

Enhancing supply chains agility – The development of logistics capabilities by automotive producers in Central and Eastern Europe following Russia’s invasion of Ukraine

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ABSTRACT

This research investigates the proactive and reactive measures applied by Czech and Hungarian automotive companies following Russia’s invasion of Ukraine. We apply a qualitative methodology and analyse interviews with company managers to learn about the applied measures. The results reveal that the resilience gained during the COVID-19 pandemic involved proactive measures, which companies have kept in place. Reactive measures involved production replanning and alternative transportation. Adopting multiple sourcing strategies in the automotive sector is limited and more reactive rather than proactive. The important antecedents of agility are information sharing and cooperation within multinationals.

KEYWORDS

supply chain management, Czechia, Hungary, automotive industry, agility

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1. INTRODUCTION

Since 2019, automotive supply chains (SCs) had been challenged by the COVID-19 pandemic. Another unexpected event then hit the industry hard in the first half of 2022. Both the war, caused by the invasion of Ukraine by Russian troops, and the sanctions against Russia resulted in supply chain and transport link disruptions (Guénette et al. 2022) and production losses for European companies (Projektgruppe Gemeinschaftsdiagnose 2022). The COVID-19 pandemic was an opportunity for companies to build their supply chain resilience (Belhadi et al. 2021; Mendoza-Velázquez – Rendón-Rojas 2021; OECD 2021; Spieske – Birkel 2021), although the situation caused by the war still resulted in new uncertainties and challenges. Problems were announced by all car producers on the old continent. In March 2022, BMW and Volkswagen announced the temporary suspension of their operations in some factories due to supply chain disruptions (Just Auto 2022). Skoda also suspended its electric vehicle assembly in Czechia for eight weeks (Skoda 2022). Audi was forced to reorganise production in Hungary (Telex 2022). In March 2022, the Mercedes factory in Hungary switched from three to two shifts in some production areas (Jarmuipar.hu 2022).

The disruptive impact of the war on European businesses was mainly through sourcing. The first announced SC problems concerned a lack of spare parts. This was mainly driven by the lack of automotive electrical wire production, which was concentrated in Ukrainian factories. In extreme situations, agile reaction to new conditions helped companies respond quickly and efficiently to the new situation to fulfil their obligations. Skoda's suppliers relocated their production from Ukraine to Czechia and increased capacities in other European and North African plants (Skoda 2022). As a result of the cooperation with the suppliers, Skoda provided the hall necessary for assembly, while the suppliers provided the equipment and knowledge. To secure the SC flows, solutions were developed jointly with suppliers (Skoda 2022; Jarmugyartas.hu 2022) who were able to secure part of the orders through relocation to other facilities, adaptation of their production programmes, and by shifting plans according to the current situation in each area (Jarmuipar.hu 2022). The situation is illustrative of the impact of geopolitical risks on SCs, which come in the form of unpredictable demand, uncertain and unreliable supply, channel instability, the unavailability of labour, concerns about SC visibility and traceability of supplies, geopolitical instability, and the establishment of temporary or project-based SCs (Sodhi – Tang 2021).

On the longer term, companies will need to consider the impact on strategic sourcing, which is amongst the most crucial of SC decisions (Frederico et al. 2021). We live in a VUCA world (Bennet – Lemoine 2014), and as such, measures need to be introduced. To solve the 'U', which stands for uncertainty, agility has been recommended as the best approach to tackle potential risks (Buckley 2019; van Tulder et al. 2019). The concerns are related to the lack of raw materials, primarily palladium and nickel from Russia, which are needed for the production of components for car manufacturing (catalytic converters and batteries) (Guénette et al. 2022). Also, neon gas from Ukraine, a by-product of large-scale steel production, may cause disruptions in semiconductor manufacturing (Teer – Bertolini 2022). In addition to the lack of raw materials, since 2022, companies have been increasingly facing rising raw material and energy prices, which the war has exacerbated. A significant cost increase must be expected in energy-intensive activities, such as component production (metal processing and surface treatment; Rába 2022; ATV 2022). At the same time, each company is affected by price increases to a



different extent in terms of its energy consumption. The sector reacted to the significant increase in the price of energy by increasing the flexibility of production and introducing strict cost management measures, as well as emphasising the improvement of production processes and efficiency (Rába 2022). In addition to the concerns above, the worsening geopolitical situation creates uncertainty on the longer term.

The unexpected events activated agile reactions by the companies. Indeed, the companies' resilience was challenged. We conducted qualitative research amongst automotive companies in Czechia and Hungary to identify the measures adopted under specific external circumstances. We observe measures increasing agility that would have occurred regardless of the disruption and are deemed proactive, and those that were initiated during the disruption, which are therefore reactive. Proactive measures strengthening resilience were partly inherited from the COVID-19 period.

The paper is structured into four parts. In the literature review, we define agility and observe existing concepts and metrics of agility. Based on the existing literature, we define our research questions. In the second part, we describe the methodology, data collection, and analysis. In the subsequent part, we present how companies reacted to disruptions in sourcing and production. We conclude with implications, research limitations, and recommendations for future research.

2. LITERATURE REVIEW ON AGILITY

2.1. The importance of agility

Agility in the context of supply chain management can be defined as a capability of either the firm's internal supply chain functions or the supply chain itself to adapt in a speedy manner to changes in the market (Swafford et al. 2008). Similarly, Çankaya (2020: 133) refers to agility as to 'the ability to undergo rapid and accurate changes in direction when the conditions require it.' Achieving agility means that the outcome of unpredictable events will be more positive in terms of both financial consequences and maintaining good relationships with clients or suppliers. Agility mitigates risk and increases response. Developing agility can result in a competitive advantage in the long run (Ganguly et al. 2009). Antecedents to the development of this capability are observed in numerous cases (Braunschield – Suresh 2008; Frederico et al. 2021), with one of the antecedents being flexibility (Swafford et al. 2008). The drivers of agility, the imminent need to become agile, strategic intent, or an entire agility strategy cause agility capabilities to be enabled by agility providers – the organisation itself, technology, people, and innovation (Sharifi – Zhang 2001).

