Technological Forecasting & Social Change 184 (2022) 122029

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Transition to electric vehicles in Hungary: A devastating crisis or business as usual?

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ARTICLE INFO

Keywords:
Transition to electric vehicles
Industry life cycle
Upgrading
Central Europe

ABSTRACT

This paper discusses the impact of the transition to electric vehicles on the Hungarian automotive sector that is highly specialised in the manufacture of internal combustion engine vehicles and parts. Building on the industry lifecycle theory, we argue that electrification conveys many opportunities for upgrading, since it requires such a proliferation of innovative tasks that, coupled with a tight deadline imposed by the European regulatory framework, can be accomplished only through further decentralisation of R&D activities.

Based on twenty expert interviews in Hungary and a review of global automotive actors' electrification-related transactions in central Europe, we find that the manufacturing-led growth model is not jeopardized by the transition to electrification, at least not in the medium run. Data suggests, however, that chances to harness the opportunities of electrification for meaningful industrial upgrading are low. Results predict continuity rather than radical change.

1. Introduction

Three of the four trends that are expected to transform the automotive industry: autonomous driving, shared mobility, and connected cars – are considered a more or less distant threat by incumbents and observers. By contrast, the responses of original equipment manufacturers (OEMs) to external pressures, such as strict emission regulations and city bans for internal combustion engine (ICE) vehicles, suggest that the fourth trend, electrification may soon be disruptive.

Indeed, transition to electric vehicles (EVs) progresses rapidly, stimulated by a variety of demand-side incentives fostering EV adoption and ever-stricter emission standards. Several OEMs have pledged to switch to all-electric vehicles and phase out ICE vehicle production, and the share of EVs in established manufacturers' product mixes is foreseen to increase from 5 % in the early 2020s to 25–30 % within a decade (Küpper et al., 2020).

Academics and practitioners alike subscribe to the view that electrification is reshaping automotive value chains: both the spatial organisation of automotive industry-related activities and the distribution of value added across value chain participants.

Discussing the ways in which the adverse impacts of EV transition can be mitigated, academic and policy discourse has so far been limited to analysing the fate of advanced economy OEMs and suppliers (Galgóczi, 2020; Lefeuvre and Guga, 2019). In contrast, relatively little attention has been devoted to investigating how the economic impacts of the transition cascade down to actors specialised in production activities within the East-Central European automotive industry (Krzywdzinski, 2019; Simonazzi et al., 2020).

The lack of this regional perspective is all the more puzzling, since due to their manufacturing-led growth model, reliance on foreign direct investment (FDI), and a strong specialisation in the manufacture of ICE vehicles and parts (Krzywdzinski, 2019; Pavlínek, 2015, 2020), the central and eastern European (CEE) countries may be hit particularly hard by this transition.

Moreover, EV production is characterised by highly automated manufacturing procedures and a massive reliance on digital technologies. This feature, alone, presents formidable threat to countries competing on the basis of low labour costs, and pursuing foreign direct

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https://doi.org/10.1016/j.techfore.2022.122029
Received 26 June 2021; Received in revised form 24 June 2022; Accepted 5 September 2022
Available online 14 September 2022

investment to sustain manufacturing-led development (Myant, 2018).

While there is general consensus that these countries will be hit hard by the shift to EVs, the flipside of the coin, the opportunities electrification represents for the upgrading of the manufacturing actors has not received the attention it deserves. Previously, in the era of the FDI-driven rapid modernisation of CEE, the upgrading opportunities and performance of local automotive actors have received substantial research attention,[1] and the limits to their FDI-driven upgrading was also extensively discussed (Krpec and Hodulák, 2019; Krzywdzinski, 2017; Micek et al., 2021; Pavlínek, 2015, 2016; Pavlínek and Ženka, 2016). The shift to battery-driven powertrains has brought this latter issue again to the fore. Due to its early integration in European and global automotive value chains (Guzik et al., 2020; Jürgens and Krzywdzinski, 2009), the CEE automotive sector is strongly specialised in ICE assembly and ICE parts and components production. Nevertheless, and despite the fact that 'e-shift' is gradually approaching a tipping point, where EVs move from niche products towards the mass market, there is a paucity of literature on the impact of electrification on the fate of the CEE automotive industry, in general, and on its upgrading opportunities and contingencies, in particular (Krzywdzinski, 2019; Simonazzi et al., 2020).

The purpose of this paper is to address this gap in the literature. Drawing on interviews conducted with twenty automotive stakeholders and experts in Hungary, we explore whether and how automotive subsidiaries can leverage this transition for upgrading. This research builds on the industry life cycle theory (Abernathy and Utterback, 1978; Klepper, 1997; Kuznets, 1930) as a theoretical framework. We argue that electrification pushes the automotive industry backwards along its life cycle (rejuvenation), which creates new upgrading opportunities for an array of value chain actors – including pure manufacturing-specialised ones.

Ever since the seminal article by Abernathy and Utterback (1978), the concepts of both the industry life cycle and rejuvenation have been extensively discussed in the literature. The car is a frequently cited example demonstrating automotive firms' successful rejuvenation strategies (Fujimoto, 2014; Schulze et al., 2015). The introduction of EVs has also been analysed through the lens of innovation economics and shown that it qualifies both as systemic and disruptive innovation that leads to the rejuvenation of the automotive industry (Von Pechmann et al., 2015). What sets this paper apart from other studies is that we conceptualise the current rejuvenation phase of the life cycle as a confluence of different types of R&D that are in theory characteristic for different phases of the industry life cycle. We argue that the recent hardening of the European regulations of automotive emissions (Pardi, 2021) push for OEMs' hasty transition to EVs, which condenses the current rejuvenation phase of the industry life cycle. We relate the emergence of opportunities for subsidiary upgrading to parent companies' quest to keep up with the regulation-driven race to electrification and address the concurrent intensification of all types of R&D by (further) decentralising and distributing innovation activities within their global organisations.

Based on a purposeful sample of twenty expert interviews, complemented with a scoping review of global automotive actors' electrification-related strategic transactions in central Europe, we propose that the electrification-induced deterioration of economic indicators, such as employment, GDP and export is not fate. Building on the industry life cycle theory, we show that electrification conveys many opportunities for upgrading – even for value chain actors currently specialised in ICE-specific manufacturing.

These opportunities, however, are not necessarily identified, seized, and exploited. Therefore, it is essential to explore stakeholders' perceptions and approaches to be able to predict whether and what kind of upgrading might actually happen. Accordingly, the research questions to discuss in this paper are: 1) What are the impacts of the transition to electric vehicles on global automotive companies' local subsidiaries specialised in ICE-specific manufacturing? 2) Which are the possible upgrading trajectories related to the e-shift in the automotive industry for these actors?

The context of the research is Hungary, a country markedly exposed to automotive FDI (Gerőcs, 2022; Molnár et al., 2020). In 2019, the share of the automotive industry in both manufacturing GDP and manufacturing exports was 29 %. Direct automotive employment accounted for 4 % of total and 17.8 % of manufacturing employment. Foreign-owned automotive companies made up 92 % of total automotive sales (Central Statistical Office). Automotive industry epitomises the dual economic structure that characterises CEE economies, exhibiting large gaps between domestic and foreign companies in value added, productivity, R&D intensity, and digital maturity (Drahokoupil, 2020). Total industrial robot deployment is predominantly concentrated in the automotive sector, and robotisation is largely confined to foreign-owned companies, exemplifying what Czéfalvay (2020) referred to as *'dependent robotisation'*.[2]

This dual nature of the industry made us focus only on the upgrading opportunities of foreign-owned companies (the local subsidiaries of global automotive companies) since the upgrading perspectives of domestic-owned companies specialised in the manufacture of automotive parts and components are different from those of foreign-owned subsidiaries.

