creating groups, task forces and evaluating necessary compromises. No shortening of supply chains was reported. Some companies introduced new key performance indicators (KPIs). Furthermore, we found a proactive approach toward information searches and risk assessment. One company stressed the speed of analyses and reporting, for example by employing new tools to gather data and analyse them. This finding contributes to the research by Frederico et al. (2021), who argue that capabilities and proactiveness should be observed during the resilience development phase, for instance, by newly added KPIs. Other important aspects are information sharing and regular meetings at managerial levels, which can be a step towards building resilience on a strategic level as opposed to findings on predominance of operational level measures by Herold et al. (2021). Most companies have not increased automation, either because they had already done the bulk of it before the pandemic or because they did not find it necessary.

To observe if there are any differences among the applied measures by the interviewed companies, we created three groups: domestic firms (2), foreign affiliates of companies present in a few countries (3), and subsidiaries owned by large global companies present in lots of countries (5).

We found that domestic companies (C-HU, D-HU) applied capital-intensive measures to gain agility, e.g. switching to airfreight and increasing stock as well as proactive measures such as risk assessment and coordination with other supply chain members. We could identify a relatively short-term focus in the adopted measures. During the decline, the companies managed to cut costs. Communication with partners increased, but sometimes there was not enough information because of the uncertainties.

A similarity among foreign companies (e.g. multinationals with a few off-shore operations, B-HU, G-CZ, F-CZ) was advanced work with data and information, collaboration, joint planning (even co-design with suppliers), the application of simulations by the mother company, and a careful stock increase. The companies intensively searched for flexibility in logistics to satisfy the customer and deliver the goods.

Subsidiaries of global companies (A-HU, E-HU, H-CZ, I-CZ, J-CZ) reported increased costs of stock keeping and inefficiencies in personnel costs. These companies especially benefitted from increased communication and collaboration among organisation units, and joint planning also took place. There was also a potential to optimise resources by restructuring and making strategic decisions.

Table 2a: Resilience building (Hungary)

	A-HU	B-HU	C-HU	D-HU	E-HU
Company size	large	large	large	large	large
Supplier level	Tier 1	OEM	Tier 2	Tier 1	Tier 1
Products	Electronic components and microelectronic circuit modules.	Flatbed semi-trailers and components.	Electronics, electromechanical products, sensors, and controls.	Aluminium castings and engine brackets for automotive companies	Rear-view mirrors
Supply disruptions	Shortage of electronic chips and problems of plastic parts transport.	Shortage of raw materials (steel).	Semiconductor supply problems.	Semiconductor supply problems.	Shortage of chips and containers.
Supply chain engineering	JIT system remained and automation accelerated. Regrouping activities towards R&D, software development, opening AI centre.	Attempts to automate every possible working process. Looking for alternative suppliers.	Searching for temporary alternative suppliers, continuous risk analysis of orders and coordination on correction possibilities with customers and suppliers. Inventory policy replanning (but already done before COVID-19).	Sourcing from multiple suppliers already before COVID-19. Building up larger stocks, bringing forward orders for steel.	Books capacities for 10 weeks, changing inventory rules, increasing consignment and possible in-sourcing.

Collaboration	Improving communication among units.	Intensive contact among subsidiaries and helping each other with excess materials. Closer coordination within the SC and increased intensity of information transfer. Co-design with suppliers.	Coordination with other chain members on critical components and tracking transport. Information flow worsened because of uncertainties. EDI and data exchange. OEM, EMS and supplier coordinate planning. Risk transfer to OEM.	Intensity of cooperation with partners increased. Constant consultation with suppliers on expected deliveries and price changes.	8–10 suppliers already, somebody has always capacity. Forecast towards suppliers were made longer. Use of EDI.
Agility	Reducing complexity, increasing transparency and separating areas at GSC level.	Looking for ways to make production more efficient and smoother.	Replanning product development to use parts that are more available. Production time of new products has become twice as long. Production was more flexible depending on material availability. More air transport. Parts-components lead-times increased significantly. Orders were made for longer terms, or froze.	Built up a large stock of finished products in preparation for a sudden order of large quantities by customers.	Being creative and aggressive to find out alternative transport methods, e.g. using rail, or air.