Compared to robustness, agility enables actors to find flexible solutions that are often far from the initially intended way of work. Thanks both to timeliness and alertness (Christopher et al. 2004), agile enterprises can quickly switch their usual operations to alternative solutions. In contrast to that, SC 'robustness refers to the firm's ability to sustain and manage efficiently its operations plan under disruptions' (Queiroz et al. 2022: 2003).

There is a relationship between agility and resilience. One of the most frequently cited definitions of resilience (Al Naimi et al. 2022) describes it as 'the ability of a system to return to its original state or move to a new one, a more desirable state after being disturbed' (Christopher – Peck 2004: 2). The literature review by Al Naimi et al. (2022) ranks agility amongst the five most commonly named supply chain resilience enablers together with collaboration,



flexibility, visibility, readiness, response and recovery. Lotfi and Saghiri (2018) support the importance of agility for developing resilience, confirming the positive relationship between the two variables by empirical research. Nevertheless, not all research supported the positive relationship between agility and resilience. Queiroz et al. (2022) present results that did not support the hypothesis that SC agility positively effects SC resilience during a highly disruptive event such as the COVID-19 pandemic. The authors themselves call these results surprising and search for explanations within the specifics of an emerging economy and unprecedented event. Others (Deloitte 2022) see two different strategies with an intersection of some of the capabilities e.g., alternative supplier sourcing can strengthen resilience and support flexibility simultaneously. The need to develop new agile capabilities causes pressure on efficiency, which agile capabilities can increase, but at the same time, are challenged by agile operations management.

Automotive supply chains are characterised by lean management. Compared to lean SCs, which have proven positive outcomes and cost savings in relatively stable and predictable conditions, agile SCs are suitable when demand is volatile and predictability is weak (Çankaya 2020). The combination of leanness and agility in 'leagile' supply chains enables cost-effectiveness and at the same time emphasises high customer service levels in a volatile and unpredictable environment (Agarwal et al. 2006). Sharma et al. (2022) argue that greater vertical complexity (meaning a longer distance between the top and lowest tiers in the supply chain) decreases agility rapidly. On the other hand, horizontal complexity (meaning more options of suppliers to choose from) increases agility – despite increasing administrative and management costs to maintain such a network of suppliers. Automotive supply chains are highly vertically integrated.

We base our study on the resource-based view (RBV), which is suitable when studying logistics capabilities. RBV enables the study of firms in terms of their resources (Wernerfelt 1984), which can potentially be sources of a firm's competitive advantage. Resources are any tangible and intangible assets that can be considered a firm's strengths or weaknesses (Wernerfelt 1984). Resources especially characterised by immobility and heterogeneity can become sources of sustained competitive advantage (Barney 1991). Capabilities are externally focused and are derived from competencies (Prahalad – Hamel 1990). Logistics capabilities can help coordinate a firm's activities, manage a firm's assets, and enhance supply chain agility, enabling firms to react and adjust operations to SC disruptions. Studying logistics capabilities reveals evidence that some of them have a direct impact on SC agility (e.g. increase in stock, an increasing number of suppliers, having more freight options at hand), and some have an indirect impact (e.g. information sharing; Gligor – Holcomb 2014). The strategy of agile SCs requires coordination, communication, and agreement amongst SC members. Therefore, it is difficult to imitate or transmit to different environments. It can result in a competitive advantage in the long run, and it has a positive relationship to performance. Previous research also studied the relationship between agility and cost performance, operational performance, competitive advantage, competitive performance, competitive firm performance, profitability, and firm performance (Çankaya 2020).

2.2. Agility concepts

Li et al. (2008) propose several solutions for agility at the strategic design level (structure of business), operational design level, and episodic design level (immediate reaction to disruptions). These three dimensions differ by the scale of decision impact: big and high-level



questions require strategic decisions with a long-run impact, whereas operational issues on a daily basis require small decisions. However, all of these are interlinked and usually require handling at the same time. Li et al. (2008) also mention flexibility (the range of available solutions, response capability) and timeliness (the speed of adaptation to new realities, alertness) as two main dimensions of agility. These can be discussed at the level of sourcing/procurement (upstream), manufacturing/production, or distribution/logistics (downstream; Swafford et al. 2006). In our research, we focus only on sourcing and manufacturing, as sales and product distribution are quite different disciplines. It might seem that downstream activities do not depend on the firm itself and upstream and manufacturing activities then fully depend on the firm, but firms are located within a complex global value chain, where decisions in both directions are influenced by the value chain altogether. Another way to divide agility solutions is according to how these are achieved – virtual, process integration, network-based, or market-sensitive solutions (Christopher et al. 2004).

Each of the questions in our questionnaire (see Appendix 1) aim to address each of the dimensions of agility. The dimensions are sorted based on the length of the effect and its frequency, location within the firm where the effect takes place, speed and nature of the firm agility capabilities, and focus and actors of the agility capabilities, whether these are centred around customers, within the stakeholder network, or based on integrated processes inside the firm (Table 1).

For example, the question ‘Did production flexibility increase compared to 2021?’ addresses strategic, manufacturing, flexibility, and the process integration dimensions of agility. The question ‘Did you invest more in digitalising your internal processes compared to 2021?’ addresses the strategic, manufacturing, flexibility, and virtual dimensions of agility. On the other hand, ‘Did you increase your own stock compared to 2021?’ addresses operational and episodic, sourcing, timeliness, process integration, and network-based dimensions. Additionally, we find it important to address investments in innovations and digitalisation because digitalisation in operations management and logistics supports information sharing, visibility, traceability, timely risk alertness, and agility (Song et al. 2022). Information sharing has little direct impact on supply chain agility, but it does have an indirect impact through integrated logistics capabilities. This means that information sharing across the supply chain facilitates the development of integrated logistics capabilities (Gligor – Holcomb 2014).