Our analysis of experts' perceptions and approaches to electrification contributes to the nascent literature on the impact of the transition to electric vehicles in the integrated periphery of Europe. From a theoretical perspective, this research contributes by portraying the current rejuvenation stage of the automotive life cycle as a concurrent intensification of science-based research, new product development, and process development. Opportunities for upgrading are explored through this theoretical lens, which allows for going beyond ringing alarm bells with respect to the fate of countries excessively specialised in the manufacture of ICE-specific parts and components and moving the needle on the upgrading opportunities brought about by this transition. Another contribution concerns the under-researched context that this study focuses on. Most of the prior micro-level studies discussing automotive incumbents' adjustment to technological discontinuities focused on lead companies (Bohnsack et al., 2020; Song and Aaldering, 2019; Werner et al., 2022). In contrast, this study is concerned with actors specialised in activities represented at the bottom of the smile curve of value-added (Mudambi, 2008). Our findings can be used as a basis for comparative explorations of the potential impact of EV transition in other FDI hosting factory economies that are similarly exposed to ICE-specific manufacturing. From practical and policy perspectives, our analysis of developments and experts discourse shows the limits of the

[1] The concept of upgrading concerns the ways countries, regions and firms increase the value added of their activities to improve their positions within global value chains (Fernandez-Stark and Gereffi, 2019; Gereffi, 1999). Humphrey and Schmitz (2002) identified four types of upgrading at the firm level. These include product upgrading (moving to higher-value products); process upgrading (improving the efficiency of the production process by introducing process innovations); functional upgrading (moving to or diversifying the activity mix with activities the value added content of which is higher than previously); and chain upgrading (moving to new industries and/or entry in new value chains).

[2] Drahokoupil (2020) compared the differences between the automotive and other industries in terms of industrial robot density. He showed that the automotive to other sector ratio of industrial robot density is much higher in CEE than in advanced economies. For example, in 2018, this indicator was 8.0 in Hungary, 9.0 in Czechia, and 19.9 in Slovakia. At the same time, the German, Italian, and Swedish industries suggest much more balanced across-industry investments in industrial robots: the respective indicators being 6.5, 4.4, and 3.9.

emerging opportunities.

Following this introduction, the paper starts with a brief summary of the successful, albeit dependent transformation and upgrading of the central European automotive industry (Section 2) and reviews the predicted impacts of the transition to electrification (Section 3). Next, it develops propositions regarding the opportunities that shifting to electric vehicles generates for the automotive actors in the European integrated periphery (Section 4) and presents the research design and methodology (Section 5). Subsequently, we present and discuss our results, provide concluding comments, and elaborate on policy implications.

2. The development of the central European automotive industry

One of the most spectacular developments driving and accompanying the transformation of the central European countries from the 1990s on, was the FDI-driven expansion and integration of the local automotive industries in the European and global production networks (Guzik et al., 2020; Jürgens and Krzywdzinski, 2009; Pavlínek, 2015, 2017). From an economic geography perspective, the outcome of this process was the emergence of well-delineated, low-cost production areas, geographically adjacent to core regions of the automotive industry, that exhibit an agglomeration of core actors' FDI in production activities. Pavlínek (2018) coined the term 'integrated periphery' referring to the role of actors in these geographic areas in transnational automotive production networks (the concept was further developed in Pavlínek, 2020).

From the perspective of the integrated peripheries, the evolution of the automotive industry has been a poster case of dependent market economy development (Farkas, 2011; Myant, 2018; Nölke and Vliegenthart, 2009), with labour-intensive, low-skill assembly of imported components accounting for the lion's share of local value added.

Over time, local subsidiaries have undergone substantial product, process, and functional upgrading (Guzik et al., 2020; Sass and Szalavetz, 2013). This latter applies quite selectively though. Since subsidiaries' engagement in strategic R&D activities is limited to flagship cases of OEMs' local standalone R&D centres, aggregate indicators, such as share of automotive firms conducting R&D or R&D expenditures relative to the overall value of automotive production indicate that R&D is marginal (Pavlínek, 2012, 2017). However, functional upgrading in the broader sense of acquiring higher level functions and increasing the value added of activities (Blažek, 2016) applies to a broader set of actors. Over and beyond the flagship cases of large local stand-alone R&D centres, there is an increasing number of subsidiaries taking over the responsibility for technical support of production and process development. The knowledge-intensity of local R&D employees' assignments also shows an upward trend: from activities such as engineering, technical support, testing, and manufacturability assessment towards simulations, development of product components, and software development (Cieślik, 2021; Markiewicz, 2020). Automotive companies with local subsidiaries have started to invest in local skill formation, establish local R&D departments, engage in R&D collaboration with local higher education institutions, and delegate additional high-value activities to subsidiary level (Guzik et al., 2020; Markiewicz, 2020), which enabled these actors to accumulate technological and R&D capabilities (Szalavetz, 2019).

By contrast, the spillover effects of automotive FDI towards domestic component producers was minimal (Gáspár et al., 2020; Iwasaki and Tokunaga, 2016; Pavlínek, 2016, 2017). Domestic-owned suppliers, usually small and medium-sized companies, still belong mainly to the lowest tier in the automotive value chain. Except for a handful of highly competent suppliers that have undergone decades-long learning-by-supplying development, few domestic companies have had the wherewithal and managerial capabilities to invest in competence accumulation and move to higher-value activities. Accordingly, they remained trapped in cost-based competition (Krpec and Hodulák, 2019; Krzywdzinski, 2017; Pavlínek, 2016, 2017).

Notable in this respect is a claim proposed by Guzik et al. (2020), namely that barriers to the upgrading of domestic producers are stronger now than ten or twenty years ago. In line with Hallward-Driemeier and Nayyar (2017), these authors argue that in the medium term, domestic suppliers will be able to maintain their value chain position only if they fulfil higher requirements than previously in terms of production capacity, operational excellence, flexibility, and functional capabilities, such as design, testing, and R&D.

In this context, it is essential to understand how the impact of the e-shift cascades down to automotive actors in factory economies, and more importantly, how they can adapt to these developments.

Recent developments in the Hungarian automotive industry do not seem to confirm worries about the short-run adverse consequences of the shift to EVs, in terms of closures and unemployment. On one hand, Asian investors have channelled significant amount of investment in battery production (a total amount of EUR 5.29 billion since 2016 – ITM, 2021), which rapidly turned Hungary into one of the top producers of EV batteries in Europe (Bhutada, 2022). Note, however, that although greenfield investments in the expansion of the local battery production capacity increase gross output and create new jobs, the labour-intensive and low-value-added character of battery production suggests that it is fair to interpret the rising share of batteries in total automotive exports as industrial downgrading.

On the other hand, most of the key automotive actors (OEMs and Tier1 suppliers) continued investing in their local production sites. Some of them introduced EV-specific products[3] and flagship companies increased the headcount of their local development centres.[4] Hungary has also benefited from global companies' consolidation of ICE-specific production. For example, as part of an overarching consolidation effort, Stellantis Group relocated ICE engine production from France to its Hungarian manufacturing subsidiary in Szentgotthárd.

