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THE JUST TRANSITION IN THE CAR INDUSTRY

Abstract

The introduction of battery-powered electric vehicles (EVs) represents the most significant change in the automobile industry to date. The academic and policy debate so far has mainly focused on demand-side problems (e.g., battery performance, charging infrastructure) of the green transition. But only little attention has gone to supply-side issues concerning car manufacturers, suppliers, their workforce and unions as well as (regional) governments. In this dossier, we explore what the shift to EVs might mean for work and firms in the car industry, how different socio-technical scenarios are embedded in this simple technological shift in the end product, and what this means for global value chains and regional economies that rely on the car industry as a source of prosperity.

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Prologue: Hype, second-mover advantages and veto points in electric vehicle production

Recent news reports leave little doubt that TESLA is doing great in its (core?) car business. Unless you have a heart of stone when it comes to Elon Musk (yes, such people exist), you have to be very happy that innovation and entrepreneurship still pay off. But something rubs, and here are some of the things that cause the intellectual blister.

Lone runner

First of all, the immediate issue at hand. TESLA was doing well when everyone else in the car business, particularly the electric car sector, was doing badly. True, but not necessarily because of competitive advantages that TESLA has built up. Remember that the TESLA factory in California was actually open during the Covid-19 lockdown, while the others had pretty much closed theirs. VW produced exactly zero electric cars during the lockdown, because it produced basically zero cars. If the rest of the runners don't leave the starting line, even I can win an Olympic sprint. More importantly TESLA was not only producing cars but also externalities in the shape of severe health risks for its employees and local communities, while other car manufacturers adopted social and physical distancing rules that preserved public health. Free-riding is the technical term for this and it is usually frowned upon.

Profits or hype?

While TESLA – after years in the red numbers – has finally posted profits in 2019 and Q1-3 in 2020, its profitability seems to largely depend on the sale of regulatory credits. The EU and several US states require that clean vehicles make up a certain percentage of car makers' annual sales. Automobile companies not reaching the specified benchmark can buy credits from other firms like TESLA who, by virtue of exclusively selling electric vehicles, have a lot them on hand.

In real terms, it is not entirely clear why investors are so happy with the company. It relies on a combination of positively spinning an improving, yet relatively average production performance that only looks good in light of TESLA's even worse performance the previous few years, creative accounting, and big bets on the future of technologically driven (car) companies in financial markets with, apparently, very short memories. Remember the internet boom and bust and the subprime crisis, folks?

To put things in perspective: selling 30,000 cars is something that Yugo managed per month early in its history. In fact, Porsche, which sells its cheapest car (the Boxster) for twice the price of TESLA's best-selling Model 3, has sold three times more cars almost every year since 2000 – and made a handsome profit along the way.

Second-mover advantage

Looking ahead, then, it is obvious by now that established brands are in the game. Electric vehicles is almost certainly a sector where a second-mover advantage exists – and where the first-mover advantage touted by some observers (again, the NYT piece) can quickly turn into a *cul-de-sac*. As a second mover, you can learn from the mistakes of others, including TESLA. They will show you the bottlenecks in technology and production long before you go careening in. They will blaze the regulatory trail, after a few generations of adjustment and possibly expensive blunders. And they will effectively produce a supplier network for you, or slim down design to such an extent that all relevant parts can be bought patent-free and/or off the shelf. But most importantly, the classic car companies have an established name to build on, usually excellent sales and after-sales services that produce brand loyalty, a vast network of dealerships across the globe, and strategic links with sophisticated suppliers to weather technical surprises.

Conservative producer coalitions and industrial restructuring

This does not mean that there are no problems with the traditional producers. Refitting factories that are built on dedicated capital, specific workforce skills, and rusty technology and design legacies is not easy, especially since you cannot ease your way into the new cars one at a time. Making electric cars must mean not building traditional cars; you cannot add one electric car to an existing assembly line that makes 500 standard cars.

Conservative capitalists and unionised workers may thus end up in a veto coalition, able to influence regulators to go slowly. But those problems existed in the steel and textile industries 40 years ago as well; restructuring became a collective responsibility, through social plans, retraining and regional development. It is likely that the automobile sector is next.

In this dossier, we sketch different dimensions of this adjustment problem along the lines of how we at PEACS understand it today. Some of the points below are still rough and even vague, others are already looming on the horizon. They are part of an on-going reflection that will occupy us over the next two years, hopefully in cooperation with managers, workers and trade unions, engineers and other stakeholders in the industry. If things go wrong, Europe may lose a large part of its automobile industry – not because TESLA and other upstarts will supersede it, but because the underlying interests of employers and workers may make the transition uncomfortably conflictual. A clear sense of what is at stake is therefore a necessary condition for developing a clear sense of what to do.

