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Concentration of power: A UK case study examining the dominance of incumbent automakers and suppliers in automotive sociotechnical transitions

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ABSTRACT

Sustainable transition scholarship has recently challenged the stereotypical characterisation of socio-technical transitions, by revisiting the concept of creative destruction. The central counterargument is that new paradigms do not destroy old ones, but rather extend and complement them. Based on a case study of the UK's automotive industry, this article argues that established firms lead the industry in technological innovation, in large part due to regional regulatory frameworks and preferential state accumulation projects. That article then goes on to examine the 'power flows' surrounding incumbent firms as the primary agents of creative accumulation within global production networks. By exploring revealing linkages between evolving government-industry relations, the motorsport sub-sector, and component suppliers, this article renders a more nuanced understanding of incumbent firms as empowered, multi-level agents of innovation. Finally, this article evaluates the UK's incremental, 'zero-carbon' pathway and raises some concerns about the regime's current sociotechnical configuration, and its fitness to achieve its stated goals.

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1. Introduction

Over the past two decades, new models of technological change have risen to replace older neo-classical growth theories [1]. Among these, the multi-level perspective (MLP), developed by Frank Geels, has become one of the most widely used theoretical frameworks in contemporary transition scholarship [2]. The MLP provides a means of investigating the core debate in transition studies: (dynamic) stability vs. (radical) change. This interaction occurs across multiple tiers of an industry [3,4], particularly between the regime and niche levels [5]. Like much of the work that followed Schumpeter's concept of creative destruction [6], transition scholarship has often focused on 'the attacker's advantage' [7]. For clarity, Schumpeter's concept proposes that 'creative' innovation is effected by the invaders - new firms or entrants to the industry - while 'destruction' is the fate of entrenched industry incumbents [8]. This characterisation of technological discontinuity has also often been invoked by MLP adherents in their explanations of sustainable transitions [9], which has mostly been focused on the dismantling of existing regimes, and the emergence of new, more sustainable technological systems [10–13].

Recently however, sustainable transition scholarship has begun to move beyond the attacker's advantage characterised by regime-niche antagonism, and instead has been exploring alternative conceptual understandings of the innovation process [14]. This has been especially true in recent case studies of the automotive sector, which has been described as a complex capital good industry [8,15]. The findings in these case studies imply that incumbent firms, who are part of the automotive regime, lead the industry in low-emission innovations via a process called 'creative accumulation'. Creative accumulation proposes that (a) attackers are unable to match incumbents' accumulated knowledge and experience, and (b) this expertise allows incumbents to readjust and develop solutions at a much faster rate. Therefore, this article's first research

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question is as follows: **(RQ1)** To what extent is creative accumulation occurring in the UK Light Duty Vehicle (LDV) sector[1]? This article will pursue this query by exploring how incumbent firms in the UK deploy unique strategies and assets, some of which have been overlooked or undertheorized in existing transition literature.

To probe beyond the bounds of established literature, this article's second research question (**RQ2**) is to discern what (if anything), creative accumulation reveals about the nature of incumbent 'power' in transitions. Power asymmetries between agents in sociotechnical transitions has been a lesser explored (and developed) aspect of the MLP, and this article seeks to contribute further to this theoretical gap. Finally, after having addressed the first two research questions, **RQ3** will interrogate the UK's 'green technology' path for the automotive industry within the context of sustainable transitions. Section 2 of this article provides an overview of the relevant theories upon which this study builds, and Section 3 lays out the methods of analysis employed. Section 4 presents the main findings, Section 5 discusses their significance and Section 6 concludes with a summary of this study's findings, limitations and opportunities for future research.

2. Theoretical framework

2.1. Automakers, innovation and the policies that drive them

The MLP adopts a broad analytical approach to understanding sustainable transitions in an attempt to bridge the dichotomy between technological solutions and behavioural change [16]. This article, however, focuses on technological solutions, for the simple reason that technologies - and the policies that drive them - are the main elements of present-day sociotechnical systems. While others have argued [17–20], that demand-side considerations such as public outreach and change in personal values are unlikely to result in meaningful sustainable transitions, this article's technological focus is not aimed at this debate. Rather, this article seeks to shed new light on innovation dynamics within the automotive industry, in the context of sustainable transitions. The main assumption (from a public policy perspective) is that if technology is a means by which sustainable transitions may be achieved, then stringent regulations are the primary driver behind motivating firms to innovate [21,22]. Ideally, low-emissions regulation 'forces' a measurable reduction of harm to the environment (e.g. volume of pollutants generated) and increased levels of R&D among firms, resulting in new innovations [23]. These kinds of 'technology-forcing' policies require governments to interact with firms and markets in a manner that revolves around regulators trying to influence firms to invest in R&D. Subsequently, research has shown that firms are more likely to invest in R&D when regulators are committed to enforcing stringent regulations [24–26].

In the context of this article, low-emission technology-forcing occurs via command and control (CAC) policies, which are deployed by EU regulators in the automotive sector and are classified as general regulatory instruments. More specifically, these instruments are defined as performance standard regulations [27] for Nitrogen Oxides (NO_x) and Carbon Dioxide (CO_2) tailpipe emissions, and they require automakers to meet certain emissions targets based on a fleet average [28]. CAC regulations are a technology-forcing strategy where the regulator sets an objective for the future that cannot be met by employing existing technologies [25,29]. CAC policies generally regulate in two different ways: performance-based regulations (performance standards) and technology-based regulations (technology standards). A performance standard is usually the preferred approach when the goal is to induce technological innovation, because the only requirements are target performance outputs and how they are achieved is up to the individual firm [30,31]. In this case, emission standards for the EU automotive industry are based on CO_2 and NO_x emissions, and are considered technologically 'agnostic', because in theory, petrol, diesel, electric and hybrid propulsion technologies all have an equal opportunity to meet the specified regulations. For the practical reason that the EU does not use technology-based policies to regulate road transport emissions, they are not considered in this article.