3. Technological and economic arguments for pessimistic/ optimistic predictions

When elaborating on the impacts of shifting to a new technological paradigm, scholars and consultancy firms equally point out that changes go much beyond new kinds of engines and transmissions (e.g., Altenburg et al., 2016). Several industries that the economies of the integrated periphery specialise in are bound to become redundant. Examples include the internal combustion engine and its parts, the exhaust systems, the fuel system, alternators, starters, gearboxes and so forth. Overall, EVs have far fewer components and a simpler architecture than traditional ICE vehicles (Küpper et al., 2020). Domestic-owned Tier 2 and Tier 3 ICE component suppliers specialised in forgings, castings, stampings, engine mounts, gaskets, and so forth, are bound to face the most devastating part of this disruption, since most of them lack the dynamic capabilities, such as strategic long-term thinking, and the financial assets to adapt proactively to the changing business environment.[5]

[3] Examples include Audi, Bosch, Continental, Knorr Bremse, Linamar, Mercedes Benz Manufacturing, Schaeffler, SEWS CE (Sumimoto), Thyssenkrupp, and Valeo-Siemens eAutomotive.

[4] Examples in Hungary include Audi, Bosch, Continental, Knorr-Bremse, ThyssenKrupp, TDK Components Hungary, and Valeo-Siemens eAutomotive. During the surveyed period, Continental established a second R&D centre focusing on developing artificial intelligence-powered solutions and Jaguar Land Rover opened a technical engineering centre.

[5] Well-capitalized global ICE component suppliers started the necessary adaptation strategy already in the late 2010s or earlier, through diversification (portfolio shifts towards EV-specific components), increased automation, relocations, and restructuring (see e.g., Weber (2021, 2022) on the adaptation of Schaeffler and Valeo).

Furthermore, electrification is viewed as eliciting major changes in the ways automotive value chains are organized (Küpper et al., 2020; Masiero et al., 2017). More specifically, the new and simpler architecture of EVs will prompt OEMs to increase the automation ratio of production (Sharma et al., 2019) and revisit the existing division of labour along their value chains, in terms of the internally controlled and the outsourced or offshored activities (Gereffi, 2014).

Altogether, the digitalisation and automation-induced reduction in the labour-intensity of production, together with the electrification-induced structural transformation in the automotive value chain may turn out to be disastrous for low-cost manufacturing locations specialised in ICE-specific labour-intensive activities.

Notwithstanding, investments in the conversion of existing plants and the location of new industries, for instance, EV batteries and other EV-specific components may partly compensate for the adverse economic and employment effects of the activities that have become redundant (Küpper et al., 2020; Mönnig et al., 2019).

In this paper, we introduce another argument for the optimistic view, starting with the claim that the transition to EVs represents a shift backwards along the automotive industry life cycle. Regulations push for OEMs' hasty transition to EVs, which condenses the current rejuvenation phase of the industry life cycle. Specifically, the current phase in the automotive life cycle shows a concurrence of different types of R&D efforts that would in theory characterise different phases of the industry life cycle. Time pressure, combined with the proliferation of e-shift-related R&D tasks compels OEMs to (further) decentralise and distribute innovation activities, which creates multiple upgrading opportunities for a wide range of actors along the value chain. Obviously, outcomes are contingent on actors' capability to seize and exploit these opportunities – another issue this paper sets to explore.

4. Conceptual background and propositions

The concept of industry life cycle was introduced by Kuznets (1930), advanced by Abernathy and Utterback (1978), and further developed by Klepper (1997), Nelson (1994), Tushman and Anderson (1986), and many other scholars (Peltoniemi, 2011). This theory postulates that the evolution of industries is classified into four stages: emergence, growth, maturity, and decline. Each stage is characterised by different patterns of growth, competition, market structure, and innovation.

Automotive industry was long regarded a mature, stable, and oligopolistic industry (Sturgeon et al., 2009), characterised by high barriers to entry, an extremely concentrated firm structure, and mature technology, improved predominantly through incremental innovations. However, the current accelerated technological change indicates that this stability is over (Ferràs-Hernández et al., 2017). Radical innovations redefine the patterns of competition. The intensification of inter-industry knowledge spillovers suggests that there are many unexplored technological opportunities and unresolved research challenges (Stephan et al., 2021). New entrants attack the established, vertically integrated industry structures and engage in a fierce competition for new standards. Since each of these phenomena characterises the early stages of an industry life cycle, these developments indicate a rejuvenation of the industry, or else, a reverse movement along the industry life cycle (Fig. 1a).

Combined with the regulatory drive for introducing low-emission vehicles, the shift backwards along the life cycle may transform the established division of labour among value chain participants.

The European Commission imposed strict passenger car emission standards for newly sold vehicles (regulations (EC) No. 443/2009, and 631/2019). As of 2021, fleet-wide CO_2 emission per kilometre must be reduced from 130 to 95 g CO_2 per kilometre for passenger cars. The schedules of further ambitious reductions, the high penalties for non-compliance, and incentives such as 'super credits' for low emission vehicles[6] triggered a race towards electrification (Pardi, 2021), since these fleet-wise targets cannot be reached only by improving the emission performance of ICE vehicles (Fritz et al., 2019).

A notable particularity of the regulation-driven transition is that OEMs face an unprecedentedly tight deadline to bring new EV models to the market. They have to accomplish formidable tasks in a compressed timescale: develop (in collaboration with Tier 1 suppliers) the new building blocks of their EV models and modify the existing architecture of the car to be able integrate the new electric components or develop a brand new platform for the EV. They have to understand, test, and validate the functional interactions among the new and old building blocks of the vehicle architecture. New EV products require non-negligible science-based fundamental research efforts,[7] architectural product development, advanced engineering, and software development. OEMs face a compressed timescale not only for their product R&D efforts to bear fruit. The regulation-driven race to electrification has made the development of new manufacturing processes and technologies – and the mastering of new kinds of production capabilities – equally urgent as product development itself. Reducing production costs and improving efficiency through implementing and mastering new production technology contributes to cutting the purchase price premium of EVs, which is indispensable for achieving large-scale commercial deployment.[8]

Accordingly, in parallel to the formidable – basic and applied – R&D challenges related to new product development (i.e., developing both the new end product, components, and complements, e.g., charging technology), production-related technological capabilities need to be accumulated, new technological processes set up, new production technology implemented, new machinery installed, plant layout adapted, and support functions such as testing and in-plant logistics modified. Workers need to become familiar with and master new tasks and new tools.

Considered from an industry-life-cycle perspective, we propose that the above-discussed developments provoke a *confluence* of different types of R&D efforts that would in theory characterise different phases of the industry life cycle (Fig. 1b). In theory, fundamental product development efforts characterise the early stages of the industry life cycle. Incremental product development and the development of the manufacturing processes are predominant in later stages of the industry life cycle (Peltoniemi, 2011). However, with compressed development timescales, fundamental research and new product development coincide with R&D aimed at enhancing the efficiency of the manufacturing processes, as well as with incremental product development efforts. OEMs have thus no choice but to redistribute the responsibilities for innovative activities (Fig. 1c) – both within their global organisations and across their value chains. Often, they also involve third party actors, such as new technology-oriented start-ups.

Source: Author's elaboration.

While these developments may bring about an upgraded activity mix for all actors along the value chain, our propositions below will focus on the upgrading opportunities of Hungarian manufacturing subsidiaries and on the prospects of industrial upgrading in Hungary.

According to a benign scenario, OEMs' local manufacturing

[6] Starting in 2020, each vehicle emitting less than 50 g CO_2 per kilometre (note that only EVs can fulfil this criterion) is counted twice for determining the average emissions for each carmaker (Pardi, 2021).