Table 1. Dimensions of agility

Effect length and frequency	Location	Speed and nature	Focus and actors
Strategic	Sourcing	Timeliness	Virtual
Operational	Manufacturing	Flexibility	Process integration
Episodic	Distribution		Network based
			Market sensitive

Source: authors, based on Li et al. (2008), Swafford et al. (2006), and Christopher et al. (2004).



2.3. Metrics of agility

Tsourveloudis and Valavanis (2002: 329) state that ‘agility metrics are difficult to define in general, mainly due to the multidimensionality and vagueness of the concept of agility itself.’ Sarkis (2001) proposes an evaluation matrix based on the topics of resources, technology, processes, environment, and demand. The resources dimension evaluates their availability. The technology metric joins all the firm’s internal capabilities when it comes to business intelligence or product innovation. Processes address the process innovation within the firm. The environment considers all members within the supply chain below and above the firm and other stakeholders affected by the firm’s operations. Demand takes into account all supply chain members above the firm and the changing needs of the final consumer. Ramasesh et al. (2001) offer a quantification of agility to compare various firms’ agility – ranging from product metrics (time to market, number of products, delivery times, number of partnerships during product development), across transformation systems (number of various products, material, volume or schedule flexibility, number of multi-skilled workers, reusability, scalability, etc.) to input (number of supply sources, procurement policy availability, etc.). Yauch (2011) mentions and quantifies two important metrics of agility – success (financial and operational) and turbulence (product customisation, product variety, and relationship with the mother company). Tsourveloudis and Valavanis (2002) propose various measures in the domains of production (e.g. versatility, substitutability, or commonality), market (expansion ability, range of volumes), people (training, job rotation, etc.), and information (interoperability).

Measures can be distinguished as proactive (i.e. being an initiative of the firm itself without specific ‘push’ factors) or reactive (i.e. being forced by external influence). Tsai and Lasminar (2021: 2) coin proactive measures as ‘how the company adjusts to the changes in the external environment’, in other words how companies’ supply chain systems introduce new ideas to the market’ (i.e. proactive manufacturing, product development, supply and distribution flexibility). Meanwhile, reactive measures are seen as ‘the adaptive capabilities of companies’ supply chain management to the uncertainty of market conditions.’ Reactive measures mean creating ‘buffers’ (Angkiriwang et al. 2014) or ‘protections’ (Ivanov et al. 2017), such as increasing stock, improving production capacity buffers, searching for supplier backup, or announcing longer safety lead times. In contrast, proactive measures serve for ‘redesigning’, such as component commonality, postponement, risk pooling, outsourcing, creation of flexible supply contracts, lead time reduction, setup time reduction, and alternative routings. Elluru et al. (2019) point out that proactive measures encompass all the firm’s actions where risks are evaluated and considered before they transform into real events.

When it comes to the speed and cost of the measures, Ali et al. (2021) have categorised possible solutions into a matrix using two categories – fast vs. slow responses, and expensive vs. cheap responses. For example, communication improvement is a fast and relatively cheap response. On the other hand, increasing back up capacity and developing a supply chain network is a relatively slow and expensive solution (Table 2).

Scholten et al. (2019) determine six learning mechanisms by which companies foster their supply chain resilience: processual learning (leading unintentionally to new operating routines) vs. anticipative learning on an intentional basis; situational learning vs. collaborative learning as a response measure; experiential learning vs. vicarious learning as a recovery measure.



Table 2. Speed vs. cost of reactive measures

Expensive – fast: contract flexibility, backup suppliers, easy switching of suppliers, knowledge sharing
Expensive – slow: mutual created knowledge, joint decision making, inventory buffer, backup capacity
Cheap – fast: communication, information sharing, quick supply chain design, distribution channels, flexible production, volume flexibility, coordination, cooperation, training, resources slack, multiple suppliers
Cheap – slow: multi-skilled workforce, culture and mindset

Source: authors, based on [Ali et al. \(2021\)](#).

The literature review reveals that external conditions are usually not taken into account, but at the same time, they are mentioned as important factors influencing the conditions, such as demand stability and predictability ([Çankaya, 2020](#)). Therefore, for our study, the settlement into a specific time is highly important. Our research also fills the gap described by [Aldrighetti et al. \(2021\)](#), pointing to the lack of research investigating the integration of different proactive and reactive measures. We define our research questions as follows:

- RQ1: What was the impact of the war on automotive supply chains?
- RQ2: What were the reactive measures adopted by companies?
- RQ3: What proactive measures were adopted by companies, and how did they change during the war?
- RQ4: How do companies combine proactive and reactive measures?

In our paper, we reflect above all on the contrast between reactive and proactive measures. Also, in accordance with [Sarkis \(2001\)](#), during our interviews the questions are structured in the particular categories of resources (topics like stock or workforce), technology (IT and digitalisation), processes (process and product innovation, reduction of product development time, delivery times), environment (external disruptions, how the war has impacted production) and demand (changes in demand). We specifically ask about the situation of agility related to the product, transformation and input, as reviewed by [Ramasesh et al. \(2001\)](#).

3. METHODS

Similarly to [Montenero and Cazorzi \(2021\)](#), we employ a semi-structured interview approach. Cases were selected based on convenience or the snowball approach to become instrumental for generalising certain concepts within the selected industry ([Fletcher et al. 2018](#)). The interviews took place via phone calls with mid- and upper-level managers. The length of the interviews ranged from 30 to 50 min. The average interview lasted 40 min. We collected the data in September and October 2022. We included eleven companies from the automotive industry, eight from Czechia, and three from Hungary. The difference between the Czech and Hungarian samples was due to the fact that some responses were not assessable and, therefore, some companies had to be excluded from the sample. Automotive companies have been in an extremely tense situation due to recent supply chain disruptions. Management was significantly overworked and, despite repeated requests, it was difficult to find an opportunity to conduct an interview.