The EU regulatory framework for the automotive sector is characterised by the certainty and stability that it provides to the region's member states, and this can be seen in the UK's wholesale adoption of EU emission performance standards in its domestic market. The EU model of performance standards is also visibly propagated in UK Government-Industry ventures such as the Advanced Propulsion Centre (APC), where national innovation competitions select 'technology agnostic' low-carbon innovations that meet future EU emissions targets [26]. EU CAC regulations also make use of time-horizons to reinforce certainty and predictability in this type of policymaking, where for example, emissions targets are planned out to 2050, where the expected result is an 80–95% reduction in the EU road transport emissions [32]. Therefore, CAC regulation predictability can reduce ambiguity around what is expected from automakers.

A second characteristic of CAC regulation that makes it especially effective in 'forcing technology' is its degree of stringency [23,31], and EU emission regulations are an especially good example of where currently, car manufacturers are obligated to attain a fleet average of 130 g CO_2/Km, regardless of the technologies used [26]. This rule has been enforced by levying an Excess Emissions Premium (EU fine) on each car registered of €5, €15, and €25 for the first, second and third g/km of exceedance respectively and €95 for each additional g/km. As of 2019, however, the fine will be €95 from the first gram of exceedance onwards [28].

Historically, these types of fuel economy and GHG performance standards have proven to be some of the most effective means of reducing global oil demand and GHG emissions [33]. At their core, environmental CAC regulatory frameworks exist to facilitate transitions towards lower-emissions technologies [34], and EU CAC regulations have been responsible for reducing the sulphur content in petrol, as well as phasing out leaded petrol in Europe [35]. In fact, researchers have estimated that if EU fuel efficiency regulations were abandoned, a 50% increase in current fuel taxes would be necessary to induce similar fuel savings [36].

The Multi-Level Perspective (MLP), however, cautions that while governments can stimulate innovation with CAC policies, there is a risk of too narrow a technological focus and inward-looking technical learning. We are also reminded that policy makers are beholden to the electorate, public opinion and the automotive industry for jobs, taxes and economic growth. For these reasons, it is argued that policy makers can only govern from within the confines of 'the cockpit', as they are in fact part of the system and are constrained by their dependence on other actors [3]. Despite these caveats, transition scholars recognise the effectiveness of automotive emissions regulations, and EU legislation in particular, citing that while initial emissions targets could be met incrementally, longer-term targets would probably require radical innovations [3]. MLP studies remain sceptical of EU policymaking, however, arguing that its measures are oriented towards a green technology path rather than a more holistic system-wide transition pathway [37].

[1] Light Duty Vehicles are defined by the UN as passenger cars and commercial vans [104].

2.2. Creative destruction: the classic regime-niche actor dichotomy

The MLP recognizes that in the automotive industry, the acceleration and diffusion of niche innovations depends on the involvement of regime actors (established firms) and, more specifically, relies on collaborations between these firms and newcomers for the development of 'green technologies' [38]. Established automakers (OEMs[2]) possess complementary assets such as specialized manufacturing capabilities, distribution channels and service networks that are otherwise unavailable to industry newcomers [39]. Despite this recognition of the important role played by OEMs, the MLP has traditionally portrayed these regime actors as defensive in nature, constantly protecting their entrenched technologies and avoiding collaborations that could endanger their core markets [5]. The incumbent strategy toward new technologies has most often been perceived as a 'hedge' against the possibility of shifting market conditions in an attempt control the pace of technological change, without ever genuinely committing to resolving fundamental environmental issues [38]. A classic MLP argument is that industry incumbents are burdened with 'core rigidities' of the old technological regime [40] and thus when technological discontinuities occur, new entrants may gain access to the industry through various modern-day versions [8,41] of Schumpeter's creative destruction (1942).

2.3. An alternate theory of change

There have been however, counterarguments that creative incremental accumulation has been occurring in recent times rather than radical waves of creative destruction, where new paradigms do not destroy old ones, but rather extend and complement them, offsetting the attacker's advantage [42,43]. Transport studies looking at powertrain competition in the car industry [8] and multi-level actors in the heavy vehicle sector [15], seem to align with this view. They describe the automotive industry as a routinized regime, characterised by conditions of high variability and cumulative resources, which allows incumbents to accumulate technological knowledge and innovative advantages over industry newcomers. This results in technological leadership among incumbents, which explains the concentration of innovation and hierarchical stability among them and the low rate of entry typically observed in the automotive industry [23]. Thus, complex systems regimes like the automotive industry are characterised by high entry requirements in knowledge, scale and persistence of innovation [44]. Another distinctive feature of established firms is their high levels of knowledge diversification, particularly in upstream technologies coupled with access to external sources of knowledge. These firms are 'active in a wide range of technological fields along similar search trajectories' [23]; p. 569) and possess the ability to exploit opportunities with high degrees of relevance within their network of R&D activities. A good example of this variation in knowledge assets is the motorsport industry, discussed in later sections, which is identified as an important feature of the automotive regime and their innovative strategy. The central argument here is that the complex knowledge-base is a fundamental barrier to entry for newcomers in the automotive industry. However, aside from this complex technical knowledge-base, there exists a sophisticated network of actors that must also be taken into consideration. For example, the long-standing relationship between OEMs and component suppliers in the development of new technologies is crucial to the analysis of low-emission innovation in the automotive industry. The complexity of these automotive supply chains has been explored in various other studies, where it has been shown that global, regional and national actors and institutions influence the configuration of these value chains [45] and even the geography of production [46]. This high degree of cumulativeness of innovation in the automotive industry gives way to incremental innovations along a particular technological trajectory, which in this case, manifests as low-emission innovations that can be integrated into the regime's current trajectory [23].

2.4. 'MLP 2.0': creative accumulation

[8] expand on the concept of cumulative innovation by observing that creativity is difficult for incumbent firms in complex capital goods markets. While previous literature presents cumulative innovation as incremental, step-by-step refinements [8], put emphasis on the tensions between creativity and accumulation. Creativity implies responses beyond the range of existing practices and can be manifested through improvements in cost, performance or quality over previous iterations. Accumulation, on the other hand, implies knowledge creation based on existing practices, rather than making them obsolete. Creative accumulation closely resembles a concept Geels refers to as 'competence-expanding' innovation [47], which builds on previous competence-based models of innovation [48]. Firms in complex product industries involved in creative accumulation therefore must seek a balance between deep component related knowledge and broad systems related architectural knowledge, implying the added challenge of balancing and using existing knowledge with new knowledge [8]. This perspective explains why potentially competence-destroying or disruptive innovations have thus far failed to supplant OEMs within the automotive industry and why automakers have managed to survive and even increase their competitive capabilities. The main reasons given by Ref. [8] are that (a) attackers are unable to match incumbents' accumulated knowledge and experience; (b) this expertise allows incumbents effectively to develop solutions at a much faster rate; and (c) competition between established firms means that new entrants are constantly trying to hit a moving target. In addition, evolving industrial standards guiding the regime's technology roadmap, like the EU's emissions regulations, represent an additional 'moving target' for newcomers. This article concedes however, that Tesla has bypassed these evolving regulations by 'leapfrogging' the internal combustion engine (ICE) and focusing on battery electric vehicle (BEV) development instead.