[7] Science-based research is necessary among others, for reducing the weight of the vehicle (new materials), improving battery energy density, and enhancing battery management systems.

[8] The current high purchase price is considered as a major barrier to the mass deployment of EVs (Parker et al., 2021).

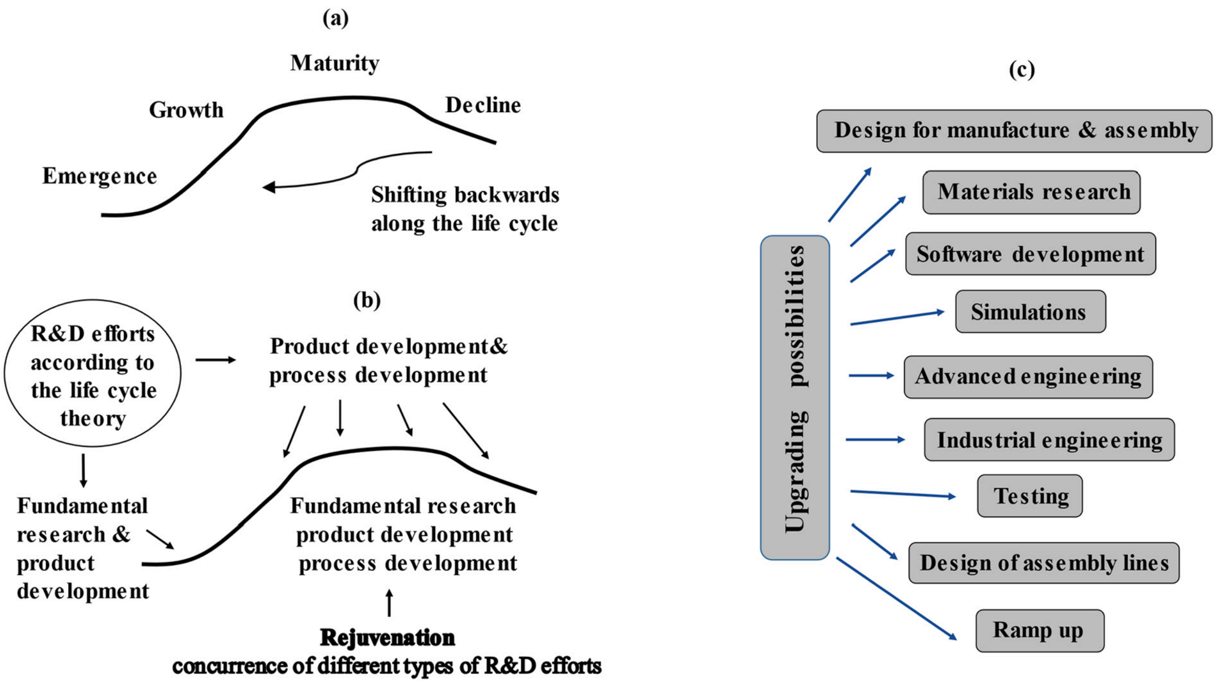

Fig. 1. OEMs' compressed development timescales drive the confluence of R&D efforts that would in theory characterise different phases of the automotive industry life cycle.

subsidiaries will undergo product, process, and functional upgrading alike. OEMs may decide to start the production of specific EV models, subsystems, or components at their local facilities. This requires the conversion of the existing assembly lines and involves learning about new processes and technologies. Traditionally, to reduce the operational risks associated with captive offshoring, global companies would launch the production at central locations: test, validate, and improve the processes, and offshore only when the transfer of production equipment can be accompanied by the necessary production-related know-how. Altogether, mastering new manufacturing processes requires, in principle, years of incremental capability building. However, given the tight deadlines for introducing new EV models to the market and achieving a large-scale market uptake, parent companies have no time to adhere to the traditional schedules of production offshoring. In this vein, local subsidiaries may be assigned the lion's share of process development: they may take over engineering-intensive assignments, set up the new manufacturing processes, ramp up production, and progress rapidly down the learning curve to increase operational efficiency.

Local engineers may also participate in related high-value activities such as manufacturability assessment, design for manufacturing and assembly, simulations, and production planning, which also represents functional upgrading.

Another opportunity for functional upgrading at local manufacturing subsidiaries is participation in software development. Currently, cars run on more than 100 million lines of code (Filloux, 2020), and this number keeps increasing. Recognising that software has become the main differentiator of vehicles, OEMs are rushing to develop their own operating systems and bring programming skills in-house. These developments present utmost opportunities for functional upgrading in local subsidiaries. Relatedly, the complexity of software embedded in automotive production systems also increases, which requires more programming input from the local IT departments.

Over and above the upgrading of local subsidiaries, technological entrepreneurship is another opportunity of a high-road integration in new automotive value chains. Market intelligence data suggest that electrification provides plentiful opportunities for technology entrepreneurship.[9] Transition to electrification is widely regarded as lowering barriers to integration in global value chains for technology entrepreneurs (Ferràs-Hernández et al., 2017; Nieuwenhuis, 2018; Perkins and Murmann, 2018). Apart from technology start-ups, knowledge-intensive services providers may also find it easier to integrate into the otherwise high-barriers-to entry automotive value chains with design, software, R&D and technical consultancy services provision (Cassetta et al., 2017).

Against this background, we developed three propositions regarding the opportunities that shifting to electric vehicles generates for the automotive actors in the European integrated periphery.

(1) Automotive companies with local manufacturing subsidiaries in the integrated periphery are converting part of their local production facilities for EV or EV component production. This diversification of the product mix to include future-oriented products creates opportunities for product, process, and functional upgrading at production facility level.
(2) Global companies' quest to develop the core competencies that are paramount to sustaining their competitive position in a software-driven automotive value chain (Burkacky et al., 2021) will prompt them to expand their workforce specialised in areas

[9] EV technology start-ups are specialised inter alia, in the design and manufacture of EVs and key components, development of EV-related advanced materials, vehicle software for various functionalities, battery development (design, chemistry, assembly, management, charging), and EV apps (e.g., visualising the available range). Additional EV-specific R&D opportunities include, among others, fleet telematics, autonomous driving, connected vehicles and vehicle cybersecurity technology (www.cbinsights.com).

associated with research, testing, software, and technology development. Facing a scarcity of skilled labour, OEMs need to decentralise some relatively high-value, non-strategic, albeit skilled-labour-intensive development, engineering, and testing tasks. They may delegate these tasks to development centres located near their captive manufacturing facilities. This decentralisation of innovative activities not only allows for the testing and validation of the newly developed solutions in a real-world production environment, but it also enables the headquarters to focus on the most strategic development tasks. Accordingly, both the lead companies and their local subsidiaries may undergo functional upgrading.

(3) Transition to electric vehicles generates new business opportunities for local domestic-owned technology-oriented start-ups, technology providers, and business services providers. If technology entrepreneurs seize this opportunity and integrate in EV manufacturers' value chains with high-value activities, this may even generate industrial upgrading in the integrated periphery – obviously only over and above a threshold level of entrepreneurial activity.

Note that these propositions are about the upgrading *opportunities* that the transition to EVs may generate for manufacturing subsidiaries and technology entrepreneurs in the integrated periphery of the European automotive industry, and not about the upgrading *implications* of the transition. These stakeholders may seize or miss these opportunities.

5. Methodology

To investigate the impact of the transition to EVs on the integrated periphery of the European automotive industry, and more specifically, the questions whether and how local automotive subsidiaries can leverage this transition for upgrading, we developed an exploratory research design. Exploratory research focuses on identifying and explaining new phenomena and involves the contrasting of the results with existing theory, so as to confirm, extend or refine it (Welch et al., 2011).