Creation of risk management culture	Major restructuring at the owner group.	Several task forces (e.g. health, engineering) were set up to solve the problems. Damage assessment and simulation done by the parent company.	Customer orders were often too optimistic and compromises are needed. Production capacities adjusted to avoid losses of downtimes. Ensuring continuity by regrouping focus and resources. Daily evaluation of risks.	Information flow with customers improved but no long-term planning, everybody concentrates on the short-term.	Intentions to build security of supplies.

Table 2b: Resilience building (Czechia)

	F-CZ	**G-CZ**	**H-CZ**	**I-CZ**	**J-CZ**
Company size,	large	large	large	large	large
Supplier level	Tier 2	Tier 1 and 2	Tier 1	Tier 1	OEM
Products	Interior components	Interior components	Automotive components	Interior components	Automotive
Supply disruptions	Semiconductor, chips, and plastic granules supply problems.	Chips, for limited segment of our production.	Semiconductor supply problems.	Not directly hit but via the OEM's downtime.	Chips supply problems
Supply chain engineering	Collaboration with customers to speed up the approval process of new suppliers (in exceptional cases).	Searching for alternative suppliers. Inventory policy did not change.	Searching for alternative suppliers (e.g. aluminium) but problematic. Inventory policy did not change.	Changing inventory rules and increased stocks of crucial components. Closed one production plant and moved it elsewhere.	Changing inventory rules and increased stocks of crucial components.

Collaboration	Collaboration with other companies to secure supplies (e.g. with shared space in charter flights).	Joint planning of supplies with suppliers, shortening communication intervals in logistics.	Increased collaboration with suppliers, introduced risks reports from suppliers, reporting and meetings, beside EDI.	Collaboration among internal units, collaboration with suppliers (external collaboration) on joint agreement on production plan, priority shipments and partial shipments.	Increased collaboration with suppliers, regular meetings to learn about the current situation and the outlook of supplies. The information flows of the supply chain – closer connection.
Agility	Being very creative to find out alternative transport methods, e.g. using rail, or air. Flexibility in production by working during weekends.	Flexibility of production achieved mainly by employees being employed in different positions in the production process.	Additional data analysis. No big data.	When necessary: alternative transport options – air. Flexible IT reactions to find solutions. Speed up information flows.	Increased flexibility of production planning adjusted to the availability of parts. New transportation options were tested.
Creation of risk management culture	New KPIs, simplified process to get data and making fast analysis, actively monitoring the world supplies situation, and suppliers on a weekly basis.	Planning and risk reports.	Increase in operations management activity and focus on securing supplies for the next period (year).	Adapting reporting to detailed and centralised. Dedicated people responsible for sharing the information. Information flows speed up, and activity in search for information related to risk management.	Active approach to prevent supply chain disruptions with proactive communication with suppliers and the introduction of close and regular exchange of information. Regular meetings through all management levels of the company.

Discussion and conclusion

The COVID-19 pandemic had a direct and sudden effect on firms in the first half of 2020, via the 'human factor' and supply chain disruptions. These short-term effects were countered through a plethora of measures on firm and state level. By the end of 2020, production and sales recovered, but in the meantime new kinds of challenges appeared.

For 2021 it turned out that the shortage of semiconductors and certain base metals would be long-lasting, although Asian foundries intend to expand their facilities further. Policy makers and automotive companies reacted with strategic measures.

As our results showed, automotive companies reacted with measures of supply chain organisation: more cooperation with suppliers, increased transparency, and more efficient data analysis. Several companies were rethinking their inventory policies, which became a widely discussed issue in literature. Lean production can make the supply chain vulnerable in case of a crisis. However, Miroudot (2020) found that firms that reduce inventories and make their production process as efficient as possible along the supply chain are also the ones investing in the monitoring and management of risks. Therefore, in the case of a decline in demand, companies with low inventories would have smaller losses than those with high inventories. Similarly, Lotfi and Saghiri's (2018) research supports that leanness leads to better recovery performance. Customer lead times can be improved, setup time shortened, and smaller lot sizes implemented. With lot sizes decreased, inventory levels are lowered, and production flexibility is increased. Thus, leanness helps recovery performance. Besides, some of our interviewees pointed out that their companies did not have the space and financial resources to build stocks. Some companies in our research increased stock of strategic materials and managed to recover performance. It is important to note that companies were rethinking their policy under specific external conditions, which included limited reliability and flexibility in international transport.