Amongst our sample, we have selected only large companies with significant production capacity and a significant number of suppliers. In all the cases, the companies in the automotive sector achieve operating revenues between 95 and 1,200 million Euros. They range from TIER 1 to TIER 2 suppliers. Information about the cases are included in Table 3. Besides general information, we include supply chain characteristics with regard to Ukraine and Russia. Managers answered the question as to whether the company had suppliers from Ukraine or Russia or whether they supplied to these countries. There are companies in our sample that did not report direct business relations within these countries, but they were impacted indirectly by the situation.

On the one hand, the sample selection limits the generalisation of our findings; on the other hand, the supply chain agility concept emphasises companies' organisational design to master the changing conditions. Focusing the research on large companies can reveal new insights into agile practices amongst large firms (Gligor – Holcomb 2014). In our questionnaire, we asked about the first half of 2022, which included the invasion Ukraine by Russian troops and the

Table 3. Information on cases and interviewees

Case	Classification of economic activity (NACE codes)	Supply chain position	Supply chain characteristic with regard to Ukraine and Russia	Interviewee position	Country
A	2910	TIER 1	Supplier from Ukraine	Supply chain manager	Czechia
B	2932	TIER 1	Supplier from Ukraine	Project manager	Czechia
C	2932	TIER 1	Suppliers from Ukraine	Supply chain manager	Czechia
D	2932	TIER 1 and 2	Supplies to Ukraine and Russia	Project manager	Czechia
E	2453	TIER 1	-	Head of finance	Hungary
F	2610	TIER 1	Supplies to Russia	CEO	Hungary
G	2932	TIER 1	-	Production manager	Czechia
H	2561	TIER 1	Supplier from Russia, supplies to Russia	Head of finance	Czechia
I	2813	TIER 2	-	IT Manager	Czechia
J	2932	TIER 1 and 2	Supplier from Russia/Ukraine, Supplies to Russia/Ukraine	Factory director	Czechia
K	2611	TIER 1	-	Purchasing and Logistic Director	Hungary

Source: authors.



following months, during which the companies were adopting reactive measures to secure their supply chains.

The interviews were transcribed in MS Excel, and coding took place by four independent researchers. Two independent researchers developed the categories for responses and two other researchers coded the responses and sorted them into predefined categories. During the process of coding, the categories that were based on our literature review led us to distinguish between ongoing development in the longer term (strategic and operational) and immediate (episodic) responses to the Russian-Ukrainian war to compare intended and unconscious changes and, finally to distinguish between reactive and proactive measures. We identified which actions had to do with the timeliness of supplies/production and which with the flexibility of sourcing/production options. Each of the questions (please refer to [appendix](#)) was categorised in each of the dimensions, and many of them were meant to test the presence of actions contained in our research questions.

4. EVALUATION OF RESULTS

4.1. The impact of the war on companies

The companies in our sample were exposed to the impact of the war directly and indirectly. Six companies (A, B, C, H, J, and K) were supplied (through external suppliers or their own subsidiaries) from Ukraine or Russia, two companies had a customer in Russia (D, J), and the other four companies (E, F, H, and I) had no direct trade relations with Ukraine or Russia. The indirect impacts on the automotive industry were through the embargo, the losses of OEMs and other producers on the Russian market, and rising energy prices. The quotes from the interviews below illustrate these:

We were hit extremely hard; the production of cable harnesses is centralised in Ukraine. The companies, which are often European, tried to behave responsibly. On one hand, they helped employees and their families, on the other hand, they tried to start the production with the help of Ukrainians who came from Ukraine. To replace the production took maybe two months. (A)

We have one supplier in Russia. All payments from Sberbank were blocked. (H)

We had no direct relations with Ukrainian or Russian suppliers. However, due to the embargo against Russia, we lost an important customer. (F)

We have no supplies from Ukraine or Russia, but our production is affected due to the gas price increase. (G)

Company G's worries are common for the entire sector, which is concerned about inflation.

4.2. Reactive measures adopted by the companies to mitigate supply chain disruptions

The war created problems in sourcing from the directly affected countries. Delocalisation of production and sourcing from other territories was amongst the reactive measures adopted at the strategic level by companies that strived to secure supplies of products and materials



previously supplied from Ukraine or Russia. The exports from Ukraine were, on the one hand, supported by the European Union through the suspension of EU import duties (European Parliament 2022). On the other hand, delays at Ukrainian borders caused disruptions in supply chains. From our respondents, we learned that the war did not affect their sourcing strategy in most cases. The sourcing strategy undergoes strategically based changes and is competitive-focused rather than of a short-term reactive nature.

We multiplied sourcing in semiconductors or electrical parts in general. There are no effects of the war. We were affected by COVID-19 in China or by the capacity of airports and harbours or by staff strikes. (C)

In the first half of 2022, the sourcing strategies reflected the increase in prices and availability of products. Several responses related to the flexibility of sourcing, yet some companies did not identify any changes in their sourcing strategy, emphasising the costs and sensibility of the management of suppliers. This strategy contributed to strengthening the supplier network.

Expanding the supplier portfolio is one of the strategies to ensure stable supply. In any case, it can be applied mainly to auxiliary production materials. For main product materials and components, it is not realistic. There are planned processes, products, and contracts that take more than a year to change. (D)

Decision-making on reactive measures is supported by information sharing between the companies in the multinational's portfolio. Timely information contributes to the supply chain's speed of responsiveness to potential problems in sourcing. Our sample companies confirmed improved internal communication, but at the same time, no changes in external communication in the first half of 2022.

