Emerging models of networked industrial policy: recent trends in automotive policy in the USA and Germany

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Abstract: The adoption of the US-Mexico-Canada (USMCA) trade agreement and the transition to electric and autonomous vehicles has created uncertainty for automotive companies. In response, the need for government efforts to position traditional automotive regions as a source of high-quality, green vehicles is pressing. The policy mix is changing rapidly as the public sector and firms cope with the challenges associated with new trade confrontations and disruptive technologies. The article captures this evolving policy landscape through a comparative analysis of automotive policy with respect to BEVs in the USA and Germany. It examines how innovation policies help the sector navigate the current technological transition. We find that theories grounded in traditional comparative political science do not provide an adequate framework to explain the observed similarities and differences in policy trajectories in the two countries. The article adopts insights from the networked industrial policy perspective to better understand the repertoire of policy instruments adopted to manage the changing impact of alternative energy technologies in the automotive industry.

Keywords: networked industrial policy; comparative capitalisms; battery electric vehicles; USA; Germany.

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1 Introduction

The signing of a new US-Mexico-Canada (USMCA) Trade Agreement, covering the North American free trade zone, is occurring along with broader technological changes that are altering the competitive environment for companies in the sector. The new trade regime is being implemented in the context of a dramatic shift from the carbon-based technology of the internal combustion engines (ICEs) to the emerging battery electric (BEV) paradigm (Dijk, 2016). As Mathews (2013, p.11) notes, "carbon lock-in [is] a central feature of the oil-based fourth technoeconomic paradigm and its extension into the fifth paradigm based on IT/ICT and the breaking of carbon lock-in via creative destruction [is] the key challenge for the emergence of a new era based on renewable energies." While there remains considerable debate over the pace and timing of the transition, BEVs are rapidly progressing from a small niche in the automotive market to grab an ever-larger share of automotive sales. The latest data indicate that global electric vehicle sales accelerated sharply in 2020, despite the pandemic, rising by more than 43% to 3 million cars (Carrington, 2021). This rapid scale-up in the production of BEVs is part of a more significant disruption in the automotive sector that includes the introduction of connected and autonomous vehicles (C/AVs) as well as new forms of shared mobility (Alochet and Midler, 2019; Covarrubias, 2018). The pressure on traditional automotive regions and conventional automotive producers from this technological transition is intensified by the emergence of new competitors from outside the industry [Proff, (2020), p.341], as well as the growing presence of Chinese producers, with strong support from state policies (Jetin, 2020; Muniz et al., 2019).

The concurrent transition in North America to both the new technology paradigm and the new trade regime heightens the pressure on governments to reposition their automotive regions as a source of high-quality vehicle production in the emerging paradigm. The challenge is intensified by the complex mix of technology systems that comprise automobiles today. Current technologies include new applications based on sophisticated embedded electronics that provide new functionality for automobiles. Many of these developments reflect an "interplay that is occurring between the use of new materials and the blending of different technologies to create new products" [Bryson et al., (2013), p.51]. A case in point is the automobile's transformation from a "modestly complex set of hardware components into today's modern automobile, which contains 17 subsystems for which electronics is a central element" [Tassey, (2014), pp.29–30]. The shift towards electric mobility – requiring the integration of electric components, advanced materials, and batteries – confronts manufacturers with the challenge of incorporating producers from a cross-section of other industries into the automotive sector's value chain.

The emerging pressure to shift the automotive sector to a new technology paradigm is situated in more general calls to transform manufacturing by introducing enabling technologies (Tassey, 2014; Bonvillian and Singer, 2017). Governments are expected to facilitate this transition, especially considering the rising challenge from China, making the evolution of state policies in the US and Germany a critical subject for investigation. As Jetin (2020, p.172) has observed:

> "Europe and the USA do have the scientific and technological capacities to develop the next generation of batteries, but they cannot produce them at massive scale. These weaknesses may become critical. If Chinese battery makers are the first to master the solid-state battery, on top of controlling the means to mass-produce them, they may be in a solid position to negotiate a larger share of the value chain profitably."

The institutional structures shaping this transition do not exist in abstract space but are grounded in real geographic places constituted by their respective national and regional innovation systems, with their own power relations, governance arrangements, institutional structures, and firm and network dynamics. This spatial perspective underlines the need to understand the linkages and structural coupling between local innovation-related assets (technological capabilities, firms, and institutional supports) and the interests, needs and strategies of supra-national actors, particularly MNEs (Binz and Truffer, 2017; Coenen et al., 2012). Regardless of the assumption that globalisation makes the specific location of economic activity less important, geographical proximity and clustering within national and regional innovation systems provide necessary conditions for flexibility, specialisation, and innovation in decentralised production networks (Liu et al., 2013). The global dispersion of research and development activities by MNEs, linking their international research activities with national and regional innovation systems, has focused attention on global innovation networks (GIN). At issue is how complex innovation processes are embedded in national or regional territorial contexts and the different forms that embeddedness takes for specific technologies and industries (Binz and Truffer, 2017). GINs involve networks formed with the objective of enhancing the exchange of knowledge needed for innovation-related activities across different geographic locales. They are based on external collaborations that occur on a horizontal basis and are governed by network relations rather than market or hierarchical ones. The critical factor for the present analysis is that GINs are "highly embedded in territories and are pinned down to certain locations, and that, conversely, regional characteristics have a strong influence on the geography of a firm's innovation networks" [Chaminade et al., (2016), p.371].