Creative accumulation therefore highlights the significance of accelerated development, technological exploration and the integration of new competencies, which explains some of the advantages that incumbents who compete in complex capital goods industries possess [8]. The arguments made in this section, therefore, are based on the MLP's broad analytical framework, while incorporating the dynamics of creative accumulation when explaining the processes by which established firms maintain a competitive advantage in knowledge assets and speed of innovation. This article's rationale for adopting the Bergek's concept of creative accumulation (2013) is further supported by Geels et al.'s (2016) recent reformulation of sociotechnical transition pathway typologies, originally conceptualized by Ref. [49] nearly a decade earlier. In redefining the Transformation pathway, they acknowledge that established firms are also capable of pursuing radical innovations, contrary to what has been commonly assumed in classic MLP literature. By going beyond the dichotomy of 'incremental incumbents' and 'radical newcomers' [14], openly embrace the validity of creative accumulation [8,15].

[2] OEM literally stands for Original Equipment Manufacturer, however within the automotive industry, this acronym is commonly used to refer to established automakers the likes of Honda, Ford etc.

3. Methods

Transport studies often follow the epistemological trend of using quantitative methods with a positivist world view [50,51], which at times, has been critiqued as being archaic [52,53]. On the other hand, it has been argued that qualitative approaches have been steadily contributing more fully to understandings of transport practices and policies [54–57]. Hence, there has been an appeal for more critical (qualitative) analysis in transport studies, to compliment the already well-established technical (quantitative) scholarship [58]. While comparing the merits of qualitative versus quantitative approaches is a false dichotomy, there have been calls for the application of more varied methodologies and holistic approaches, that offer more robust theoretical underpinnings from a wider range of disciplines [50].

Qualitative methods in transport studies are particularly useful for inductive purposes, as it permits the identification of concepts and interpretations from the respondent's perspective [12,59]. This article makes use of such methods, with the intent to capture relevant themes from the perspectives of automakers, regulators and other industry stakeholders based on their experiences. It then becomes possible to establish linkages between collections of different sets of knowledge within the industry. The multi-level perspective (MLP) – which is the overarching theoretical lens used article - seeks to explain sociotechnical transitions as a systemic theory of change [3]. Thus, this article makes appropriate use of interpretative analysis, which combines theoretical sensitivity with empirical expert assessments, often seen in other contemporary MLP case studies of the automotive industry [8,15,38].

This study took place between 2014 and 2019, and the findings in this article are based on the analysis of primary data from 17 respondents that has been sampled from a larger pool of 48 semi-structured elite interviews with key industry decision-makers within the automotive sector (industry and government). These stakeholders operate at the niche and regime levels of the socio-technical system and are thus qualified to provide well-rounded accounts of incumbent innovation within the automotive industry. Respondents were based in the UK, US, Germany and Belgium, and were selectively targeted for their opinions on the role of established firms in the process of sustainable transitions within the industry. Table 1 lists the sample of elite respondent interviews used in this article.

Interviewees were specifically selected (non-probability sampling), and in this case, a combination of purposive and chain-referral sampling, which allowed for the inclusion of key institutional actors in the data gathering process [60]. While these methods of sampling run the risk of suffering from selection bias and limited potential to generalize about the wider population; many of the respondents in this study were from competing multinational firms (automakers and suppliers), and thus their international portfolios often qualified them to give opinions that extended beyond national borders. Respondents also often had competing interests (policy and commercial), and this corroboration of evidence from multiple sources made possible the triangulation of information, which lends validity to these findings [61]. For these reasons, the number and variation of actors sampled should remove most of the above concerns. Other advantages of non-probability sampling is more direct control over the selection process, and the inclusion of key institutional actors in the data gathering process [60]. Additional primary data was collected from audio recordings of presentations and Q&A panel discussions at select industry conventions in 2015.

The data used in this study was also supported with documents published by the automotive sector, official European Commission and UK government documents, and news articles in the press. While reports in the press are not widely used for academic support, this secondary source of data was invaluable in tracking the daily shifting landscape of events within the automotive industry, as well as providing context to what respondents were saying. These secondary sources of data represent the sociotechnical landscape within the MLP framework, which is characterised by aspects of the exogenous environment that are outside the direct influence of individual actors. In this instance, the landscape is a useful metaphor used to envision the large-scale material context of how OEMs develop and integrate low-emissions innovation into the automotive value chain [38]. The use of secondary data also has the added benefit of contributing to the triangulation of information effect.

In accordance with the ethics approval guidelines of this study, express permission was granted before the recording of each interview, participants were guaranteed anonymity and were assured that recorded data would be destroyed in accordance with the UK's Data Protection Act 1998. Recorded interviews were transcribed and thematically coded using the Template Analysis method, which gives an account structured around central themes that have emerged, and draws on examples from interview transcripts as required [62]. The conclusions of this study are meant to provide a robust overview of how CAC regulation affects established firms in sustainable transitions within the automotive industry.

Table 1
List of interviewees.