1. The just transition in the car industry: At a glance

Imagine you could order a more or less customised car from your laptop: the power of the engine, the colour and the size of the car and much of the interior. Imagine, then, that a few days later a delivery service hands over the parts of the car to your local garage, where a skilled mechanic puts it together, checks all functions and arranges a time for you to pick it up. Too much imagination? Not necessarily: the shift to battery-powered electric cars (henceforth EVs, for electric vehicles) suddenly makes this barebone assembly model easily feasible.

In this dossier, we intend to think about what the shift to EVs might mean for work and firms in the car industry, how different socio-technical scenarios are embedded in this simple technological shift in the end product, and what this means for regional economies that rely on the car industry, directly and indirectly, as a source of prosperity.

Surprisingly, these organisational and job implications, with their repercussions for supply chains, regional economies and industrial relations, have not received much attention. Most of the research in the social sciences and the policy debates seems to have revolved around ‘range anxiety’: will the battery perform – will it allow the customer to drive several hundreds of miles at sustained motorway speeds (the answer is not much beyond 400 to 450 kilometres at the moment)? The issue is crucial, of course: no market, no product – though much of the range anxiety is somewhat overblown, since few of us drive more than 50 km per day. Similarly, many government communiqués are focussing on the lack of EV-friendly charging infrastructure; Germany has recently pledged to raise the number of electric charging points from 21,000 in 2020 to 65,000 in 2022 and 1 million by 2030 (including at least one at each German petrol station). And finally, the need for fast-charging batteries often shows up as a preoccupation for the car-buying public, and thus as a potential bottleneck in the construction of this new market. Again, this is a very important set of considerations: if you have to wait several hours each time your battery runs low before you can take off again, long trips become very difficult. There is no doubt, therefore, that the consumer side of the problem, the construction of the product market, is important, and governments are rightly thinking deeply about this.

But very little attention has gone to what making such cars might entail for the number of jobs for car workers, the types of tasks and skills in those jobs, how the reduction of parts, from about 20,000 complex ones today to about 6,000 simpler parts in EVs, might influence the nature of supply chains, regional development and international trade, and the impact such a shift might have on industrial relations. In a broader sense, this technological and organisational shift raises the question if producing cars will remain a viable option in Europe. We will always have consumers, but we may lose car factories and with it much of the industrial and trade union templates that were associated with this organisational model.

This PEACS dossier explores these questions on the production side of things. Not just because we care about the just transition, but also because we can envision potentially strong, not very enthusiastic producer coalitions in companies. It is far from difficult to imagine how engineers, managers, unions and local governments could develop a vested interest in slowing down or even vetoing the transition to EVs. Despite the lip service that many employers, unions and governments pay to green goals, when jobs, investment and regional economic development are on the line, the 'just' in the just transition may lead to a stalemate.

While we readily admit that our earlier extremely decentralised scenario of a single car assembled in a single workshop after individual customisation (often from relatively standard parts) is far-fetched at the moment, the simple fact that we can think it means that it ought to be part and parcel of the possible production futures associated with the transition to EVs. Technology and society have this uncanny ability to surprise you: talking to your colleagues in a meeting on a videophone was considered the stuff of science fiction only one generation ago; today no one can work without it.

If it can happen, then we also need to understand better what will happen to the production side, if only to make sure that major stakeholders in the industry see the green transition in the car industry as much as an opportunity as a threat.

We start with a section on the two ideal-typical models work organisation that will be the guiding lights for the future of work in the car industry. Part of that story, as captured in section 3, is a flashback to a model of production and work organisation developed by Volvo in the late 1980s, which radically broke with the concept of the moving assembly line and built cars through stationary, cellular assembly. Sections 4 and 5 shift the focus one level up: what does the shift to EVs imply for supply chains and, by extension for regional economies and international trade? In the final two sections, we discuss the role of macro-level institutions – how industrial relations will be affected but also structure the transition, and what the overall picture means for the future of the European car industry. Anticipating this last question: our crystal ball is not any better than that of most readers, but the reflections in the different sections do privilege some possibilities over others. The conclusion maps those adjustment pathways.

2. Jobs, tasks, and work organisation

Work in the car industry, and its future, has been a perennial topic of research, analysis and debate since Henry Ford combined the assembly line – copied from Frederick Taylor (who himself reverse-engineered carcass dissection in a slaughterhouse) – with a decent wage. In one of its latest incarnations, the lean production debate in the early 1990s, the argument was made that highly standardised tasks, executed in small groups, and where workers were involved in quality control, against a background of delivery of parts when needed in assembly (just-in-time or JIT henceforth), was the most efficient way of organising complex assembly tasks. That is the historical background against which the EV revolution over the next few years will play out, and understanding it is, therefore, absolutely crucial to making sense of tasks, jobs, and work organisation in that process.