We have learned from COVID-19. We report to headquarters, a process left over from COVID-19, and receive information from sister companies. There is a customer that successfully plans, processes forecasts and communicates with us better than before COVID-19, but it is not always the case. (A)

A major shift in communication was the implementation of automated information exchange within the company. (I)

The management of stocks was impacted by the uncertain global situation, not by the war. Most of the companies applied a proactive strategy of increased stock of critical parts and did not change the strategy of low stock. However, there were companies (E and K) that tried to increase their stocks, but this was only limited to preventing temporary disruptions. Stock management was reactive in episodic situations that occurred on specific projects where, due to supply disruptions, companies were forced to search for alternative supplies or, where possible, alternative materials.

Some of the raw materials required for production come partly from Russia and Ukraine... here we are constantly switching to alternative sources of supply. (K)

Companies in our sample mentioned flexible production planning, rescheduling, and replanning. The decrease in demand was compensated by the decrease in the number of agency workers. The measures were reactive at an operational level. Flexible work contract arrangements depend on individual companies and the position in the company.



The demand is basically influenced by the production of integrated circuits, which is considered a bottleneck. (F)

Clients reduce demand when they lack other components like chips or cables. (H)

... sales numbers are still low, but the reason for this is not demand, but supply bottlenecks. (K)

With a stable supply base, no strategic transportation and routing decisions were adopted. Switching between transportation modes was a reaction to unexpected supply disruptions, routing constraints over Russian territory, capacity constraints, or changes in demand. Proactive measures were adopted at the operations level. Changes in demand were solved through proactive measures in transportation or flexible production planning.

We do not decide on the delivery methods at the company level. Depending on the needs, a specific division may change the delivery methods during daily operations. (F)

In 2021, the company greatly shortened the speed of its transport systems, when it switched from shipping to rail for import shipments from Asia...the Russian-Ukrainian war partially affected the delivery routes of the goods. We have since adapted to this and are once again delivering by rail on alternative routes. (K)

4.3. Proactive measures applied to mitigate supply chain disruptions

The strategy of increased stocks of critical components remained from the COVID-19 period. Increased stocks enable quick response to changes in production (timeliness), but burden a company's cash flow, represent additional costs, and the application of such a strategy is limited by suppliers' availability of materials and parts. In general, the industry applies a strategy of minimal stock and stock increases only due to volatile material availability, forecasts, and in the case of strategic components.

The sample companies were unanimous that no measures were adopted to increase visibility or transparency along the supply chains. Strategic considerations often play a role in this. Companies are reluctant to share all information with each other. Visibility can be increased by complete information about the inventory along the supply chain, lead times, delivery dates, or information about firms involved in the SC (Song et al. 2022). This either means that companies already have complete information or that there is no will to share more information within the SC.

We need and we do have an overview over the flows. (A)

There are standard tools for reporting and settings in SAP. Purchasing tools are standardised and already very transparent for a longer time. (C)

To avoid being vulnerable to their partners, companies do not share all information. (F)

There are no changes in reporting requirements. (G)

Due to the lack of spare parts during the epidemic, companies facing downtime wanted to reduce it, so they transformed production processes. Therefore, thanks to the measures taken earlier, these companies did not have to develop new measures for the production transformations necessary for the current supply chain disruptions.



There was no need to redesign production. The necessary measures were already taken during COVID-19. (E)

Due to supply difficulties, certain companies increased their inventory during the pandemic, and this practice has also been maintained in the post-COVID period. However, this has not become common, as it depends largely on the suppliers and the number and complexity of the products. In addition, an excessively large inventory also results in additional costs for inventory management.

We have increased inventory in some parts. This remains from COVID-19. (A)

During COVID-19, we had the opportunity to stock up, and we still use it today. During the course of COVID-19, the company embarked on quite a few developments, including warehouse stock, which can provide a much faster response to problems... (E)

The semiconductor shortage during the post-COVID recovery significantly reduced production, which the companies tried to solve by procurement strategies and increasing the number of suppliers. Multiple sourcing is also used in the case of current supply chain disruptions.

...we multiplied sourcing in semiconductors and electrical parts in general. (C)

The procurement/sourcing system was reformed as a consequence of COVID, not in 2022. (G)

For some critical electronic components, additional suppliers were also involved. (K)

The same company reported that the rules for selecting a supplier did not change in the first half of 2022, which was the case also for other companies in our sample.

The system was reformed as a consequence of COVID-19, not in 2022. (G)

It seems that proactive measures, such as additional supplier selection criteria, were applied as a reaction to the pandemic in the previous two years.

As a result of COVID-19, relations within transnational companies have strengthened. During the closures, the widespread use of digital solutions (IT) made communication within a company more efficient. In particular, the frequency of communication with headquarters and other subsidiaries increased, a practice that has continued ever since. Companies utilised this during the current shortage of spare parts, solving supply chain disturbances by predicting them and reducing reaction time.

...you can see that we have learned from COVID, the set communication has remained, and it helps significantly even now. (A)

At the corporate level, a central organisation holds regular discussions with suppliers about the allocation of available shipments. This information is also delivered to the factories through a digital interface. (K)

Developments in data and database analysis introduced during the epidemic improved the ability to plan production and reduce losses.

'...data analysis methods are continuously changing. Development is a continuous process' (C)



Special attention has been dedicated to technologies and digitalisation. Some respondents emphasise investments in the virtual dimension with ongoing automation. These measures are nothing new. Nevertheless, investments into remote work opportunities, virtual collaboration of teams, EDI, and automated monitoring of office and factory operations had already been going on for some time and, according to responses, were not impacted by the war.

4.4. Agility development through reactive and proactive measures

After coding the responses and assigning different agility dimensions to each reply, we found that firms do not act consciously towards increasing their agility. The scores presented in Table 4 are relatively low. Solutions for episodic issues had a slightly higher usage (34% of the replies indicated a possible agility increase at the episodic level). While sourcing was hardly dealt with, manufacturing received relatively more attention. Timeliness and flexibility were addressed in 28% and 29% of the situations, respectively. From the content of the agility measures, virtual solutions had a positive reply in 31% of the cases, process integration only in 24%, network-based (i.e. agility measures focused on increasing collaboration with other stakeholders, mainly suppliers) gained 27%, and, most of all dimensions, market-sensitive solutions attracted 42% of the possible replies.