Institution/Organization	Title/Department
Advanced Propulsion Centre (APC)	Senior Executive, Business Development
Audi	Senior Executive, Powertrain Development
AVL Powertrain UK	Senior Executive, Leadership
European Commission	Policy Analyst, Directorate-General for Climate Action
Formula E	Senior Executive, Leadership
Ford Motor Company UK	Former Chairman
Jaguar Land Rover	Senior Executive, Engineering
Motorsport Industry Association (MIA)	Senior Executive, Leadership
Qualcomm	Senior Executive, Business Development
Ricardo	Senior Engineer
Ricardo	Senior Executive, Transmission Systems
Society of Motor Manufacturers and Traders (SMMT)	Senior Analyst
Tesla	Senior Executive, European Leadership
Torotrak Group	Senior Executive, Leadership
Transport Systems Catapult (TSC)	Senior Executive, Leadership
UK Government's Office for Low Emission Vehicles (OLEV)	Senior Executive, Leadership
Williams Advanced Engineering (WAE)	Senior Executive

4. Results

4.1. The Post-2008 UK automotive industry[3]

Respondents in this study describe 2008 as a pivotal year for the UK automotive industry; a time when significant change occurred, and the sector was transformed into one that is now led equally by industry and by government. According to respondents, this was a period of transition when the UK automotive industry was adjusting to several crises, the first of which was the 'hollowing out' of the UK automotive supply chain, which had started in the 1970s. Hollowing out refers to a gradual reduction in the locally sourced content for vehicles built in the UK, involving the flight or dissolution of many automotive supply chain companies, or their rationalisation within bigger groups. Respondents believe that OEMs were partly complicit, by encouraging supply chain companies to achieve low-cost sourcing in overseas territories. This loss of productive capacity reduced the local content in UK-built vehicles to approximately 35% by 2008, compared to Italy, Germany and Spain whose levels of locally sourced content typically approached 60% [63]. A second, more immediate, crisis was that several OEMs were in danger of bankruptcy as a result of the global financial crisis [64]. The final major problem for the industry was that OEMs were also in the midst of readjusting their corporate strategies to meet CO_2 emissions targets that had just been re-negotiated with the European Commission that same year. The first target to be met was a fleet average of 130 g CO_2/km by 2015 [28], which was considered to be a relatively short timeframe in the automotive industry.

In response to these challenges, the New Automotive Innovation and Growth Team (NAIGT) was formed in 2008 and was tasked with developing a comprehensive strategy that would help navigate the industry past the difficult times ahead. After a year's worth of research and discussions on the future of the UK automotive industry, one of the major results was the creation of the Automotive Council in 2009 and the publication of its industrial strategy in 2013. At the heart of this strategy, was the UK's decision to transition to a completely different business model for the island's automotive industry. One of the major impacts was the establishment of the Catapult network, which has been described by respondents as the UK's equivalent of the German Fraunhofer Society. After the Second World War, Germany established a nationwide network of technology innovation centres, part-funded by the federal government, and part-funded by local state funding and regional banks. Their mission was to help small and medium-sized enterprises (SMEs) develop their products, processes and commercialisation capabilities in the marketplace. That network, built upon relationships between academia, industry and government, is the German Fraunhofer Society. During interviews, several senior respondents believed that within the last 7–8 years, government policy in the UK had been influenced by the success of the Fraunhofer network in ushering in innovation and commercialisation of R&D capabilities. Thus, the UK Catapults have come to symbolise the government's adoption of this innovation framework. In total there are eleven centres in the Catapult network, which are part-funded by the British government with a mandate to develop and produce new technologies in various UK sectors, while attracting industry funding to match the government's contributions. It is important to note that a crucial element of the Catapults' endeavours is to involve SMEs, as they are considered vital to the domestic value chain. Respondents believe the UK government's hope is that Catapults become successful models of innovation, and a means of introducing new firms and technologies to the marketplace, while making the UK more competitive against other car manufacturing nations like Germany, Japan and the USA.

Similarly, economic geographers have described these government-industry hybrids as 'state accumulation projects', whose function is to shape strategies that create, enhance and capture value from Global Production Networks (GPNs) at a national level [65]. It has also been argued that governments make use of Schumpeterian Competition State (SCS) strategies to develop stronger university-firm research networks [66] for the purpose of financing pre-competitive research [67] and technology development. These points are important given further arguments that place-specific institutions, coupled with the contingent nature of power within production networks, are critical in the mediation of major industrial restructuring exercises [68], such as the one undertaken by the UK in the wake of the 2008 financial crisis.

4.2. The UK's innovation approach: consolidated research and development

The automotive strategy set out in the industry's 2013 technology roadmaps[4] is heavily focused on energy efficiency and technological innovation, specifically low-emissions innovation. These areas were perceived by industry respondents as an opportunity to significantly reduce CO_2 emissions from road transport. What stood out about the UK's revised industrial strategy was the highly integrated (government-industry) approach that was kick-started by the NAIGT. Take for example the UK Office for Low Emission Vehicles (OLEV), which is made up of representatives and ministers from the Department for Transport (DfT), the Department of Business, Innovation & Skills (BIS) and the Department of Energy & Climate Change (DECC). OLEV's day-to-day operations are overseen by ministers within those three departments in a collaborative mission to reach 'zero emissions' in the UK.

Another example of integration was the leveraging of complementary assets such as the motorsport[5] industry, in order to accelerate low-emissions innovation [69]. Respondents argue that the relevance of FIA (Fédération Internationale de l'Automobile) motorsport to mainstream automotive became increasingly clear as the capability of motorsport companies to engineer more rapidly solutions for testing and demonstration was recognized as a potentially significant asset. The focus on low-emissions innovation, brought on by stringent EU emissions regulations, meant that much more research and development in the areas of electrification and systems integration (hybridisation) would need to be undertaken by the EU automotive industry. Fortunately, not only had the FIA - through its various championships - been developing energy efficient solutions for many years, they had also acquired key competencies that were highly relevant to low-emissions innovation in the form of rapid prototyping and highly skilled engineers. FIA motorsport further supported its contribution to low-emissions innovation by encouraging the 'right technologies' on the racetrack. This was achieved with the implementation of 'relevant regulations', such as the rule changes that mandated Formula One's transition to hybrid-electric propulsion in 2014. This 'common vision' also went beyond regulatory and technical integration, and included administrative cooperation as well, where the UK's Motorsport Industry Association (MIA), for example, was on the Automotive Council, as well as the Technology Council and each had their own technology roadmaps. So, a much closer and intentional alignment developed between these related industries, and according to a senior MIA official:

[3] For the purposes of this study, the 'Automotive Industry' refers exclusively to the Light Duty Vehicle market.

[4] For more details see Ref. [105].