We conducted our research in two phases, combining a scoping review of data on EV-specific transactions with qualitative expert interviews. According to Munn et al. (2018) the general purpose for conducting scoping reviews is to map the available evidence in emerging research topics and identify patterns that guide more systematic research.

Accordingly, the first phase involved an extensive review of the business press and the grey literature reporting on EV-specific investments and other transactions in central Europe.[10] The surveyed period was between 2018 and March 2021. Grey literature refers to analyses and insights produced by non-academic actors and published in non-peer-reviewed outlets. Examples include white papers and reports produced by consultancy firms, blogposts and case studies by practitioners and industry experts, and analyses produced by government bodies and/or NGOs. According to Mahood et al. (2014) inclusion of grey literature can broaden the evidence base of the research, which is particularly important in the case of complex and emergent research topics, such as the subject of this paper.

The second phase comprised qualitative data collection from semi-structured expert interviews conducted with a sample of key informants. Expert interviews are essential methods for tracing and contrasting contradictory interpretations of complex processes and are therefore widely used in social sciences (Bogner et al., 2009). We applied purposeful sampling (Patton, 2002), and selected experts that were regarded as being able to provide relevant and in-depth insights on the topic we were investigating.

Additionally, we tried to adopt a maximum variance approach, to be able to illustrate the diversity of context-specific developments. Accordingly, the experts interviewed represent and/or have special knowledge about the upgrading opportunities and limitations of local manufacturing subsidiaries of global automotive companies specialised in (a) ICE parts and components production; (b) EV and EV component manufacturing; (c) technology-oriented entrepreneurial ventures providing knowledge-intensive services to automotive customers. Other experts interviewed represent NGOs, trade unions, industry alliances, consultancy firms, and governmental organisations. Altogether, in order to triangulate and contextualize the results of the scoping review with the observations of experts, twenty expert interviews were conducted (Appendix Table) over a period between June 2020 and April 2021.

Interviews were semi-structured, containing open-ended questions designed to elicit detailed responses to issues raised. This interview design made it possible to get a wide perspective of stakeholders' views on the impact of the shift to battery-driven powertrains and the related upgrading opportunities and/or downgrading threats.

We started our interviews with interviewee-specific questions, derived from data accumulated on the given context prior the interview.[11] We continued with inquiries about what transition means for the business of the given company, and the measures taken to prepare for this transition, in terms of new product introduction, investments in process upgrading, areas of competence accumulation, and factors enabling or inhibiting upgrading.

As a summary question, that was utilised to provide opportunity for the interviewees to return to aspects that they considered crucially important, we asked our informants to share their general view of the changes ahead and elaborate on risks and opportunities.

In contrast, the questions we prepared for interviews with NGOs, trade unions, industry alliances, consultancy firms, and governmental organisations were more of a general character. We asked interviewees to evaluate recent trends and companies' strategic responses to them, and to elaborate on the expected impacts, risks, and opportunities in a Hungarian context.

Our data analysis process started with an exercise referred to by Miles and Huberman (1994) as data reduction. Data reduction is a painful, albeit indispensable analytical exercise of sorting and organising data. It necessarily involves discarding some of the rich but irrelevant insights obtained during the conversations with informants, in order to sharpen the focus of the research. The next step of the analysis involved content analysis enabling to draw initial conclusions – to be verified through thematic analysis.

Once these steps were completed, we sent the first draft of this paper to our interviewees and asked them to check the accuracy of our conclusions and make comments.

6. Results

6.1. Scoping review

Our review of automotive transactions in the surveyed period revealed three conspicuous patterns regarding the development of the automotive industry in central Europe. The first pattern is the predominance of new investments over divestiture and downsizing. Part of these

[10] The principal sources of our review included reports and insights by McKinsey, Boston Consulting Group, www.automotivemanufacturingsolutions.com; www.electrive.com; www.automotiveworld.com, www.e-cars.hu; www.villanyautosok.hu.

[11] An example of context-specific question is as follows: "Since we are conducting research about the impact of the transition to electromobility, my initial assumption was that companies manufacturing ICE vehicles or components are facing hard times. I was all the more surprised to learn from the business press that you invested €32 million to increase capacity. Can you elaborate on the motivations driving this investment?" (expert No. 20).

investments created new industries, including battery (and part) manufacturing. Several battery Gigafactories have been established by Asian investors, which made Li-ion battery an increasingly important export commodity in these countries.[12]

Additionally, substantial investments were observed in the conversion or expansion of existing ICE-manufacturing facilities, enabling these plants to accommodate for both electric and conventional vehicle models.[13]

A seemingly counterintuitive result is that lion's share of the surveyed new automotive investments intended to expand and upgrade existing facilities specialised in ICE (end products, parts, components) production, or even establish new ICE-related greenfield facilities. By contrast, there were only few transactions involving divestiture, downsizing, or closure of automotive facilities during the surveyed period.[14] These findings indicate a consolidation of ICE-specific production to existing low-cost locations.[15] Capacity increases in central Europe may also be the result of temporary factors, e.g., recovery of volume demand after the Covid-crisis.

The second conspicuous pattern in our scoping review is that investments in EV and part production were accompanied or preceded by meaningful upgrades in production operations. New industrial and service robots have been installed, automating an increasing number of activities. This result is consistent with studies pointing out that the manufacturing of EVs, parts, and batteries is characterised by high automation ratio (Sharma et al., 2019), and was also supported by interview data. Interviewees reported ongoing investments in advanced manufacturing technologies, including collaborative robots, and digital solutions automating support activities or supporting employees. Examples include in-plant logistics (autonomous transport robots) and intelligent quality control, production control, and maintenance management systems. At the same time, they underscored that as opposed to the high-publicised consequences of automation in terms of technological unemployment, automation is paramount to address the increasingly pressing labour shortages.

The third pattern we identified from both the primary and secondary data is that although shifting to EV production requires R&D in a variety of disciplinary fields, except for two particular sets of firms, no stakeholders are involved in EV-specific R&D or other knowledge-intensive activities, such as design or testing.

The first set of firms encompasses the highest-flying local subsidiaries of global automotive companies: subsidiaries that have undergone decades-long organic development (for the list of Hungarian R&D-intensive automotive subsidiaries see footnote 4). The first phase of their development trajectory was marked by the expansion of production and upgrading of production technology, which, combined with a rapid accumulation of production capabilities drove productivity improvement. By contrast, increases in the unit value added in the second phase were driven by the upgrading of their technological capabilities, complemented with the accumulation, deepening, and institutionalisation of local R&D capabilities (Guzik et al., 2020; Markiewicz, 2020).

Our review revealed that these subsidiaries continued co-evolving with parent companies. When lead companies became increasingly committed to shifting to zero-emission vehicles and increased their related R&D outlays, the highest-flying subsidiaries could harness the new opportunities and obtain new, EV-specific R&D assignments.[16]

The other set of stakeholders associated with EV-related knowledge-intensive, high-value activities are universities, start-ups, technology-intensive services providers, and domestic companies with self-developed, own-brand products. Regarding this latter sub-group, although we have identified press reports about central European companies with self-developed electric buses, electric light vehicles for personal mobility in cities, electric batteries, etc., the market of these firms have remained marginal. As an expert (No. 7) put it, these companies have hardly moved beyond the phase of having promising prototypes.[17] Since overcoming the ‘valley of death’ and achieving profitable operations requires multiple engineering man-months of testing and validation, and substantial complementary investments to obtain the necessary certification, these companies are showcases of local talent, but they are hardly likely to exemplify ‘industrial upgrading by shifting to innovation-driven growth’.