The challenge for national governments is to frame policies that embed GINs in their respective economies while respecting the broader trade and production arrangements that guarantee access to larger continental markets, as well as regulations and policy supports that influence and constrain firm strategy. Several bodies of literature frame the policy debates over the political and institutional factors that shape government responses to the new technology paradigm. Two alternatives relevant for this analysis are the literature on comparative national institutional contexts for innovation, including the varieties of capitalism (VoC) perspective (Hall and Soskice, 2001), and the literature on the networked industrial state (Negoita, 2013; Keller and Negoita, 2013). The VoC literature distinguishes between the ideal types of liberal market (LME) and coordinated market economies (CME), quintessentially represented by the US and Germany. The comparative politics literature portrays these models of national institutional structures as having distinct implications for firm strategy and behaviour. In contrast, the literature on networked industrial policy focuses on the emergence of new forms of state-industry collaboration to promote the diffusion of new, innovative technologies, but its application has largely been confined to the US. The article bridges that divide by bringing the insights and perspectives from the networked industrial state literature to bear on the comparative analysis of national responses to the current technology transition. It situates the analysis of recent policy trends (to accelerate the diffusion of BEV systems) in the contrasting interpretations afforded by literature on VoCs and the networked industrial state. It presents a comparative analysis of automotive policy in the US and Germany, examining how regional, national, and supra-national policies have repositioned the sector to navigate the complex trade and technological requirements of the emerging paradigm.

The research indicates a growing convergence of policy instruments in both institutional settings toward networked industrial policies to build and sustain the networks of production and learning needed in the current era (Whitford and Schrank, 2011; Keller and Negoita, 2013). Both countries have introduced initiatives to support cross-sectoral linkages conducive to more open forms of innovation in the automotive industry, reflecting a departure from traditional models of market coordination. The article advances a new understanding of the repertoire of instruments, models, and norms used to manage the changing patterns of globalisation and electrification in the automotive industry. It begins with a review of the recent literature on the comparative capitalism (CC) and the role of research, technology, and innovation policies in facilitating the shift to a new production paradigm within the automotive sector. It reviews the literature on the converging role of policy mixes in the networked industrial state and links this to an analysis of the comparative differences in state institutions and the ensuing policy implications. It continues with a detailed overview of US and German automotive policies over the past decade and a half. The last section concludes with the policy implications set forth by the preceding discussion and suggestions for future research.

2 Comparative political institutions and networked industrial policy

The need for innovative policies to promote the transition from ICE vehicles to BEVs is driven by a broader recognition of the underlying structural changes needed to move to a more sustainable economic paradigm. This transition has been framed in terms of the need for a new generation of transformative innovation policies to tackle the grand societal challenges we face, such as the imperative of decarbonisation. Recent policy initiatives, such as the EU's Horizon Europe program, have explicitly adopted the concept of mission-oriented strategies to address these grand societal challenges. Such mission-oriented innovation policy is depicted as a promising means to achieve strategic goals that require a substantial degree of system transformation to cope with societal challenges. However, there is also recognition that policymakers and analysts face significant issues in designing and implementing these policies (Hekkert et al., 2020; Mazzucato, 2018).

This recognition implies the need for greater focus on the policy processes though which the mix of mission-oriented policies is designed, and the appropriate policy instruments selected to respond to the challenge of transitioning to a new energy paradigm (Kern et al., 2019; Flanagan et al., 2011). Differences in institutional settings for low carbon energy policy creation can lead to variations in the route taken toward alternative energy futures. According to Rosenbloom et al. (2019, p.175) "institutional design is notoriously complex and context-dependent", hence the need to understand how respective national institutional structures support or constrain alternative policy outcomes and the potential for change. Of relevance is the interaction among different instruments in the policy mix and the dynamic nature of that interaction. Both demand pull and technology push instruments play a role within the policy mix to promote change at a systemic level [Rogge and Reichert, (2016), p.1632; Kern et al., 2019].

2.1 The relevance of national institutional structures for energy transitions

The more active role for state policies in the transition on both sides of the Atlantic challenges the VoC's prediction of continued institutional heterogeneity and the implications of path dependency for the continuing divergence between liberal and coordinated market economies (Meckling and Nahm, 2018). The literature on comparative national institutional differences emphasises the importance of path dependency and the likelihood that certain economies will be slower to adapt or alter their policy mix in response to a shift in the trajectory of technological innovation systems. The VoC places the US and German systems in two distinct types of market economies, whose differences are the product of a degree of complementarity between distinctive national sets of institutions. Germany's institutional model (CME) is regarded as a better fit for diversified, quality manufacturing due to its reliance on non-market relations, credible commitments, and deliberative collaboration, which is primarily conducive to a pattern of incremental innovation. In contrast, the US liberal market economy (LME) is characterised by the predominance of arms-length market transactions as the primary allocative mechanism and is viewed as more conducive to radical forms of innovation (Hall and Soskice, 2001). The VoC approach presumes a relatively passive role for the state in both CMEs and LMEs; CMEs rely on coordination with social partners and eschew a more strategic role for state policy, while in LMEs, it ascribes a hands-off approach to the state. Further, VoC theory questions the government's ability in both institutional models to develop capacities that are incompatible with established institutional norms (Carney and Witt, 2014; Schmidt, 2009).

However, VoC theory has been subjected to an increasing number of conceptual critiques and empirical testing, both of which question the degree to which the models hold up. Alternative approaches challenge the VoC's oversimplification of the connection between the institutional context and on-the-ground actions, as well as the dichotomous explanation of capitalist variety [Deeg and Jackson, (2007), p.157; Herrigel and Zeitlin, 2010; Streeck, 2009]. Critics of VoC argue that its firm-centred perspective restricts the range of varieties considered. On the other hand, including a broader range of institutions opens the possibility of greater diversity in the types of capitalism than the dichotomous model proposes (Amable, 2003). Other critics contend that institutional domains are composite entities, "loosely coupled and hence open to strategic repositioning independently of each other" [Herrigel and Zeitlin, (2010), p.639]. Researchers have discerned CME-type elements in firm strategies, organisational forms, and modes of governance in LME economies and there is growing evidence of CME economies incorporating elements of more liberal market economies (Herrigel and Zeitlin, 2010; Berger, 2013; Block, 2008).