[5] Motorsport in the context of this article refers to Formula One racing, Formula E, and the World Endurance Championship (WEC), which are all owned by the FIA.

In a time of great difficulty, the UK automotive sector found an invaluable ally in the motorsport industry.

The current funding for UK propulsion technologies over the next 10 years is set at £1 billion, which is split 50-50 between government and industry, each contributing £500 million with a total budget of £100 million a year for 10 years [70]. Respondents insist that these funds do not cover production costs; instead they have been strictly allocated to the development of future powertrain concepts. Respondents also note that the industry's language has transitioned from 'engine' to 'propulsion', which more accurately reflects their low-emissions R&D agenda. According to one industry executive: 'Everything on the drawing board is up for consideration'.

Among the various organizations observed in this study, the UK's Advanced Propulsion Centre (APC) most aptly embodies the theme of collaborative effort within the context of low-emissions innovation. The APC was formed in 2013 as a government-industry collaboration orchestrated by the Automotive Council, with the aim of positioning the UK as a global leader in low-emissions powertrain development and production. The APC hosts biannual competitions where entrants compete by submitting low-emissions technology project proposals. These competitions are completely technology agnostic, meaning that any type of propulsion system (electric, diesel, etc.) is considered, if its CO_2 emissions are in line with EU regulations. Very importantly, the submission must be part of a collaboration between a SME - generally a university and/or a supply chain company – and an OEM or Tier 1 supplier, because the point of the competition is to advance those types of projects through the 'valley of death'. The 'valley of death' is an industry term that indicates a specific point in an innovation's lifecycle and is underpinned by an industry measurement of 1–10, which is known as the Technology Readiness Level (TRL).

Therefore, a newcomer (small innovator/SME) to the automotive industry may have a working prototype, but lacks the required resources (funds, relationships, knowledge) to get that innovation through to the open market. Industry respondents refer to this innovation phase as the 'valley of death' (TRL 4–6). According to one senior engineer of a leading Tier 1 supplier:

Unless newcomers can actually get their innovations into production state, it just sits on a shelf at home. So, while newcomers may dream up superb innovations, they cannot practically get them as an effective change in the market without knowing how to do that, mastering the game of scale.

Therefore, according to SME respondents, niche innovations eventually encounter a barrier, where SMEs must set up production lines and invest millions in equipment, and this independent endeavour quickly becomes prohibitive. Hence if an SME wishes to continue the transition into the LDV market, the support of an established firm becomes essential, because considerable effort and capital is required to 'de-risk' the proposition for OEMs who might be interested.

As a tangential point of interest, newcomer respondents, who were owners and engineers, viewed the acquisition of SMEs by established firms (T1s or OEMs), and the sale of their intellectual property as a desirable financial transaction. Some SME owners were even kept on as non-executive directors within the incumbent organization after the sale, as was the case when the small electric flywheel firm Flybrid Automotive, was bought by the Torotrak Group in 2014 [71].

4.3. Component suppliers

The role of component suppliers, particularly Tier 1 suppliers (T1s), in automotive innovation has been undertheorized and mostly neglected in transition studies. This section of the findings discusses role of these actors in process of automotive innovation. According to the chief engineer of one of the UK's largest component suppliers:

A Tier 1 supplier is a company that can supply a component or module that is fit for purpose for primary assembly onto a vehicle. It is delivered into the production facility of the OEM and it meets all of their specifications and requirements. All validation (if necessary) has already been done on that component and it is fully approved, certified and ready to be assembled onto the vehicle.

The first revealing fact to consider is that according to all respondents in this study, T1s are responsible for between 75% and 90% of the technological content in any given passenger car. This implies that OEMs are increasingly becoming systems integrators rather than actual manufacturers, and that T1s are doing most of the R&D and production of new technologies. According to respondents, Tier 1 suppliers have become comfortable with being the 'R&D departments of OEMs', and some have stated that they are simultaneously aligning themselves with research partners such as universities or small-companies that can feed into their business model by providing the research capacity while they focus on the development end. In general, suppliers have been calling for better cooperation between themselves, universities and OEMs. For example, in Germany, the component supplier FEV works very closely with Aachen University [72], while AVL, another supplier, also works closely with Graz University [73]. This type of cooperation has been described as an area of weakness in the UK by German supplier respondents, where greater engagement with academics as well as engineers is needed, and was expressed by a senior executive of AVL as follows:

I just think honestly, if the UK wants to stay producing wonderful cars like JLR [Jaguar Land Rover] does, we need R&D companies. We need companies like ourselves and FEV as well as smaller R&D companies, and what we need honestly is a better cooperation between universities, OEMs and companies like ours. We have great universities in the UK, but what we're missing in the UK – sorry I'm German – [is] more engineers educated in the UK, which [is] more practical, and not [just] academics. This is the thing I would say we have to put emphasis on in the UK, because this is done much better, sorry to say, in my own country [Germany].

UK industry respondents are especially keen to establish partnerships between universities, SMEs, OEMs and suppliers; facilitating the appropriation of intellectual property (IP) at the academic level. This framework would allow OEMs to spot more easily promising but undeveloped ideas that they wouldn't usually entertain, and translate them into production through an existing, known and proven supply chains. One such example is the recent long-term commitment between Jaguar Land Rover (JLR) and the University of Warwick, with the establishment of the National Automotive Innovation Centre (NAIC) on the university's campus [74]. While interesting for various reasons, the commercialisation of academic research in this context is beyond the scope of this article but is certainly worth future academic attention.

4.4. Supplier relationships

Among respondents, a strong sub-theme concerning the nature of the various relationships that suppliers maintain with other actors began to emerge when discussing the role of component suppliers in the industry. Hence, this sub-theme has been isolated and given further consideration here.