While it needs to be acknowledged that this review of secondary data sources fails to provide an exhaustive list of relevant actors, our results suggest that the intensity of EV-related technology entrepreneurship in central Europe leaves a lot to be desired. Although the shift to electric mobility opens up new niches for high-value, knowledge-intensive services provision, and the growth in the market for automotive software is expected to outpace growth in the automotive market, few domestic-owned actors managed to carve a niche and scale rapidly.

6.2. *Thematic analysis and discussion*

The experts interviewed have provided rich and nuanced accounts complementing the picture suggested by and refining the initial conclusions drawn from the scoping review. In this section, we organise our findings along the possible dimensions of local subsidiaries' upgrading (Humphrey and Schmitz, 2002, cf. footnote 1).

The majority of the experts interviewed stated that the adverse effects of the ongoing transition to electrification are beyond the horizon or will materialise only at specific domestic-owned low-tier component suppliers. In the short and medium run, Hungary will rather benefit from further production relocation, driven by the global consolidation of ICE-specific manufacturing activities. The largest actors (the local subsidiaries of OEMs and Tier 1 global companies) will not necessarily run the risk of lock-in in an outdated product mix. Industry experts have mentioned multiple examples of local automotive subsidiaries revamping their factories for electric mobility related production and gradually diversifying their product portfolios to include future-oriented (EV-related) products (cf. footnote 3). New products are thus expected to compensate for the ones that are gradually phased out.

While new product introduction represents product upgrading, global companies' decisions to stop the further development of ICE-specific products (e.g., combustion engine) will have contrary effects

[12] Poland is among the top exporting countries, where, according to www.statista.com, lithium-ion battery export accounted for EUR 609 million in 2020.

[13] Examples include Fiat-Chrysler's expansion of its Polish location in Tychy to begin producing hybrid and electric models, Toyota's investment expanding its Walbrzych plant in Poland, specialised in hybrid cars, Kia Motor's expansion of its existing engine factory in Slovakia, and Kirchhoff's capacity expansion at its Hungarian and Polish plants specialised in body-in-white structures.

[14] Our data analysis identified two plant closures in Hungary in the surveyed period: Lear Corporation closed one of its Hungarian plants and relocated wire harness production to Ukraine and Serbia. Johnson Electric closed its automotive component production facility in Ózd. Neither of these companies mentioned transition to electric mobility as a reason of their decisions. Sharply reduced global demand in 2020 prompted downsizing at Mercedes-Benz's, Suzuki's and Continental's (ContiTech Fluid Automotive) production plants in Hungary (in particular, the number of temporary agency workers were cut).

[15] Examples include VW's moving the production of Passat to its Skoda plant in Czechia and the relocation of Jaguar Land Rover to Slovakia.

[16] Besides the high-flying companies with stand-alone R&D centres (listed in footnote 4) there are some other automotive companies that managed to expand their R&D assignments. Examples include AVL Hungary that increased powertrain testing and production engineering activities, and Hanon systems, specialised in production support, tooling and product design (refrigerant valves for electric cars).

[17] A notable exception is the Polish bus manufacturer Solaris that has become a serial manufacturer of hybrid buses and fully electric buses in the mid-2010s. In 2018 Solaris was acquired by the Spanish CAF.

on their local R&D departments and/or on domestic-owned contract R&D services providers.

"We stopped receiving new R&D assignments related to turbochargers. By contrast, we receive a larger number of assignments in the field of automotive data communication."

(expert No. 9)

Regarding the impact of battery manufacturing on host countries, experts' views were divided. Most of them underscored that battery manufacturing is a low-local-value-added activity and precludes industrial upgrading. Notwithstanding, experts have acknowledged the substantial job creation associated with the establishment of battery production facilities.

Experts No. 6 and 12 even proposed that similarly to conventional car, part, and component manufacturing subsidiaries, battery companies may also undergo functional upgrading over the coming years, since electric batteries still require substantial interdisciplinary research, product and process development, and design. Some of these high-value activities may later be gradually collocated to the newly established local battery production facilities.

Regarding process upgrading, experts have acknowledged that companies converting part of their production to EV and part manufacturing usually switch to a higher degree of automation. Process development is especially spectacular in those cases where EV-specific production is located in a dedicated plant or workshop. New plants are usually highly automated and apply cyber-physical system technologies.[18]

Furthermore, since some EV-related manufacturing and assembly processes are different from those of conventional vehicles, employees have to learn new processes (e.g., coiling). Subsidiaries have to invest in new kinds of quality control solutions and new equipment for different joining and sealing techniques, and they have to modify the production software. Altogether, shifting to EV-specific products is an important trigger of investments in advanced production technology and process upgrading.

On the issue of R&D-based functional upgrading, the experts interviewed acknowledged that the increasing R&D-intensity of EV development cascades down to subsidiary level, as parent companies delegate an increasing number of diverse assignments to manufacturing subsidiaries. The example recounted by the representative of an industry association (expert No. 4) illustrates how the multiplication of research tasks in the current phase of the life cycle compels global actors to increasingly decentralise R&D, as set out in Fig. 1b and c). If local capabilities enable subsidiaries to seize the emerging opportunities, this can set off a virtuous circle and prompt upgrading.

"I recently heard the presentation of the CEO of (anonymised): their case is relevant to your question. The local competence centre was founded already in 2004 and kept growing gradually since then. In the past couple of years, however, the headcount of the local team, specialised in electric power steering technology, grew quite rapidly. Of course, R&D outlays grew not only in Hungary but at the corporate level, in line with the transformation of the powertrain division towards e-mobility. New competence centres were inaugurated in France and in Singapore. Besides e-mobility research, the global company has many other large-scale projects: it is progressing with the digital interconnection of its manufacturing locations and the digitization of management functions. These projects will require that the engineers and the IT staff at each of the four Hungarian manufacturing facilities perform both applied and adaptive R&D. In sum, the Hungarian competence centre is growing since group-level research tasks are growing like yeast."

Obviously, this development relies on nearly two decades of knowledge accumulation at the local subsidiary. However, apart from a couple of similar anecdotal success stories, the current decentralisation of automotive R&D is not expected to bring about trend-breaking spectacular increases in the number of local automotive subsidiaries with R&D activities. It may at best set off a long and gradual journey of R&D-based functional upgrading at a couple of additional foreign-owned production facilities. Furthermore, as described by Pavlínek (2012) already before the emergence of the current disruptive technologies, the functional hierarchy characterising the offshoring of advanced R&D functions applies also to the spatial distribution of EV-related knowledge-intensive activities. Accordingly, except for stand-alone local research centres[19] that increased their headcount in the surveyed period and contributed to corporate strategic R&D, the concept of subsidiaries' R&D-specific functional upgrading refers mainly to increases in applied research assignments. Examples of such activity include engineering (associated with the integration of electric cars into the existing production lines or with technical support to production ramp up), functional and end-of-line testing, production optimisation, powertrain and vehicle testing, and validation of automotive software on electronics hardware.

While these R&D activities generate higher value than what assembly does, this kind of functional upgrading does not enable host countries' transitioning to a higher-road growth trajectory, since the aggregate value added of these high-value activities is dwarfed when compared with that of manufacturing or assembly.