Most significant for the present analysis are criticisms levelled against VoC's presumption that path dependency and lock-in limit the prospects for institutional change in both VoC (Jackson and Deeg, 2008), as well as the assumption that each model is better suited to one mode of innovation. The claim that CMEs excel at incremental innovation, while LMEs are better suited to radical innovation has been tested empirically over the past two decades, using patent data, as well as comparative trade performance, and found wanting (Schneider and Paunescu, 2012; Taylor, 2016; Witt and Jackson, 2016). These results support the counterargument that individual countries have evolved in ways that diverge from their archetypal institutional make-up in VoC. They also maintain that a combination of institutional elements from both models may be more effective in dealing with the challenges posed by the need for radical or mission-oriented forms of innovation. Recent analyses have concluded that hybrid economies evincing mixed institutional logics may better sustain strong export performance in high technology industries, an indicator used to represent the national capacity for radical innovation (Boyer, 2004; Witt and Jackson, 2016).

In sum, the VoC firm-centred approach fails to account for the changing role of the state. It thus does not offer an adequate explanation of the evolution of German and US policy to promote the transition to a new energy paradigm. Recognising its limitations, we go beyond its institutional reductionism to consider how globalisation and technological innovations alter the policy options required to facilitate a major technology transition. The alternative framework based on the developmental or networked industrial state literature accounts for the state's evolving role, triggered by internal and external (e.g., trade) conditions. It provides a valuable lens to frame the research on US and German policymaking. The growing significance of new technologies – such as ICT and batteries – makes radical innovation essential for the future success and viability of the industry, as well as combining existing technologies to produce novel products that incorporate both radical and incremental innovations (Geels, 2005).

2.2 Networked industrial policy

The concept of the networked industrial state and associated policy initiatives is grounded in the observation that when markets are characterised by volatile demand, rapid and disruptive innovations and conditions of heightened uncertainty, production and distribution relationships can be governed most effectively through network arrangements, rather than the more conventional alternatives of markets or hierarchies (Powell, 1990; Whitford and Schrank, 2011). Following from this observation, state structures and patterns of intervention are critical for building and supporting production and learning networks suitable for diffusing the needed technologies. Growing evidence from empirical studies indicates that government efforts to stimulate the growth of new firms and industries around the diffusion of disruptive technologies have gained traction since the 1980s (Negoita, 2013).

Kraemer (2006) argues the groundwork for networked industrial policies was laid in the first decade of the 21st century. The shift to a more networked form of industrial policy reflects the need to facilitate more effective linkages between firms, research institutions, and government to stimulate platform-based and network-oriented innovation. Policies include promoting sector networks and regional clusters, the preferential funding of SMEs, and strengthening the diffusion and commercialisation of new technologies, including user's involvement in technology development. The networked approach is the latest stage in the evolution of industrial policy, which has moved from a traditional approach based on product-market intervention (subsidies, state ownership, tariff protection), through a set of measures to combat market failures, for activities such as research and development, environmental restoration and labour market programs, to the current stage of strengthening systems, creating networks, developing institutions and aligning strategic priorities (Warwick, 2013; Negoita, 2013). O'Sullivan et al. (2013) reach similar conclusions in arguing that recent initiatives are characterised by

1 public-private collaboration in designing manufacturing support

2 long-term investment and planning in the context of program design

3 the coordination and alignment of manufacturing-related policy measures.

These government policies are part of an institutional framework required to develop and commercialise cutting-edge research in traditional manufacturing sectors such as automotive.

Not all regions or all firms within them have the types of resources needed to sustain disruptive innovation. However, there is growing recognition reflected in national initiatives of the value of the networked industrial policy approach. Such initiatives, designed to promote network relations, are usually implemented at the regional level and often involve a role for intermediary organisations, which enable manufacturers, particularly SMEs, to access intra and extra-regional innovation resources. Intermediary organisations within a region can be industry cluster organisations, regional economic development agencies, consortia, and new or established cooperative research centres, such as those found in the US Manufacturing Institutes or the German 'Spitzen' Cluster program (Bonvillian et al., 2017; Canter et al., 2013; Sautter and Clar, 2012). They address network failures by creating more effective linkages between the knowledge infrastructure, industry, and government. They are frequently deployed as critical elements of mission-oriented innovation policies.

The policies identified address each country's unique institutional obstacles to linking research and innovation with production, resulting in a more hybrid variation of their respective institutional structures. In the US, this has meant growing institutional support for the commercialisation of technologies of the kind present in Germany and greater emphasis on creating regionally networked intermediary organisations to diffuse technology (Berger, 2013). Conversely, German authorities have increased their R&D investments through competitive initiatives that promote more active business-science relationships. In both cases, a critical goal has been the creation of innovative small and medium-sized enterprises (SMEs) and their integration into the production chains in established industries, such as the automotive sector. Based on these trends, we argue that as both countries adopt a more mission-oriented innovation policy mix to support the development of BEV technologies, they have departed from their archetypal institutional structures towards a more networked industrial policy model. The next section turns to a consideration of this evolution in the US and Germany.

3 Evolution of policies in the US and Germany: towards networked industrial policy

The transition to an alternative, energy-efficient technology paradigm for the auto sector is part of a broader set of disruptive changes sweeping across the industry. They include incorporating connected and autonomous digital technologies into automobiles, and adopting new forms of shared mobility, collectively referred to as the CASE model (Covarrubias, 2018). However, prior to recent policy interventions, both Germany and the US lacked battery manufacturing capabilities and access to the necessary raw materials (Jetin, 2020). This constituted a critical disadvantage because closer interaction between innovation and battery production can provide a competitive advantage. In this context, and consistent with insights afforded by the literature on policy mixes, the transition to a new BEV paradigm in Germany and the US has been driven by the interaction between supply-push and demand-pull policies (Rogge and Reichert, 2016; Kern et al., 2019). Governments in Europe and the US implemented a combination of policies designed to increase demand for BEVs, while also supporting the development and diffusion of new battery-electric technologies and the control systems needed to implement them in vehicles.