Tier 1 suppliers develop technologies that they sell to the automakers, hence they are considered as part of the industry lobby. They understand, however, that EU emissions regulations forces money to be spent on the development of new technologies, which results in reduced emissions and better fuel economy for consumers. Hence a lot of the companies that provide hardware and software emission control equipment, like BOSCH for example, are T1 suppliers and therefore pay close attention to the legislation and maintain close contact with regulators. So, it is in the interest of technology suppliers that regulations exist because it means that they can develop new technologies to sell to manufacturers. During this study, it was apparent that the good working relationship between EU policymakers and component suppliers, particularly Tier 1 suppliers, has proven to be a valuable resource to the European Commission in bolstering their credibility as regulators. The Regulator-Supplier relationship is an important one because suppliers are keenly aware of what is technically possible in the context of providing regulators with feedback on future regulations. This relationship helps to compensate for the technical knowledge asymmetry between regulators and OEMs and allows regulators to better approximate the real emissions targets that OEMs can achieve. There is a balance that must be preserved, however, and suppliers are careful to remain neutral because they must balance their relationship with the OEMs who are their primary customers, with the demands and requirements of the legislators. Suppliers therefore – according to one respondent - try to keep a 'low profile' in their interactions with regulators. It is important note however, that while suppliers can help regulators close the knowledge gap with OEMs, suppliers can equally conspire to deceive regulators. This was made painfully evident when Tier 1 supplier BOSCH, designed and supplied malicious software with the engine control unit (ECU) at the heart of the Volkswagen diesel scandal [75].

On the other hand, the relationship between Tier 1 suppliers and OEMs can be contentious and even adversarial at times, for a variety of reasons. One popular point of contention among respondents was the issue of open book pricing. Open book pricing (or costing) is a parts-buying program where the OEM forgoes conventional supplier bidding. Instead, the OEM inspects the suppliers' factories, analyses their internal cost data and makes them an offer based on that analysis. Suppliers who agree may be privy to an exclusive contract with that OEM for periods ranging up to the life of a vehicle. Open book pricing has been difficult for suppliers as they perceive it as OEMs 'flexing their muscles'. According to one senior executive, when OEMs use open book pricing, they are in effect saying; 'Tell us exactly how you've priced this component, otherwise you won't get the businesses'.

In the past, suppliers have perceived this practice to be ruthless [76], but some supplier respondents now believe there has been some softening and leniency from the OEMs. These respondents are of the opinion that OEMs realise their success is becoming increasingly reliant on good relationships with their suppliers. Recently Tier 1s have also been partnering together, creating a larger, more stable and commercially robust presence in the marketplace.

4.5. *The OEM advantage in scale and scope*

We have already seen that the ability to develop and deploy innovation quickly is one of the crucial differences between incumbents and newcomers. Not only are OEMs able to deploy their upscaling capabilities in their R&D and innovations, but they are also able to use this same concept of scale when sourcing from suppliers as a cost cutting measure. A senior executive of a major OEM gave the example of grouping together with other OEMs to procure electric batteries at a significantly reduced price. This tactic was not only an exercise in cost cutting, but also a strategic move to keep overall costs down in the face of incoming competition from industry newcomers. According to one industry executive:

The expertise of the OEM lies in their ability to get an innovation into production and make 20,000 cars of it.

Another strategy frequently employed by OEMs is economies of scope, in the form of 'platform sharing'. Due to the modular architecture of the automobile, OEMs may share several design components between themselves and then apply their own branding to the finished product. Respondents admitted that they know, and have already proven, that consumers buy brands not engines. The example given by a senior automotive executive to illustrate this was that the Bentley Continental and the Volkswagen Phaeton share the same chassis, yet one demands £250,000 and the other £60,000. He argued that the platform, ride quality and many other features are comparable, yet consumers are content buying both Bentleys and Volkswagens. There is already extensive platform sharing occurring between automakers, and respondents have signalled that this practice is moving towards collaborative technology development and is bound to accelerate in the face of challenges from 'outsiders'.[6] One example of this is the collaboration between BMW, Nissan, Renault and Volkswagen on the Rapid Charge Network (RCN) where they are jointly developing a multi-standard, rapid charging network for electric vehicles throughout the UK and Ireland [77].

5. Analysis and discussion

5.1. ***RQ1:*** *established firms as multi-level agents in the UK LDV sector*

The findings in this article align with recent reassessments in transition literature [8,14,15] about the role of established firms in the automotive industry. This study found that OEMs leverage strategic relationships (with newcomers and other incumbents), and economies of scale and scope (mass production and platform sharing), which further reinforces their dominance of incremental innovation within the industry. In particular, this article highlights the OEMs' use of the motorsports industry, which represents a specialized and complementary asset, as yet another example of incumbents' disproportionate access to complex knowledge and expertise [5]. More significantly, this article's examination of component suppliers contributes to a clearer understanding of types of established firms as multi-level actors within the automotive sector. This study identified component suppliers as the most innovative, yet the most obscured, 'class' of established firm in this particular regime. They conduct the majority of R&D, while maintaining good relationships with OEMs and regulators. Thus, their expertise makes them indispensable to any firm within the automotive value chain. Relationships with suppliers are not only unavoidable, but also mutually beneficial, especially for newcomers, who are trying to commercialize their intellectual properties and penetrate the mainstream market. OEMs, on the other hand, use component suppliers to reinforce their innovative and productive capacity - and by proxy - their dominant position within the automobility regime. This article therefore proposes that in the UK, the predominant means of automotive innovation occurs via creative accumulation, and that OEMs and (to a lesser extent) suppliers are its principal agents.

5.2. ***RQ2:*** *power in automotive sociotechnical transitions*

Historically, the concept of power has been malleable and 'notoriously open to interpretation' [78], however, this study draws upon more realist understandings of power [79] from research in global production networks where power 'is both *causal* in that it derives from structures and *actual* in that it only exists when active' [65]; p. 522). Thus, unlike other perspectives (like actor network

[6] Newcomers to the industry were referred to as 'outsiders' by most respondents.

theory) where power is viewed as performative and network-based, this section examines how accumulation and financial size enables some firms to exert 'power over' others.

Political and economic power as a determinant in sustainable transitions has long been identified as an area in need of more academic attention within the context of the MLP [4,80], and is relevant here as this article discusses the creative accumulation process, which is a derivation of the former. In response to the MLP, other researchers have insisted that regime power players are able to influence multi-level dynamics disproportionately compared to other agents within a given sociotechnical system. Furthermore, it has been argued that newcomers' success ultimately rests on sponsorship from these 'more powerful' regime agents, and thus newcomer potential is ultimately screened and filtered through regime power structures [4,81].