To further analyse how companies combine proactive and reactive measures, we first grouped the measures retrieved from the qualitative data analysis into categories and linked the proactive and reactive measures based on individual cases. Figure 1 visualises the reactive and proactive measures related to sourcing, and Fig. 2 to manufacturing. Each line represents one company. The thicker line represents the situation in more than one company. This is the case when different companies apply and combine the same measures.

Firstly, we observed the measures related to sourcing. Figure 1 shows that multiple sourcing in the automotive sector is not commonly applied as a proactive measure, and if applied, then linked to stock increases for strategic components. By contrast, multiple sourcing to face suppliers' interruptions or as a solution to non-available supplies by existing suppliers, as described by Aldrighetti et al. (2021), is applied by companies in our sample. The important proactive measure in relation to reactive multiple sourcing or sourcing relocation is visibility and transparency. Visibility is also linked to alternative transportation, which seems to be the most applied reactive action. Nevertheless, finding alternative transportation was not without problems, as acknowledged by the companies that reported congestion and capacity problems. Alternative routing is linked to the requirements of suppliers. The search for alternative routing

Table 4. Proportion of firms addressing the agility dimensions

Strategic	30%	Sourcing	21%	Timeliness	28%	Virtual	31%
Operational	30%	Manufacturing	36%	Flexibility	29%	Process integration	24%
Episodic	34%	Distribution	n/a			Network-based	27%
						Market sensitive	42%

Source: authors.



Sourcing

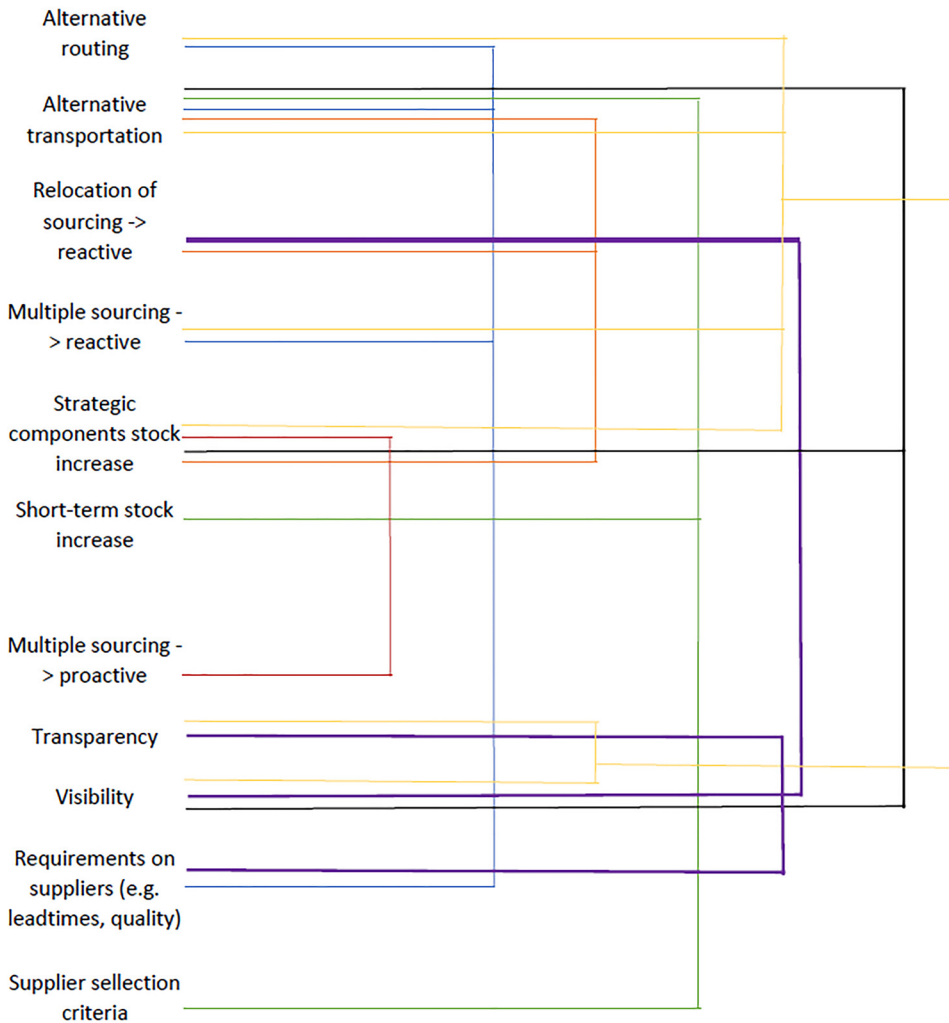


Fig. 1. Links between proactive and reactive measures applied in sourcing
 Source: authors.

does not stem from the war, but the war has created the necessity to search for alternative continental, mainly rail routes connecting Asia and Europe.