Transitioning to a higher-road growth trajectory may rather be driven by chain upgrading, in terms of achieving an intra-industry structural change through significantly increasing the share of revenues from vehicle software development at the expense of brick and mortar manufacturing. Our informants were pessimistic about the viability of chain upgrading. Experts warned that the examples of a couple of high-flying subsidiaries with EV-specific development centres should not be generalised. On one hand, it took decades of organic development for OEMs' large local research centres to achieve their current position within their OEMs' global value chains. On the other hand, and more importantly, the shortage of electrical and software engineers is a significant barrier to the expansion of even the existing development centres.

"Bosch has established a large, stand-alone research centre in Budapest. It is said that this is the largest European R&D unit of Bosch outside Germany, employing nearly 3,000 engineers. However, if Bosch wanted to double the headcount of its Budapest centre, it would be unable to do so: there are simply not enough software specialists to hire."

[18] A salient example is Schaeffler that opened a new production plant dedicated to electromobility in Szombathely, Hungary. The plant features a high degree of automation, modular production buildings, and end-to-end digitalization. Other examples include the new electric motor production hall of Audi in Győr, Mercedes Benz's full-flex factory in Kecskemét, and Vitesco Technologies, the former powertrain division of Continental, that opened a highly automated and digitized facility specialised in the production of automotive electronics and transmission controls.

[19] Local stand-alone R&D centres are integrated in the global research activities of their lead companies. They are specialised, among others, in advanced simulations, development of vehicle software components and application software, system integration, and in the development of electronic control unit and sensors. Other research directions concern functional safety, modelling new EV components, and autonomous driving and connected car technology (e.g., Thyssenkrupp's, Bosch's, Knorr-Bremse's, and Continental's R&D centres in Hungary). Besides software development, some of the local R&D units are engaged in partial product development tasks. For example, the database of Hungarian R&D projects that received public support comprises several automotive companies engaged in component development e.g., integrated modular steering switches (Valeo Auto-Electric), passive electronic components (TDK Hungary Components) and sensor development (Continental Hungary).

(expert No. 14)

Transitioning to a higher-road growth trajectory may, in principle, be driven also by intensifying technological entrepreneurship. However, our data analysis identified only two notable[20] domestic-owned technology-oriented companies that could harness this opportunity. Expert interviews with representatives of automotive consulting firms and domestic-owned technology companies have both confirmed and clarified this result.

One reason of the low prevalence of domestic-owned entrepreneurial ventures entering automotive value chains with self-developed products is the risk of partnering with start-ups.

> *"OEMs are cautious. Although they consider our prototype innovative, they would say, let's come back to this issue if your company can document its viability: if you are still in the market in five years, we can talk about business."*

(expert No. 10)

Software providers are no exception to this rule. Since OEMs are required to have a formal software update management system, they would hardly contract young domestic-owned software companies – however innovative they are.

Another problem innovative domestic SMEs face is that they underestimate the costs of getting integrated in automotive value chains.

> *"Technology SMEs would only calculate the costs and time requirement of developing the prototype. They forget that for scaling up, this budget should be multiplied by ten! Since automotive quality and safety requirements involve formidable testing and validation efforts, the real hurdles will start once you have a proven, well-functioning prototype."*

(expert No. 10)

According to expert No. 7, technology-oriented domestic SMEs have no wherewithal to invest years of engineering hours in the necessary validation of their products and additional months of management hours to obtain the necessary certifications. Consequently, they remain stuck in the prototype phase. Their competitive advantage lies in developing unique and customised products (e.g., prototypes for testing specific functions, special-purpose production machinery, or industrial automation and digitalisation solutions), or in providing specific engineering or R&D services for hourly fees. This activity is characterised by high-value generation and enables capturing decent profit. However, these SMEs can rarely scale and become high-growth businesses.

7. Concluding remarks and policy implications

"For me, shifting to electric vehicles means that cards are being reshuffled, opening up unprecedented opportunities." Against this background, summarised by expert No. 11, this study investigated whether the dominantly foreign-owned Hungarian automotive sector could build on its prior competitive advantages and sustain or, rather, upgrade its position in the transforming global automotive value chains.

We have synthesised the possible upgrading trajectories related to the e-shift in the automotive industry and argued that shifting to electric vehicles opens up several opportunities for upgrading, since it requires such a proliferation of innovative tasks that, coupled with a tight deadline, can be accomplished only through further decentralisation of R&D activities. Accordingly, the local subsidiaries of flagship OEMs and Tier 1 suppliers are likely to continue along their evolutionary trajectories involving process and functional upgrading. The first signs of this development are already present, as several subsidiaries started to develop their EV-related production and technological capabilities.

If, however, only low-hanging fruits are harvested, that is, local subsidiaries benefit from co-development with parent companies, learn new processes, and master the newly transferred equipment, this produces a mere Red Queen effect: local subsidiaries may at best survive the transition and sustain their position within their parent companies' global ecosystem.

From their perspective, these developments can definitely be interpreted as upgrading since they increase the value added of their activities. If, however, upgrading is defined in terms of catching up and improving the position of the local manufacturing subsidiaries in the European automotive value chain (industrial upgrading) neither component of this definition applies. There is no catching up since, as noted previously, transition to electrification may bring about an upgraded activity mix for all actors along the value chain. Delegating some relatively high value added R&D assignments to manufacturing subsidiaries such as simulations, development of the manufacturing execution system, support of serial production, and so forth, and focusing on the highest-value activities instead, the parent companies of local manufacturing subsidiaries increase the value added of their own activities even more than their manufacturing subsidiaries. The decentralisation of innovative activities progresses according to the hierarchy described by Pavlínek (2012). Strategic R&D remains to be centralised and only partial tasks and non-strategic R&D activities will be decentralised.

Moreover, even if transition to EVs sparks a meaningful R&D-based functional upgrading at flagship manufacturing subsidiaries, the scarcity of adequately skilled employees prevents industrial upgrading. Industrial upgrading would require an order of magnitude increase in the number of local subsidiaries that conduct research – instead of six to eight celebrated (and a couple of additional, less well-known) cases.

As a flipside of the same coin, our results indicate that the (automotive) manufacturing-led growth model, involving reliance on FDI in low-wage, labour-intensive activities, is not necessarily jeopardized by the industry's transitioning to electric vehicles, at least, not in the medium run. While electrification intensifies the ongoing consolidation processes in the automotive industry, the current host economies may continue to be on the receiving end of global actors' relocation decisions. Additionally, they can harness the rapid growth of European demand for electric batteries. By hosting the related massive FDI inflows, they benefit from the establishment of new labour-intensive industries.

The analysis of global automotive actors' electrification-related transactions in Hungary, specifically the massive inflows of investment in the battery industry and parent companies' investments in the conversion of their local facilities, suggests that in the context of the current technological discontinuity, the dual structure of the Hungarian automotive industry, specifically the marginal role of domestic automotive companies in total output and exports[21] can be considered advantageous, however exaggerated as it may sound. While the low-tier domestic-owned suppliers that are specialised in ICE-specific manufacturing can easily be erased from the market if they fail to adapt and reposition themselves, the dominance of foreign control can shield the Hungarian automotive industry as a whole from the short-run devastating impacts of the transition to electromobility. The actors that account for the lion's share of the Hungarian automotive output and

[20] AIMotive and Commsignia, specialised in autonomous driving and connected car technologies have managed to scale, involve meaningful venture capital, and partner with global automotive actors. A third noteworthy actor is NNG, specialised in automotive navigation, infotainment, and automotive cyber security solutions. Founded in Hungary in 2004, this company has achieved a global footprint. While it is foreign-owned since the early 2010s, its corporate headquarters is in Hungary. Over and beyond these companies, there exist about a dozen of specialist technology providers and engineering offices, specialised in embedded automotive software and advanced manufacturing technology, that managed to acquire the local subsidiaries of global automotive companies as customers.