Over the years [80,82] has responded to these critiques, and while acknowledging that 'power struggles' in the MLP are less developed, he argues that political science research has begun to fill this gap by classifying power in the MLP as relational, dispositional and structural at the niche, regime and landscape levels respectively [83]. Others have also conceptualized power in the MLP in various forms from political processes [84] and shifting power relations [85], to Foucauldian inspired perspectives of constitutive power [86,87]. While the authors of creative accumulation [27] have used it to explain incumbents' various advantages within regimes, they have thus far not linked these advantages to power beyond niches' susceptibility to contradictory agendas.

This article, however, seeks to develop additional theoretical linkages between power and the process of creative accumulation. First off, while government-industry partnerships involve the active participation of government, universities, SME's and incumbents (OEMs and suppliers), they remain primarily state accumulation projects. As such, they represent regulatory institutions and local socio-cultural conditions that are part of larger accumulation strategies or models of economic growth [66]. Thus, while states may freely set the conditions of engagement with firms, state strategies and revenues still very much depend upon capital accumulation, and thus are inclined to favour supporting larger firms and multinational agents (OEMs) [65]. Furthermore, while OEMs – as agents of the automotive GPN – are subject to these state policies [88], they have a greater capacity to lobby said state policies in pursuit of their own interests [89]. This tendency for state projects to favour large incumbents is also reinforced by globalization and the 'internationalization of the state' [65,90,91] as it endeavours to capture key segments of the GPN within its national boundaries. It must be noted that states can also pressure OEMs to establish production close to end markets, as the high costs and visibility of passenger vehicles can attract political backlash if the share of imported vehicles becomes too large [46]. Thus, the UK retains the power to negotiate its incorporation into the automotive GPN using a variety of strategies.

[82] describes the government-industry alliance as a 'stable and hegemonic historical bloc', however, others have asked [4] how shifts in such an alliance might affect the balance of power for or against a certain sociotechnical regime? The argument can be made that deep shift occurred in 2015, beginning with the Volkswagen emissions scandal (aka 'Dieselgate'), where the interests of government and automakers diverged, trust was eroded, and various adversarial consequences ensued, including fines, arrests and more stringent regulatory oversight [26]. [83] argues that achieving and maintaining trust within multi-actor environments is key 'in exercising power to foster change' [83]; p. 283). Thus, while the UK 'techno-institutional complex' [92] or 'historical bloc' [93] may well remain intact today, its configuration and strength of relationships (and subsequently its ability to influence transitions) may vary.

At the incumbent level, we see them leveraging economies of scale and scope, specialized and complementary assets, and inter-firm arrangements, which is further reinforced by UK state accumulation projects in the form of government technological roadmaps and government-industry partnerships; resembling [83] notion of dispositional power. Incumbents' power, specifically OEMs, is largely due to their strategic role in coordinating and organizing automotive GPNs [65]. They are in essence 'empowered network agents' that 'collect and condense' power [94], and thus their accumulated resources and corporate strategies confers upon them a certain 'power' over suppliers and SMEs. This study encountered one example of this in the previously discussed practice of 'open book pricing'. Another example is 'follow sourcing' where large suppliers are required to 'co-locate' or establish local parts production centres close to OEMs' final assembly plants to ensure timely delivery [46].

Within technological niches (were incumbents also operate), we see the differences in innovative competencies (rapid prototyping, IP acquisition, tacit knowledge asymmetries) between incumbent and newcomer agents, which is what [83] would describe as relational power. In sum, the size and power of OEMs results in asymmetrical power relationships within multi-level networks and selection environments, where OEMs can appropriate innovation developed by actors at the micro level (niche), and in turn capture local and regional economies of scale and scope fostered by state policies (regimes) [65].

5.3. The UK's creative accumulation pathway

The UK's automotive sector is a longstanding, stable industry, characterised by deeply entrenched isomorphism and powerful landscape determinants that reinforce the existing regime [95]. However, in 2008, the landscape shifted and threatened to usher in an era of de-alignment or breakdown in the regime [3]. Faced with several challenges, the automotive industry moved quickly to restructure itself in a manner that integrated the efforts of policymakers and industry stakeholders into a common vision. The new partnership between government and industry was built around a vertical development framework, where the common vision transcended from the landscape level down to the niche levels of the industry. The transition pathway chosen by the UK was one of incremental low-emissions innovation, which is promoted as being technologically agnostic, and was supported with the establishment of development centres such as Transport Systems Catapult and the APC. Post-crisis, the UK engaged in overt industrial policy intervention, as it considered its automotive sector 'too big to fail'. Some academics have since suggested that public policy must move beyond simple 'market fixing' to mission-oriented 'market-creating' [96].

For the UK, the automotive sector is considered a 'pillar' industry and therefore an era of technological transformation [14,49] was introduced in alignment with the newly conceptualized technology roadmaps. This new era, however, was not led by 'niche-innovations', but instead was driven by public-private partnerships or 'state accumulation projects' [65], which shaped the UK strategy to create, enhance and capture value from the automotive GPN at the national level. These state projects play a crucial role in the 'scalar management' of industrial restructuring [90], and by proxy privilege incumbent firms, particularly OEMs, within the automotive regime.

The cooperation between government and industry in the UK effectively acts as a translator [97], or a bridging construct [39], for the rapid development of new technologies beyond incubators or niches and into broader market spaces [5]. In the case of the UK market, established firms engage in innovation at all levels of the sociotechnical system and use the 'bridging construct' to support the steady development of promising technologies.

The valley of death represents the 'Schumpeterian barrier' [78] to entry for newcomers, however as the UK government pairs SMEs with established firms to overcome this challenge, this in effect funnels viable niche IPs into larger firms and onto OEM production lines. This an example of how the national governance infrastructure around innovation acts as a 'R&D pipeline' of sorts for incumbents, where niche technology development in the UK is screened and filtered by government-industry projects. While newcomers can often signal new technological opportunities, their cognitive search for innovation in the UK is ultimately guided by the post-2008 low-emissions agenda.