The gradual convergence toward the networked design of industrial policy, as well as the departure from their respective institutional models, has not been a linear process in either the US or Germany. These policies were more resolutely adopted following the 2008 crisis as the two countries undertook the common goal of restructuring their respective manufacturing sectors by promoting the adoption of new materials and digital technologies. Their federal governments started assuming a more central role in the formulation of initiatives to strengthen both the automotive industry specifically and advanced manufacturing more broadly through investment in developing and commercialising key enabling technologies (Clark, 2013). However, despite certain shared aspects, initiatives continue to target different parts of the German and US innovation systems. This is because globalisation has presented a unique set of challenges for each country as both confront the adoption of emerging technologies.

The US innovation system has been differentiated historically by two fundamental characteristics – its large size relative to that of other industrial countries; and the critical role played by industry, large research universities, and the federal government as performers and funders of innovative activity [Mowery and Rosenberg, (1993), p.29; Ergas, 1987). Both characteristics figured prominently in the continuous economic growth and prosperity enjoyed by the US throughout the post-war period. However, American success was also linked to its technological leadership, which stemmed from its long-standing expertise in standardised mass production, with roots in the development of assembly-line techniques in the early twentieth century. This strength was closely tied to the core technologies of the post-war paradigm, oil production, and auto assembly, both of which were US-dominated [Freeman and Louçã, 2001; Nelson and Wright, (1992), pp.1937–1941].

Commencing in the 1970s, the US innovation system experienced a period of crisis and change. The transfer of US investment and technology to some of its leading competitors, especially Japan and Western Europe, promoted their rapid growth through the post-war period and helped close the gap on the US as the technological leader. Further, the rapid mastery of the new manufacturing techniques associated with lean production in the automotive industries, as well as the sophisticated manufacturing and product development capabilities displayed by the Japanese consumer electronics and related industries, widened the trade gap with the US by the 1980s (Dertouzos et al., 1989). In the 1980s and 1990s, economic restructuring eviscerated the old institutions that nourished the 'industrial commons' of regional innovation ecosystems and supported the transfer of research and technical skills to firms in the manufacturing economy (Berger, 2013). Growing outsourcing led to innovation without production, making the transition to a new energy paradigm more challenging. The impact of the global financial crisis in 2008–2009 sparked a dramatic restructuring of the industry that formed the context for the transition to a new energy paradigm (Klier and Rubenstein, 2013; Grunwald, 2012). The focus has been on reviving the industrial commons to enable a new wave of innovation in manufacturing (Bonvillian, 2021).

On the other hand, the hallmark of German economic strategy throughout the post-war period was to support the industrial commons and boost the exports of capital goods-producing industries. A defining feature of the German political economy was the highly networked or organised nature of German capitalism that ascribed a key policy role to numerous industry, labour, and intermediate associations (Allen, 2010). These associations often fulfilled quasi-public roles in key policy areas such as the German vocational training system. In contrast to the US pattern, innovation policies in Germany followed a diffusion-oriented model, with a focus on improving the technological capabilities of SMEs through vocational education programs, establishing a strong system of industrial standards, and promoting cooperative R&D (Ergas, 1987). This contributed to the establishment of a complex institutional infrastructure mobilised in the launch of various thematic programs often essential to the ability of firms (including SMEs) to adapt in a rapidly changing economic environment (Thelen, 2004). Berger identifies a large range of institutions with the task of enriching the terrain for industrial innovation, including trade associations, development banks, Fraunhofer Institutes, industrial collective research consortia, which play a role in diffusing new technologies with general applicability (Berger, 2013).

However, despite the fertile industrial ecosystems, scholars have identified a gap between disciplinary research in German universities and inter-disciplinary research in the private sector. This was in part due to the dominance of large corporate actors in research networks, mainly in the automotive sector, resulting in a lock-in to the ICE paradigm. As in the US, Germany experienced growing concerns about weakening institutional coordination and German manufacturers' ability to maintain their competitive edge due to a lack of research into cutting-edge technologies (NPE, 2010). In addition, SMEs' innovation spending declined, with only 5% spending on research in the electric and autonomous vehicle space (Koch et al., 2018). Although not to the same extent as in the US, there has also been increasing outsourcing of operations, leading to a greater focus on high-quality products domestically (Herrigel, 2015; Krzywdzinski, 2014).

Recent scholarship, however, has identified processes of incremental hybridisation of Germany's institutional model. In line with this claim, Lehrer suggests that German policy has sought to shift from corporatist networks to emergent ones designed to bridge the gap between universities and industry. The federal government has promoted science-industry collaboration to improve the ability to commercialise basic research. Longer-term institutional partnerships, tasked with animating regional economic and social development, resembling US-style university-industry research centres reflect relatively novel roles for German university and non-university research institutions (Koschatzky, 2014).

Consequently, there are indications of strategic intervention in both the US and Germany to deal with increasing competition in battery electric technologies. Studies show that electrification expenditures do not diverge in line with the national VoC framework (Whitford and Schrank, 2011; Negoita, 2013). Both countries are actively investing in enhanced R&D and manufacturing to promote the shift to more energy-efficient alternatives. Both have responded to the globalisation of production by shifting to a more networked industrial policy model. Changes in governance mechanisms to include both state and non-state actors allow governments to sustain production and learning networks needed because of the move toward decentralised production arrangements. The state's emerging networked role in the US and Germany reflects a period of growing convergence toward industrial policies with a partially shared design, objectives, and strategies to overcome imbalances created by national institutional models, resulting in a growing hybridisation of their respective institutional models. It reaffirms the potential of specific forms of publicly supported innovation policy to support the auto industry's transition to a BEV paradigm.