Second, we focused on manufacturing and demonstrate the results in Fig. 2. Companies were forced to replan production as a reaction to supply or demand fluctuations. These reactive measures were named together with internal communication (in the company or amongst the multinational’s affiliates), data analysis, and digitalisation. In one case, these measures were



Manufacturing

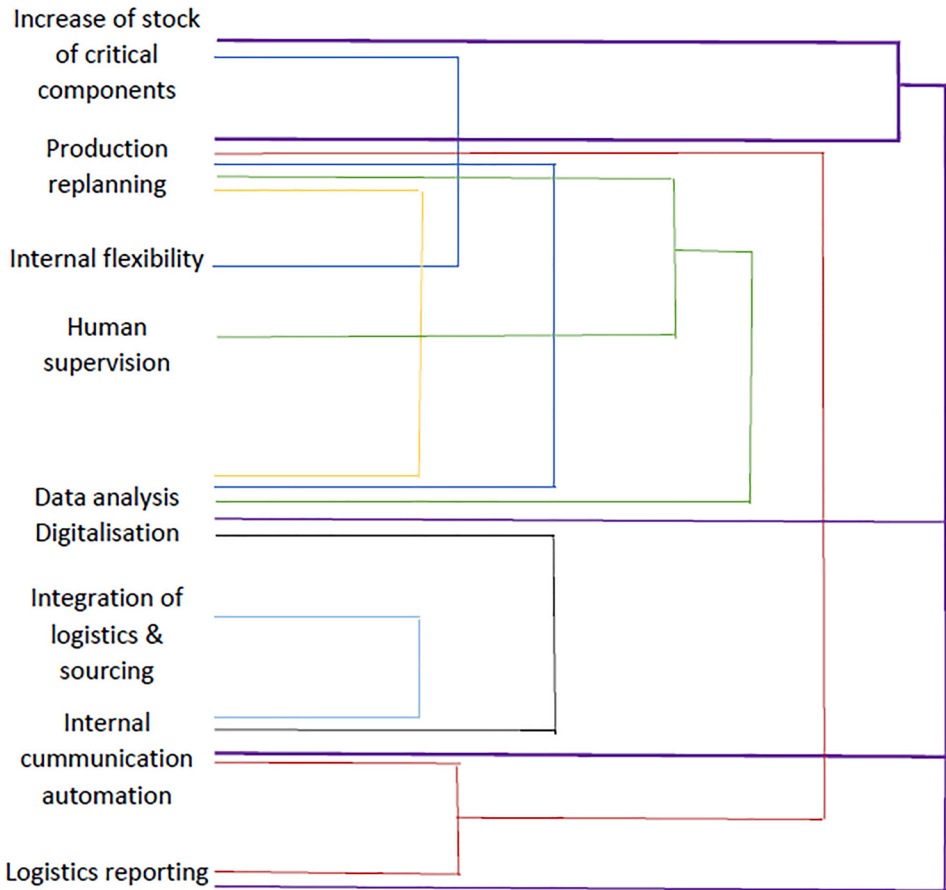


Fig. 2. Links between proactive and reactive measures applied in manufacturing
 Source: authors.

applied together with manual supervision. Supply chain disruptions result in more demanding work for employees and depend on human supervision and decision-making. This reactive measure can be supported in the long term by digitalisation, data analysis tools, and an up-to-date databases. Flexibility in production is enabled by available stock as well as the preparedness of the workforce. The increased stock of critical parts was mentioned together with internal communication. We believe that the increased stock needs to be first justified and well adjusted, and second, acquired. Internal communication can support the successful management of critical components. Companies mentioned less the interaction of production flexibility and logistics and strategic sourcing. Still, this link is worth further attention.



5. DISCUSSION

Automotive suppliers have limited possibilities to apply sourcing from different suppliers or to switch between them. This strategy's application depends on the complexity and type of sourced goods and materials. The global raw materials and spare parts shortage also limits the companies' room to manoeuvre. In the case of complex or highly processed products, the necessary joint technological development and quality assurance hinder a short-time supplier change. The diversification strategy increases administration and quality management costs (Sharma et al. 2022).

The results in Table 4 indicate a fairly low involvement of automotive suppliers in the transformation towards a more agile firm. It should be added that, as several of our interviewees pointed out, although supply chain disruptions are part of daily business, they had never encountered disruptions of this magnitude and duration before. Maintaining day-to-day operations took up all their resources. Many of the solutions demonstrate simple responsiveness in the face of surprising events and long-term ongoing projects often imposed by the owner, parent firm, or lead client(s). This goes hand in hand with the result that the highest proportion of possible agility actions was identified in the market-sensitive dimension of agility (48%). In the results of the survey, no differences could be found between Czech and Hungarian companies. The difference between the responses was rather individually based on the nature of the product, the raw material requirements, including the place of sourcing, and the complexity of the product.

Coming back to the supply chain agility parameters, as presented by Tsourveloudis and Valavanis (2002), we see that most new changes mostly involve the market (range of production volumes, expansion ability), and many in information (interoperability and network). There are activities in production agility, yet they do not seem to be very agile after all (versatility of production and substitutability of suppliers, part variability, etc.). The safety buffers mentioned by Angkiriwang et al. (2014) have several limitations. In many cases, it is not even physically possible, and it would be an excessively large financial burden for the supply chain (in terms of production and logistics).

The ultimate objective of the respondents is increasing business success and addressing turbulence, as coined by Yauch (2011). The framework of Ali et al. (2021) on the nature of agility responses has not really been utilised, as respondents were reluctant to share the costs of the used measures. However, from the description, we can identify that all kinds of responses were utilised – slow and expensive ones like digitalisation, and cheap and fast solutions, like improved communication, information sharing or resources slack.

During the COVID-19 pandemic, companies experienced rising operational expenses. Based on annual reports and our interviews, the effort of automotive companies was to increase efficiency. The rising inflation rate in 2022 multiplied this effort which might have limited the effort in developing agile logistics competencies. Likewise, Aldrighetti et al. (2021) linked the increased robustness and resilience to increased operational and investment costs. On the other hand, we learned that companies reacted flexibly despite the increased operating costs to satisfy customers' demands.

The information revealed has an important mediating role. Companies achieved the most progress in communication during the COVID-19 pandemic. The introduced measures were preserved to support resilience. In addition to previous research, our findings support the findings of Gligor and Holcom (2014), that information enables supply chain agility.



6. CONCLUSION, IMPLICATIONS, AND RESEARCH LIMITATIONS

Researchers need to be sensitive to business realities in the first place. Implementation of any change brings about costs and operational risks, above all among these the risk of employee rejection or implementation failures. Also, in the case studies, we have sensed large determinism and subjection to the needs of large clients, usually OEMs.