[21] The index of foreign control in the Hungarian automotive industry was 94.9 in 2015 (Pavlínek, 2020).

exports possess the capabilities and resources (or rather their parent companies possess them) to adapt proactively.

At the same time, these developments indicate a *lock in a dependent model of capitalism* (Farkas, 2011). Since the transition to EVs engenders industry concentration in all stages of the automotive value chain, a dependent factory economy like Hungary will become even more exposed to the strategic decisions of global companies.

In summary, our results confirmed that the current rejuvenation phase of the automotive lifecycle is indeed characterised by a confluence of multiple types of research tasks. Coupled with strict time constraints stemming from the hardening of the European regulations of automotive emissions, this presents opportunities for the upgrading of the best-prepared[22] manufacturing subsidiaries. However, our results also highlighted the limits of seizing and capitalising on these opportunities.

Interviews have substantiated the narrow focus of this paper on the upgrading opportunities of foreign-owned manufacturing subsidiaries by making it clear that exploiting these opportunities requires significant tangible and intangible resources that are mostly out of reach for domestic-owned companies.

Data have also supported the second proposition regarding OEMs' expansion of the headcount of their local automotive development centres. This kind of functional upgrading was, however, gradual and incremental rather than radical: according to the data of the companies with stand-alone R&D centres (footnote 4) this expansion was below 10 % on average during the surveyed period, indicating that the scarcity of skilled engineers is a hard-to-overcome barrier to R&D-based functional upgrading.

Finally, our results offer no support to the third proposition regarding the intensification of electric vehicles-related technology entrepreneurship. Although about altogether a dozen excellent domestic-owned start-ups, innovative software firms, automation technology providers, and contract R&D services providers can indeed be identified, their cases remain sporadic, failing to shift the growth models of these countries to a qualitatively different trajectory that could be referred to as industrial upgrading.

Overall, we interpret these results as predicting continuity as a best-case scenario in the medium term, but with significant downsides emerging, reflecting significant challenges from the weaknesses in a dependent market economy like Hungary for any widespread seizing of the theoretical possibilities for upgrading. If policy intervention remains limited to attracting FDI (e.g., in the battery industry), this can effectively stimulate the building of new manufacturing capacities and the creation of jobs (‘bad jobs’ in the case of battery manufacturing) but fails to facilitate industrial upgrading. Building the requisite technical skills, improving STEM education and enhancing local absorptive capacity are paramount to exploiting the theoretical opportunities transition presents for the countries hosting OEMs' relocated automotive production. Accomplishing these formidable tasks in a compressed timescale is, however, even less feasible for host countries than launching new EV models for OEMs that have procrastinated on preparing for it.

Some limitations of this research need to be acknowledged. Apart from the relatively small number of experts and the narrow focus of the research on the upgrading possibilities of foreign-owned manufacturing subsidiaries it must also be acknowledged that little time has elapsed since the strong and enduring momentum in the market for electric vehicles became obvious. It remains to be seen whether electrification, combined with progressing digitization will indeed induce a trend-breaking, radical further decentralisation of global automotive actors' R&D activities. Moreover, considering that upgrading itself is a gradual and protracted process, the surveyed period may not reliably capture the extent of change. Additionally, expert interviews were conducted only in one country, and the results may not automatically be generalised even at CEE level. This calls for further longitudinal research and involvement of experts from other central European countries. Future research is needed also to investigate the upgrading perspectives and possible trajectories of domestic-owned lower-tier suppliers.

Author statement

I hereby confirm that I am the only author of the manuscript ‘Transition to electric vehicles in the European integrated periphery: a devastating crisis or business as usual?’. I confirm the manuscript has not been submitted elsewhere: it is not under consideration in another journal.

The funding statement is as follows.

This work was supported by the International Visegrad Fund under Grant No. 22030183.

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Declaration of interest

None.

Data availability

The data that has been used is confidential.

Acknowledgement

This work was supported by the International Visegrad Fund under Grant No. 22030183.

Appendix A. Overview of interviewed experts

Expert no.	Professional role	Type of organisation	Additional information
1.	HRM officer	Private, Fo	Subsidiary of a large EV battery manufacturing firm
2.	Leader of e-mobility related activities, PR and external relations manager	Private, Fo	Subsidiary of an OEM specialised in EV production. It has no manufacturing plants in Hungary but is very active in promoting local EV adoption, and sponsors EV-specific local R&D
3.	Managing director	State-owned	A subsidiary of a state-owned energy company specialised in electric mobility: responsible for installing and operating e-charging stations in Hungary
4.	Founder		Specialised in the interest representation of e-mobility related stakeholders

(*continued on next page*)

[22] Obviously, there are many local subsidiaries that do not and will not produce components that are specific to EVS (e.g., tires, seats, automotive mirrors). These suppliers may not necessarily have upgrading opportunities related to the transition to EVs. At the same time, not all local subsidiaries specialised in products specific to ICE vehicles will convert their production: some will definitely fail to survive and close down. (The author is grateful to an anonymous reviewer for raising these points.)

(*continued*)

Expert no.	Professional role	Type of organisation	Additional information
		NGO (industry association)	
5.	Trade union official, president of its federation	NGO	A sectoral federation of Hungarian trade unions, representing the interests of workers in automotive, electronics, metal, and machinery industries
6.	Head of employment office	Government	A government office in a NUTS3 region that is strongly specialised in automotive industry
7.	Managing director	Private, Do	A consultancy firm specialised in automotive industry
8.	Managing director	NGO	Interest representation of electromobility stakeholders; participates in drafting e-mobility national action plans
9.	Chief technologist	Private, Do	An engineering office specialised in simulation technology; materials research; design and implementation of industrial automation solutions
10.	CEO, development engineer	Private, Do	Develops and implements custom electronics hardware and software for electric vehicles
11.	Advisor to the CEO	Private, Do	Project manager: development of an electric bus and related charging solutions
12.	Researcher	PRO	Basic research on energy storage materials
13.	Deputy managing director, marketing manager	Private, Do	Tier2 supplier of several OEMs, supplying high precision steel tubes used in automotive parts (airbags, seats, wiper systems)
14.	Chief information officer	Private, Fo	Tier1 supplier: automotive parts with new EV-specific products in the product mix
15.	Business unit manager	Private, Fo	Manufactures electronic components, e.g. automotive sensors; R&D: sensor development
16.	Managing director	Private, Fo	Tier1 supplier: automotive safety solutions
17.	Managing director	Private, Fo	Tier1 supplier: automotive electronics; conducts R&D
18.	E-mobility project manager	Private, Fo	Subsidiary of an OEM. Has no manufacturing plants in Hungary but is very active in promoting local EV adoption; member in a variety of industrial associations and sponsors EV-specific local R&D.
19.	Research and development director	Private, Fo.	Tier1 supplier: parts and components of braking systems for commercial vehicles and railways; conducts R&D
20.	HRM officer	Private, Fo	Tier1 supplier: manufacture of advanced turbo charging system for ICE and hybrid vehicles

Do = domestic-owned; EV = electric vehicle; Fo = foreign-owned; HRM = human resources management; NGO = non-governmental organisation; OEM = original equipment manufacturer; PRO = public research organisation; R&D = research and development.

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