The following section presents an overview of how German and US automotive policies reflect the current transformation of state governance mechanisms. The study adopts the most different approach to show that similar outcomes are possible in different institutional contexts (LME and CME, or the US and Germany). Findings are based on 30 interviews with German (GF:1–GF:6) and USA (UF:1–UF:4) firms, intermediaries (GI:1–10 and UI:1–3), and policymakers (GP:1–4 and UP:1) over two years (2016–2018). We also undertook an extensive review of primary and secondary documents on the countries' industrial policy transformation.

3.1 US policies: national strategy

In recent decades the US placed less emphasis on the relevance of manufacturing than its German counterparts. This contributed to a lack of a coherent national industrial policy, which has made the initiation and coordination of collaborative efforts across agencies and government levels challenging to achieve (Bonvillian, 2012). The 2008 financial crisis prompted a re-evaluation of the US industrial structure and brought the automotive industry's relevance to the forefront. In addition to the automotive industry bailout, the federal government launched initiatives focused on several national priorities (Galvin et al., 2015). Not all were automotive sector-specific, but they aimed to promote manufacturing and energy-efficient technologies, which are vital to the modernisation of the industry and the revitalisation of regional economies.

For the Obama administration, the challenge of rescuing the auto industry from the Great Recession was part of a more complex problem – the long-term hollowing out of the manufacturing sector. The restructuring of the sector during the recession altered the geography of auto production in North America in three distinct ways:

1 it changed the clustering of production along ‘auto alley’ to include a fuller integration of assembly plants in south-western Ontario

2 the clustering of production outside auto alley was extended to include Mexico

3 auto alley was separated into distinct northern and southern segments [Klier and Rubenstein, (2013), p.9].

The reactive policies used to rescue the auto industry were complemented by new programs to support networks in de-risking the adoption of new technologies across traditional sectors. Particularly relevant for automotive suppliers, an important goal was to enrich regional industrial ecosystems to enable coordination and intermediation activities overlooked in US industrial policy (Clark and Doussard, 2019).

The new approach took the form of a series of policies designed to reconnect knowledge creation and production systems. They sought to shift the US away from the siloed and uncoordinated character of federal programs and agencies and use public-private initiatives to connect research and commercialisation with production to renew the industrial commons. These initiatives built on the foundation of existing agencies and programs that advance basic research and the development and prototyping of new products, such as DARPA, the Small Business Innovation Research (SBIR) program, and the Manufacturing Extension Partnership (MEP) – all designed to support the commercialisation and diffusion of technologies. Emerging from the recession, the government launched a series of new policies to support industry modernisation and the shift to more efficient energy sources and new materials.

A critical objective was to reduce US dependence on Asian battery manufacturers by reinvigorating domestic research and the production of electric batteries. Many of the initiatives were funded under the American Recovery and Reinvestment Act (ARRA), which provided stimulus funding designed to reduce the cost of batteries by 70% while boosting their power and increasing their range (Grunwald, 2012). As part of its implementation, ARRA included $2.4 billion in grants to stimulate the development and deployment of the next generation of batteries and electric vehicles. The measures funded 48 new projects on advanced batteries, electric drive components and materials, involving a range of technologies across 20 US states. It also provided $24.7 billion in loans or loan guarantees to domestic manufacturing projects, many of which were predicated on collaboration between private firms and universities or public laboratories to speed the validation and commercialisation of new technologies. Of course, Tesla was the remarkable success story, as the beneficiary of a $465 million loan from the DOE, which it repaid within four years. The Advanced Energy Manufacturing Tax Credit covered up to 30% of the cost of investments in manufacturing plants producing renewable energy equipment [Keller and Negoita, (2013), p.332; Wessner and Wolff, (2012), pp.383–394]. The ARRA Transport Electrification program also provided over $400 million in cost-shared grants to eight projects deploying over 4,000 electric vehicles, along with the infrastructure to support them. Several other national programs involved vehicle research. In August 2011, Energy Secretary Chu announced $175 million in funding to support 40 projects in 15 states to accelerate the development of advanced vehicle technologies and support innovations to create longer lasting and cheaper electric batteries.[1] The DOE continues to invest annually in green energy research and innovation through the Vehicle Technologies Office, which supports R&D on advanced transportation technologies. It spent $106 million in FY 2019 on the development of high-energy batteries for EVs and high-power devices for hybrid vehicles (Vehicle Technologies Office, 2020).

The multiple initiatives included in ARRA were complemented by those in other agencies, including the Departments of Defense and Energy, which intensified their efforts in the advanced manufacturing space. These initiatives took the form of public-private partnerships and federal and sub-national cluster strategies focused on developing and strengthening regional industrial ecosystems (Bonvillian, 2012, 2014). A central initiative was the establishment of the Advanced Research Projects Agency for Energy, ARPA-E. ARPA-E projects are designed to speed up the commercialisation of clean-energy technologies through small investments in transformational energy projects over a defined period. One of the most critical projects funded by ARPA-E is the Batteries for Electrical Energy Storage in Transportation (BEEST) initiative. It was created in 2010 to find an alternative to the nearly $1 billion the US spends daily to import petroleum for energy use. The BEEST initiative is designed to reduce petroleum dependence by developing rechargeable battery technologies, which would enable EV/PHEVs to equal or exceed the price and performance of gasoline-powered cars.[2] Among the BEEST-funded projects that have garnered considerable attention is the company QuantumScape.[3] Recent reviews of the agency found that when measured by the number of patents filed, ARPA-E start-ups were more innovative than non-funded SMEs (Goldstein et al., 2020). However, while ARPA-E helped SMEs bridge the Valley of Death, additional interventions, such as demonstration and procurement programs, were required to ensure successful business outcomes.