Based on our research, we recommend investing in alternative solutions, provided the costs are reasonable (e.g. having a list of available suppliers when not having to process lengthy compliance monitoring sessions, or investing in joint stock monitoring mechanisms in cases where the data are already available in various locations). In cases where it does not strongly affect the operations of the firm and its suppliers, firms could work on the integration of logistics capabilities, as suggested by [Gligor and Holcomb \(2014\)](#), yet being sensitive and avoiding too much vertical integration or maintaining managerial slack ([Sharma et al. 2022](#)).

Also, in times when skilled workers are scarce, firms should invest in the training and development of their employees, so they can become more versatile and be diverted to activities that firms need when reacting to short-term disruptions. Even during COVID-19, it became clear that companies can reduce their losses with efficient and flexible work organisation during supply chain disruptions. One of the prerequisites for this is the preparedness of the workforce. Good reporting capabilities and business intelligence that is not costly and easy to use and analyse should be implemented. Any reduction of manual input into the decision-making processes will definitely yield profit in the long run and will reduce the time necessary for action during crises – in the moments when employees/managers are usually under a lot of pressure tackling emergent situations. This will increase a firm's capabilities ([Pralhad – Hamel 1990](#)) and reduce the costs of tackling problems while increasing competitiveness in the long run ([Ganguly et al. 2009](#)).

Geopolitical tensions remain a threat to the future, and territorial risk is part of risk management. This will affect strategic sourcing and supply chain management. Future research topics will relate to sourcing locations and strategies. Similarly, as [Scholten et al. \(2019\)](#) describe six learning mechanisms through which supply chain resilience can be improved, we found that some of these also happen within our sample. Resilience studies questioning the issue of measuring the effectiveness of different solutions will be relevant for future research. Our research addressed the development of internal logistics solutions, but there is potential for developing SC capabilities along the SC. The future research question is how SC flexibility is achieved in extreme external conditions and what SC solutions were applied.

Our research is mainly limited by its focus on large firms. The limited sample and qualitative research methodology limit the generalisability of our research. Being aware of this limitation, we carefully worked with the existing variety of companies in our sample. We look at diversity rather positively, proposing a variety of managerial implications. We cannot separate one event from the global conditions impacting automotive SCs. Still, we believe that the qualitative research provided a complex picture of the situation during outbreak of war on the continent, and the reactions and readiness to react of Central European companies. We extended the existing theory mainly by answering the fourth research question.



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Appendix 1. Questionnaire

Introductory questions

Main activity (NACE):

Year of establishment in Hungary/Czechia:

Headquarters and establishments in Hungary/Czechia:

Legal status in Hungary/Czechia (Ltd. etc...):

The number of employees in Hungary/Czechia, of which physical and intellectual (management, administrative, and R&D):



International relations of the company

- Do you or your parent company have a subsidiary in Russia?
- Do you or your parent company have a subsidiary in Ukraine?
- Do you have supplier relations in Russia?
- Do you have supplier relations in Ukraine?
- Do you supply to the Russian market?
- Do you supply to the Ukrainian market?
- Due to the current situation, have there been any supply chain disruptions with Russian or Ukrainian companies?
- Are you experiencing a decrease in orders due to the embargo against Russia?
- How have sales developed in the first two quarters of 2022 (Q1, Q2)?

Resiliency (resilience of companies) - general questions

The following questions ask how the company's operations have changed in the current year (2022) as a result of the Russian-Ukrainian war.

1. Reduce product development time compared to 2021
How did the Russo-Ukrainian war affect this change?
2. Increase production flexibility compared to 2021
How did the Russo-Ukrainian war affect this change?
Were you replanning production based on the availability of materials/parts?
Were you replanning production based on changes in call-offs?
3. Did you invest more in the digitization of your internal processes compared to 2021?
How did the Russo-Ukrainian war affect this change?
What kind of processes? Was there any field of digitalization that you invested in/developed?
4. In order to secure deliveries, companies rely on several suppliers (multiply sourcing).
Did you increase the number of suppliers compared to 2021?
How did the Russo-Ukrainian war affect this change?
5. Did the criteria for selecting a supplier change?
How did the Russo-Ukrainian war affect this change?
6. Did you adjust your data analysis methods in supply chain management compared to 2021?
How did the Russo-Ukrainian war affect this change?
7. Did you increase your demands from your suppliers compared to 2021?
How did the Russo-Ukrainian war affect this change?
8. Do you have more flexible work arrangements compared to 2021?
How did the Russo-Ukrainian war affect this change?
9. What internal process did you speed up compared to 2021?
How did the Russo-Ukrainian war affect this change?
10. Increase "visibility" of suppliers (e.g., daily reports) compared to 2021:
How did the Russo-Ukrainian war affect this change?



11. Did you increase transparency in supply chain management/selection of suppliers compared to 2021?
How did the Russo-Ukrainian war affect this change?
12. To create more common inventory lists of suppliers' reserves compared to 2021:
How did the Russo-Ukrainian war affect this change?
13. Did you increase your own stock compared to 2021?
How did the Russo-Ukrainian war affect this change?
14. Increasing and shortening the speed of the delivery system compared to 2021:
How did the Russo-Ukrainian war affect this change?
15. Change of logistics (change to air, rail, change of carrier?) compared to 2021?
How did the Russo-Ukrainian war affect this change?

Resilience - priority factors

Are you able to cope with changes brought by SC disruptions better than in 2020/2021? Why?

RESILIENCE

Do you always have complete information like inventory availability, lead times, delivery dates, and what firms are engaged in our supply chain? If changed, why?

VISIBILITY

Is speed important for you when selecting a supplier? Can the supply chain respond quickly to special requests? If changed, why?

RESPONSIVENESS

Is it possible to switch the purchase of one item to another supplier? Can you change the number of our orders? Can you cope with demand fluctuation?

FLEXIBILITY

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