Some automotive OEMs begun to modify car development and production and their strategies showed that the role of research and development (R&D) would increase in the future. For the Visegrád countries, the implication could be what Krzywdzinski (2020) mentions: the absence of strong R&D centres in CEE is likely to impact the region's benefit from new technological developments, also in electric mobility and autonomous driving.

Based on our interviews, we observed that in the short term each company made steps to improve the transparency of GSCs, information exchange, communication among units and with suppliers. In most cases, collaboration and agility increased. Risk management was also enhanced. Thus, in all four areas of the framework of Christopher and Peck (2004) we investigated in this article,

sample companies were active. Therefore, as a response to our first research question, we found that in an unusual global crisis of supply and demand, resilience-building measures remained the same as before. However, because the disruptions now prove to be long-lasting, there are signs that these measures are raised to the strategic level and do not remain only at the operational level. Apart from that, we can say that the emphasis on collaboration and communication became greater than before, due to the global nature of the crisis and the global network connections of the firms. Collaboration was at a higher level in global, multinational affiliates than in domestic firms. Taking the RBV theory, we can conclude that on the one hand companies utilised their specific resources to solve the problems stemming from the pandemic. The organisation of logistics also proved to be a firm-specific resource that contributed to agile responses to critical situations. On the other hand, if we consider supply chain collaboration as a dynamic capability following Fawcett et al. (2011), then we can also prove the development of this factor in our sample.

Our second research question was whether resilience building steps vary among CE firms. We found that Czech and Hungarian automotive companies were rather similar in this aspect, but there are little variations according to the position of the company in the supply chain. OEMs and Tier 1 suppliers can better manage sourcing problems, and are capable of dedicating more resources to R&D and high-tech solutions. For Tier 2 and lower ranking companies, it is more difficult to find alternative suppliers and apply big data solutions.

We did not find any differences among the applied measures depending on the size of the companies. This is not surprising, as our firms are all large ones. The drop of turnover in 2020 and the following recovery of the examined companies were heterogeneous to a certain extent, but the drop operating profit margins were similar. We further explored if there were any patterns in the applied resilience measures among the companies depending on the ownership and international presence of the corporation. We formulated three groups (domestic, foreign companies and global subsidiaries) and found that firms operating in a multinational network could utilise their advantages in communication and information sharing and applying some methods of the mother company. The drop in turnover and the subsequent rebound at a company was independent of group belonging. Hence, we could not find any kind of correlation between financial performance and this kind of internationalisation level.

Our findings showed consequences of the pandemic not anticipated. Our conversations with the company representatives revealed that there was constant pressure on and exhaustion of the labour force, including managers and all employees. These findings have implications for the HR field, especially in relation to the psychological state of employees, which can further worsen inefficiency.

In the coming decades, the European automotive industry, apart from disruptions, will also be affected by the transition to electric vehicles, autonomous driving, and car sharing. All these changes will potentially have significant impacts on the structure, employment and the geography of production, and will take place at different speeds in the core, semi periphery and periphery (Pavlínek 2021). Therefore, CE governments should support the development of automotive R&D and other high-value-added activities through strategic industrial policies.

Our study has two main limitations: the companies we interviewed are all large firms. Findings could be different when small and medium-sized companies are considered. Other limitations are the focus on one sector and the small size of the sample in each country. Factors indicated as supporting firms' ability to stabilise in a short time from unexpected disruptions and to keep their competitive position, such as inventory and supplier management, need more research to prove the relationship. In addition, it seems that the impact of previous investments on the automation of processes in operation management in times of unexpected disruptions is limited. Therefore, the role of technologies as a mediating variable should also be observed.

Policy measures on the national and supranational level can be subject to future research, such as the effects of changes in the external environment, the application of AI, and the challenges of HR management. We think that there is a potential to develop communication forms inside GSCs. Studies on communication in multinationals' structures can contribute to the theory and bring implications for the management. Further studies can evaluate the inclusion of resilience building in the long-term strategies of companies as a consequence of probable continual future disruptions.

Acknowledgements

The authors would like to thank the anonymous referees for their useful comments, which allowed to increase the value of this article. The authors acknowledge the support of the research project of the Visegrad Fund (in the period 2021–2022) No. 22030183: *GVCs in Central Europe – a perspective of automotive sector after COVID-19.*

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