The parallel initiative, the ‘National Strategy for Advanced Manufacturing’ that focused on manufacturing technologies and production, was meant to fill some of these gaps. A key component of the strategy was the creation of the National Network for Manufacturing Innovation (NNMI), loosely modelled on the German Fraunhofer Institutes. The NNMI created a network of centres to facilitate industry-academia-government collaboration to support advanced manufacturing clusters. Institutes for manufacturing innovation in the NNMI perform both pre-competitive research and proprietary technology development for product manufacturing. Like the Fraunhofer, they provide shared-use facilities to scale up laboratory demonstrations and mature manufacturing technologies. The NNMI represents a significant change for federal programs, which typically focus on basic research and are dominated by large corporations and universities (Bonvillian et al., 2017). NNMI, subsequently renamed Manufacturing USA®, goes beyond the usual suspects and includes many SMEs, smaller schools, and the community colleges that will educate the next generation factory workforce. To date, Manufacturing USA® comprises 16 public-private institutes and their federal sponsoring agencies – US Departments of Commerce, Defense, and Energy – in fields as diverse as power electronics, lightweight metals, and digital design and manufacturing. Scholars report that many of the centres have successfully met their goal of aiding SMEs to cross the Valley of Death (Clark and Doussard, 2019). However, existing conditions at the regional level have led some centres – such as the Detroit Lightweighting MII – to focus support on large automotive incumbents. Thus, MII's operation can be constrained by the existing regional industry structures and power differentials (interviews UF:3–4 and UI:1–3).

In March 2013, the US Department of Energy (DOE) also launched the Clean Energy Manufacturing Initiative (CEMI) to accelerate US-based manufacturing of cost-competitive wind, solar, batteries and biofuel technologies.[4] This DOE funding supports private/public partnerships that advance clean energy manufacturing and supply chain analysis. The 2013 fiscal year budget also called for $500 million in funding for the DOE to aid advanced manufacturing in flexible electronics and lightweight vehicles. It included another $200 million to be allocated to DARPA for research to support advanced manufacturing and further increases in funding to the National Science Foundation for programs in cyber-physical systems, robotics, and advanced manufacturing [Wessner and Wolff, (2012), p.76]. The manufacturing strategy is complemented by federally funded regional cluster initiatives, such as the Energy Innovation Hubs. In 2018, the White House sought to terminate funding for both the Energy Innovation hubs and ARPA-E (Narayanamurti and Tsao, 2018). Senators mobilised against this proposed cut, and funding was maintained. These events demonstrate the ongoing political struggles to fund networked industrial policies, but also their growing importance for the US industrial commons.

As substantial as the supply push measures documented above were, the Obama administration supplemented this approach with the single most significant demand-pull measure in almost 40 years – a major increase in the Corporate Average Fuel Efficient (CAFE) requirements. On 1 April 2010, the US Government released a new regulation officially titled the 2012–2016 Light Duty Vehicle CAFE and Greenhouse Gas Standards. Although implementation of the regulation was postponed for two years, it required that automakers' 2016 vehicles achieve a fleet-wide average of 35.5 mpg. After an intervention from California to raise their state standard even higher, followed by extensive negotiations with the OEMs, the regulation was superseded in 2011 by National Program for Model Year 2017–2025 CAFE and Greenhouse Gas Standards which will raise the CAFE standard to 54.5 mpg by 2025 (Oge, 2015). While the Trump administration signed an executive order in March 2020 to rollback this requirement, the Biden administration proposed new CAFE standards in August 2021 and hearings on the standards are to be held in October 2021.[5] The White House report on securing global supply chains, released in June 2021, contains policy recommendations to strengthen the supply of lithium batteries in the US and support the domestic battery supply chain, while the infrastructure bill passed by the Senate in August 2021 contains measures to support clean energy technologies, including electric vehicles [Bonvillian, (2021), p.16, p.19].

Governments at the state and local level have facilitated the growing emphasis on developing and scaling new technologies. While the federal government has been the prime institutional actor in the recent US policy initiatives, state governments have also adopted a more active role in supporting the auto sector's transition to a more sustainable energy paradigm. State subsidies are being used, along with federal government money, to promote advanced research in a range of fields relevant to the future development of automotive technology. In Michigan and Indiana, state governments have been involved in battery development through the establishment of an Energy Innovation Hub in the former and a Battery Innovation Center in the latter. With the help of federal funding, South Carolina has focused on fuel cell technologies by establishing a partnership between the University of South Carolina and industrial members of The National Science Foundation Industry/University Cooperative Research Centre for Fuel Cells.

The implications of these policy measures for US OEMs, as well as upstarts like Tesla, have been far reaching. Major producers have announced plans to accelerate their introduction of electric vehicles over the coming decade, and to expand their battery production in the US. Rapid development of improved lithium-ion batteries continues, as well as the search for more stable and efficient solid-state batteries. On 29 January 2021, GM raised the stakes substantially for other domestic and foreign OEMs with the announcement of its goal to become carbon-neutral by 2040 and phase out the production of cars with ICEs by 2035. While this target was identified as 'aspirational' it will increase the pressure on other OEMs to follow suit.[6]

Despite these achievements, our research shows that the implementation of networked industrial policies is not without its challenges, considering the ambitious goal of rebuilding the industrial commons. Place-specific path dependencies shape how national-level funding programs are implemented at the regional level and the extent to which they help SMEs.

3.2 Evolution of policies in Germany

Historically, the German automotive industry has long been at the forefront of the dominant ICE paradigm (Canzler et al., 2011). It accounts for 17% of global passenger car production and remains the country's most relevant economic sector. It has the highest concentration of all European automotive OEMs, numerous system and module suppliers, not to mention SME tiers 2 and 3 suppliers (Galvin et al., 2015). These positive outcomes result from Germany's strong commitment to basic research and its institutionalised investment in intermediaries such as the Fraunhofer Institutes and AiF (German Federation of Industrial Research Associations), which conduct applied research. However, its export markets have proven to be less than reliable. Deutsche Bank research demonstrates that momentum slowed noticeably in 2018, with export growth coming to no more than 3% (Becker et al., 2019). Industry behemoths are also suffering from the pandemic-induced falling demand and technological transformation cost, while smaller suppliers struggle to survive (Rostek-Buetti, 2020).