At the regional level, EU regulations are reasonably broad and technologically agnostic, but they create a selection environment [24] at the national level, and in the UK is characterised by the 'common vision' of the government-industry projects, also described as Schumpeterian Competition State (SCS) strategies [65]. This common vision naturally dictates the viability of new technologies that are brought to the marketplace, meaning that these innovations end up being significantly shaped by UK state projects, which also embody EU's CAC regulations. As one APC executive aptly observed:

I'll go back to the classic quote 'necessity is the mother of all invention'. It's been EU regulations in my opinion, that drives the innovation. We've got to hit certain CO_2 targets for cars and that drives the OEMs which in turn affects the SMEs' ideas and innovations.

This quote sums up the underlying consensus among respondents, which was that EU CAC policies are a primary concern for technology firms seeking relevance in the UK LDV market.

5.4. ***RQ3:*** *the state of 'sustainable transitions' in the UK automotive industry*

This article has described the dynamics of change in the UK automotive industry as one of 'technological greening' via creative accumulation within the context of the MLP, however the purpose of this section is to contrast these processes against a few objectively observable outcomes. A commonly stated goal within the transition research community is the accelerated 'dismantling' of existing sociotechnical regimes in favour of more sustainable alternatives [4,12]. However, in the face of such motivations, it is imperative to establish feedback loops for the purpose of assessing the effectiveness any intervention tasked with achieving 'low-carbon' outcomes.

The UK government-industry project suffered a major tremor in 2015 when several OEMs, the most prominent of which was Volkswagen deceived regulators by fitting 'defeat devices' - developed by BOSCH, a Tier 1 supplier - into several of their diesel models. The result was that during real world driving, toxic NO_x emissions were up to 40 times higher than Volkswagen's stated test results. While the regulatory failures on EU's behalf [26], and technical nature of the deception [75] have been previously explored, it remains important to highlight this event as a significant 'black eye' for automotive decarbonisation in the UK. This event eroded trust between government and incumbents, prompting outright bans on diesel vehicles in some European cities [98], and sparking a national debate in the UK on a nationwide ban on the sale of new petrol and diesel cars by 2040. The general public has also been soured against diesel vehicles to the point where for the first time since monitoring started, petrol vehicles began outselling diesels in the UK and EU in 2017 [99]. Unfortunately the negative externalities do not stop there, as consumer migration away from diesels and towards petrol vehicles has now created a sort of "CO_2 bulge", where for the first time in 20 years, aggregate new vehicle CO_2 has risen in the UK and EU, not decreased [100,101]. Current (2018) new vehicle CO_2 levels in the UK has backslid to 2014 levels. While the adoption of electric vehicles (EVs) in the UK continues to increase, it not yet at a scale that can compensate for rising CO_2 emissions from increased petrol vehicle sales. In all likeliness, the UK (and possibly the EU) will not achieve the current EU 2021 passenger car CO_2 targets. At what point will EV adoption, in conjunction with incremental innovation in combustion engines, drive back down new vehicle CO_2 in the UK and the EU?

The UK's own transition out of the EU adds another layer of obscurity to these events. After 'Brexit', the EU's calculation of new vehicle CO_2 will no longer consider vehicles sold in the UK, thus fleet averages will be spread across a smaller geographic area. How will this affect OEMs' ability to achieve EU targets? Could the UK become a 'dumping ground' for higher emission vehicles? With the closure or curtailing of several OEM manufacturing plants and operations in the UK, how will the UK renegotiate its government-industry partnerships? More importantly, how will the UK reconfigure its state accumulation projects to maintain competitiveness within the automotive GPN, as it becomes untethered from EU CO_2 automotive emissions obligations? The answers to these questions will carry significant implications for sustainable automotive transitions in the UK and are deserving of future academic inquiry.

The UK's macro state strategy, which previously locked society into diesel propulsion as a 'low(er)-carbon' solution, has now decided to reverse course on that trajectory, and is aggressively pursuing the adoption of Battery Electric Vehicles (BEVs). This article also urges future transition scholars to carefully consider the near and medium-term implications of such a pursuit, given the lessons learned from the failed diesel lock-in, and emerging sustainability concerns regarding the manufacturing, recycling and eventual disposal of depleted lithium-ion battery stockpiles.

Despite sustainable transitions being somewhat of an 'essentially contested concept' [78], this article argues that OEMs' almost exclusive focus on incremental innovation reflects their control of intellectual property, value price reduction and the overall power asymmetries that exist within automotive value chains [65]. Contributing to this is the fact that publicly traded incumbents, responding to share-holder pressure to achieve short term profits, seek to minimize the risk of disruptive innovation and newcomers to their sector, whereas newcomers are more likely to attempt disruptive technologies [89]. Thus, if OEMs (and suppliers) continue to make 'tactical knowledge investments based solely on cost reduction potential' [106], where getting new technologies considered requires a cost advantage, this will compromise their collective ability [102] to move beyond incremental innovations.

6. Conclusion

According to Nelson and Winter (1977, p. 41) 'Any useful and coherent theory of innovation must recognise explicitly the factors that differ across industries'. Therefore, the 'meso-level', sector-specific analysis conducted in this article represents an attempt to deliver operational insights into the role of established firms in sustainable transitions within the automotive industry.

The article's first contribution, therefore, is a clearer rendering of how industry incumbents (OEMs and suppliers), supported by cumulative resources and state policies derived from EU regulations, dominate the multi-level pursuit of incremental energy efficient innovation within the UK automotive industry. Second, this article makes use of public policy and economic geography scholarship to offer a nuanced interdisciplinary understanding of power, and where it resides within automotive sociotechnical regimes. Finally, after having discussed the dynamics of creative accumulation and power flows throughout the UK automotive regime, this article compares present day regime outcomes with the stated goals of sustainable transitions. Thus this article's broad analytical view on agency contributes additional understandings 'about the interests and sources of power shaping selection environments and generating variations' [4]; p. 446) within the automotive industry.

While most of the findings in this article are based on a UK case study, many of them are generalizable to the wider EU industry. The three main reasons being that (1) most respondents in this study are multinational organizations that operate across borders, (2) UK automotive low-emission policies are an instantiation of relevant EU regulations[7] and (3) the UK is the 2nd largest vehicle market and the 4th largest car manufacturer in the EU [103]. Given the insights set out in this article, it may be possible for transition scholars to apply some of these concepts to better understand sustainable transitions in other highly regulated, complex capital goods industries such as the energy, aerospace and construction sectors.

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