This rising global competition in quality has pressured German producers to not only focus on innovation but also costs (Herrigel, 2015). Automakers have started to offshore a greater portion of their manufacturing. And these developments present a challenge for the many suppliers that depend on large automakers. In Germany, 2011 was the first-time international production outpaced domestic production (Cody, 2015). Large German incumbents are also engaging in transnational knowledge exchange (interviews GF:1–GF:5, cf. also Herrigel, 2015). But they continue to perform the majority of R&D in the region and control knowledge flows (Graf, 2017).

However, concerns have arisen over the German industry's ability to modernise, considering the dominance of large corporate actors in research networks and the resulting technological lock-in to the ICE paradigm. SMEs and companies in sectors other than automotive report limited access to institutions such as the Fraunhofer Institute (Sternberg, 2002; Fuchs and Shapira, 2005). Overall, the percentage of innovation-active SMEs supported by Länder programs has recently declined. In effect, there is a perceived disconnect between the knowledge infrastructure and industry with respect to the development and commercialisation of novel technologies – especially among SMEs.

The federal government's strategic role has been growing to address some of these network failures. Simultaneously, however, the automotive sector's relevance and power have also created strong resistance to limiting CO_2 emissions from cars (Meckling and Nahm, 2018).

In 2006, the federal government established the High-Tech Strategy (HTS) to meet its national climate goals within the 2002 National Sustainability Strategy. Renewed in 2015, the HTS was the first national effort to form alliances between crucial innovation and technology stakeholders in working toward a green economy, future cities, and Energiewende (energy transition) (Mennicken et al., 2016). Among these was the lithium-ion battery alliance, with the German Federal Government providing a budget of €60 million and an industry contribution of another €360 million. The global economic crisis of 2008 further prompted the German Government to adopt other measures to protect its industries (Benz and Heinz, 2016).

Support for the German car industry was included in the German Government's general economic stimulus programs approved in December 2008 and February 2009. Germany notified the European Commission of the initiatives under the 'temporary framework for state aid measures' that allowed for a relaxation of state aid rules and foresaw no formal control of individual state aids (Grigolon et al., 2012). The aid also included €500 million for electromobility R&D, market preparation, and demonstration. Although environmental targets existed as well, industrial goals played a more critical role. Given that Germany is economically dependent on its automotive industry, its mobility transition (*Verkehrswende*) is a more challenging endeavour than its energy transition (*Energiewende*) (Haas, 2020; Mazur et al., 2015; Meckling and Nahm, 2018).

As part of its post-crisis industrial policy, the government developed a National Electromobility Plan and established the National Platform for Electric Mobility (NPE) as a forum to achieve its goals. From 2010 to 2018, the NPE's task was to combine all industry, politics, and science forces to develop strategies for the run-up to the e-mobility market. It closely coordinated activities and funding programs between four federal ministries of economics (BMWI), transport (BMVI), environment (BMU), and education and science (BMBF). In total, from 2009 to 2017, the German state funded €2.2 billion for the research and development of electric mobility (Richter and Haas, 2020). However, the representation of actors, both in the NPE and initiatives stemming from it, was uneven, demonstrating the challenges associated with implementing networked industrial policies.

On the national level, the NPE consisted of about 150 stakeholders and representatives of administrative bodies. The automotive and supplier industry formed by far the largest group (22%), and the electrical industry and IT sector accounted for a further 15% of representatives. In contrast, civil society actors, i.e., representatives of environmental protection and consumer associations, accounted for just 3%, which further affirms automakers' power in Germany's innovation system. The mid-sized groups represented universities and science (14%), the chemical and battery industry (14%), and politics, administration, and authorities (9%) [Richter and Haas, (2020), p.7].

The relatively strong participation of universities can be traced to initiatives that have sought to strengthen universities' role as stakeholders in these new mission-oriented economic development strategies (interviews GI:6–10). For example, the HTS has sought to modernise the German Science System through initiatives such as a the joint pact for research and innovation

b the pact for higher education 2020

c the initiative for excellence (2007–2017).

These programs clearly depart from German funding priorities since their goal is to restructure the German university landscape and enhance its contribution to the country's competitiveness as it faces international competitors.

For example, the German Research Foundation (DFG) and the German Council of Science and Humanities coordinated the excellence initiative that included three funding streams – clusters, graduate schools, and future concepts. With competition for funds at its core, the project unleashed a new dynamism in German higher education, demolishing the pretense of egalitarianism and forcing universities to focus on defining their mission and sharpening their focus. According to Sondermann et al. (2008), the excellence initiative has led to new forms of cooperation, including collaboration between disciplines – inside the successful universities and between universities and non-university research institutions. One example is the cluster of excellence 'engineering of advanced materials – hierarchical structure formation for functional devices' at the Friedrich-Alexander-University Erlangen-Nürnberg, an interdisciplinary research collaboration focused on designing and creating novel high-performance materials essential to the goals of the NPE.

The NPE also paid considerable attention to linking technological development to industrial capacity at the regional level. It announced prestigious competitions for 'clusters of excellence', 'electromobility pilot regions' and 'electromobility showcases' to lay the groundwork for electric mobility rollout and swift market penetration. The eight model regions for electric mobility include Hamburg, Bremen/Oldenburg, Berlin/Potsdam, Rhein-Ruhr, RheinMain, Sachsen, Stuttgart, and München, with 208 partners actively involved. In early 2012, the regions of Berlin Brandenburg, Baden-Wuerttemberg, Lower Saxony, and Bavaria/Saxony were selected as the four 'showcases' for Germany (Sydow and Koll, 2017).

Coordinating agencies were founded on the regional level in 2010 to support a decidedly inter-organisational exchange among increasingly divergent interests. In the Stuttgart region, besides promoting research infrastructure, an essential part of the state initiative was implementing 'e-mobil BW', the state agency for electromobility and fuel cell technology. The agency coordinates

a the 'leading edge cluster initiative electric mobility south-west' (collaborative R&D worth €80 million, funded half by the national ministry of research and the regional industry)

b the 'LivingLab BW e-mobil showcase', i.e., application-oriented, systemic research into, and experimentation with, sustainable mobility systems, funded by the national government (€45 million), the state of Baden-Württemberg (€15 million) and the regional authorities [Späth et al., (2016), p.8].

Analysing these place-specific initiatives illustrates that pre-existing local economic and technological environments constrain or enable electromobility (Sydow and Koll, 2017). These path dependencies result in a mismatch between electric mobility initiatives' goals – creating cross-sectoral linkages and providing SME support and some of their outcomes. For example, interviews with e-mobil suggest their value proposition is to provide services to large companies (interviews GI:1–2). In other words, its declared ambition has not resulted in significant efforts from e-mobil BW or of the big players to actively support smaller companies. Scholars have found that large enterprises have mainly captured the R&D funds to diversify into electric vehicle technologies (Späth et al., 2016). Four giant companies headquartered in Baden-Württemberg (Bosch, Daimler, ZF Friedrichshafen, Porsche) filed around 50% of all national patent applications in 2014 (Koch et al., 2018). To further address these challenges, the Federal Ministry of Economics introduced programs that would help SMEs innovate. An example is the ZIM Program (The Central Innovation Program), which merges four predecessor programs (ProInno, InnoWatt, InnoNet, Nemo). Yet even such programs reach only a fraction of SMEs. Authors studying manufacturers in Germany attribute this disconnect to policy design being overly focused on R&D (Som and Kirner, 2015).

On the other hand, the NPE served as a medium to anchor electromobility in the existing industry structure for the first time (interviews GP:1–3, cf. also Richter and Haas, 2020). It helped make positions and negotiation processes more transparent and revealed underlying conflicts (Sydow and Koll, 2017). Despite its initially laggard status, Germany is now a global knowledge source at the forefront of technological development (Buchmann and Savchenko, 2017). Furthermore, the NPE laid the groundwork for the current industrial policy to facilitate the co-location of R&D and manufacturing, especially in the realm of batteries. In the 2019 budget, the Federal Ministry for Economic Affairs and Energy identified the industrial production of battery cells for mobile and stationary energy storage as one of the critical issues for the federal government's Energy and Climate Fund and has made available up to €1.5 billion over the period until 2022 (Backhaus, 2020). In 2021, the European Union (EU) also approved a program giving state aid to Tesla, BMW, and others for about €2.9 billion ($3.5 billion) (Krukowska et al., 2021). It follows another €3.2 billion EU program to fund battery research and manufacturing in seven countries, including Germany, approved in 2019 (Backhaus, 2020; Jetin, 2020).

In a departure from their historical approach, German OEMs have already begun to build their own manufacturing facilities for lithium-ion batteries, often in partnership with firms in the battery industry. Among them is Volkswagen, which has committed to battery production in Lower Saxony under several conditions, including government funding and access to a supply of energy from renewable sources (Backhaus, 2020). Furthermore, more than 30 companies along the entire value chain have indicated their interest in receiving government funding. They include automakers, automotive suppliers, battery manufacturers, chemical companies, and raw material and recycling firms, some with the support of research institutions (Backhaus, 2020). Overall, despite these developments reflecting the substantial progress being made; networked industrial policies must still overcome underlying power differentials between large incumbents and weaker parts of the supply chain.

4 Conclusions

This article demonstrates that a similar policy design is possible in very different national institutional contexts, as reflected in the US and German cases. It argues for a move away from VoC's institutional determinism to better understand how policy is supporting the transition to a sustainable energy paradigm in the automotive sector. The industries in both countries face similar challenges from new Asian competitors and domestic upstarts from outside the sector. In both cases, the increased relevance of low carbon innovation makes automotive incumbents reliant on partners to provide supporting technologies, intermediate goods, and services. This has increased the role of other actors, such as SMEs and public research organisations, as they become more essential for the innovation process. Considering this, both the US and Germany have utilised a shared canon of policy objectives and instruments to address their respective network failures. Firm-centric policy supports are being displaced by policies focused on promoting and shaping linkages between firms, research institutions, and government to stimulate platform-based and network-oriented innovation. The goal has been to both enable the growth of new innovative SME's and their integration into the automotive production chain long dominated by the ICE paradigm.

While the shifting economic environment has led to growing industrial policy convergence, remaining power differentials between large OEMs and small suppliers along the value chain have contributed to similar challenges in implementing networked industrial policies. The dominance of established interests and path dependencies in regional innovation systems in both the US and Germany create obstacles toward electromobility, especially among smaller companies. The findings signal the importance of intermediaries for driving network development and open innovation practices. In line with this view, recent public policies reflect emergent and hybrid institutional arrangements.

The analysis in this article focuses on the changes that have occurred in the two largest centres of automobile production in North America and Europe, the US and Germany, but the implications for their semi-peripheral partners in their respective trade zones are clear. As the shift to an electric energy paradigm gains momentum and networked industrial policy targets the more effective integration of research, innovation, and production, the semi-periphery risks being relegated to a more limited assembly role, given the substantially smaller number of parts and components that comprise battery electric vehicles. The three OEMs' recent announcements of new product mandates for BEVs in Ontario appear to have been driven by union negotiations with governments limited to a supporting role. As Mordue's analysis of Canadian industrial policy reveals, recent initiatives to support the transition to a new CASE paradigm have been industry-driven, rather than policy-led (Mordue, 2020). The transformation of industrial policy in the two cases examined in this article may hold important lessons for the other North American partners.

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Notes

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