While many car companies adapted the lean production principles to their own operations, the actual impact on what workers did varied greatly. In the Japanese version, teams of workers were essentially sections on an assembly line, where individual workers were told what to do but were collectively responsible for low-level monitoring, quality control and administrative tasks. In the continental European version, in contrast, teams often referred to groups of workers with multiple overlapping task sets, management responsibilities including quality control and improvement and where workers performed complementary, group-wide tasks as a collective.

The imminent introduction of electric vehicle assembly across the European and worldwide automobile industries will likely force an adjustment of jobs, tasks and their combination in work organisation. In essence, two possible extreme scenarios are presenting themselves.

Neo-Taylorism …

The first one, with the label *neo-Taylorist*, builds on the generic version of lean production. As a result of sustained simplification of product design, many tasks will become more standardised and where possible automated into very short-cycle times, pushing further existing models of car manufacturing: large assembly lines, relatively narrow individual jobs on that line, and JIT delivery of (usually quite standardised) parts. Monitoring of work is proactively done by line speed, while hierarchies play a significant role in *ex post* monitoring of work.

The skill profile associated with this scenario is a step back to the semi-skilled worker who almost disappeared in the last three decades; possibly those workers are invited to develop bundles of relatively low skills, so they can be flexibly deployed in other posts, but such an expansion of tasks is unlikely to have a large positive impact on job classifications and therefore wages. In addition to narrow direct work on the cars, much of the work in such plants is indirect: supervision and monitoring, HR, quality control, supply management, etc.

… and its mostly hidden costs

In many ways this scenario simply builds on existing industrial design and engineering knowledge from other assembly models that have prevailed in the car industry since the lean production revolution of the 1990s. Its appeal is therefore strong: a tested and tried system, which offers almost infinite possibilities for cost reduction. Yet, this model also imports a set of inefficiencies that often go unacknowledged and, most importantly, foregoes a series of productivity-enhancing possibilities associated with employee input in vehicle design, including in design for (human) assembly (remarkably, many car manufacturers design for robot assembly). Assembly lines and the factories where they are housed are expensive and inflexible; short cycle times impose high transaction costs in the shape of workers moving along the line, shifting parts and setting up tools; and JIT delivery simply means that instead of parts being stored in-house, they are now moving in trucks, paradoxically increasing the carbon footprint of the whole process and contributing to traffic gridlock. The visible benefits associated with the neo-Taylorist organisation of tasks and work may well be off-set by a series of unaccounted and therefore often invisible costs elsewhere.

In addition, because of the many efficiency losses and the many layers of indirect work – imagine your supervisor's supervisor signing off the quality control – the organisational model underlying this scenario actually drags down productivity. Equally importantly, the neo-Taylorist scenario is relatively impervious to dimensions of quality of work, skill acquisition and job autonomy (which could be added on, but only through external regulation in the guise of collective bargaining or legislation). In terms of the politics of the workplace, it heralds a step back to a world of increasingly divided tasks, in which job control rests not with employees but with managers.

A neo-artisanal model: cellular assembly[1]

An alternative *neo-artisanal* scenario builds on European traditions of group work. Its basic unit are autonomous teams, in which highly skilled workers assemble cars in very long cycles – in the limiting case entire cars rather than a handful of individual parts or subsystems – and do so in separate workshops rather than on a moving assembly line. The stationary assembly method that Volvo explored in its Uddevalla plant in the late 1980s and early 1990s is perhaps the best example of this job format. In addition to assembly work, workers can also take responsibilities in workflow organisation, division of work in the team, basic HR functions, stock and delivery management, quality control and many other indirect tasks.

Lower costs and higher gains?

The gross gains of this production and assembly model are significant. Without pretending to be exhaustive, they include low industrialisation costs as a result of the absence of assembly lines; the possibility to adjust capacity to demand, up or down, without the need for an entire assembly line; very few problems associated with balancing the assembly line so that several hundred workers perform their tasks in roughly the same time period of between one and two minutes; a significant reduction in transaction costs, indirect work and hierarchical control; and the active integration of workers' knowledge in industrial and process design.

The net benefits are likely to be substantial too. However, they can really only be evaluated by comparing aggregate costs of different production models and a proper accounting of intangibles such as flatter hierarchies, lower transaction costs, etc. Some of the costs in that regard will be related to the enhanced job design, which function much better with pay for knowledge wage schemes, and those are likely to lead to higher wages for the average worker (reflecting the higher average productivity). Moreover, since the model is new – in the sense that it combines knowledge of trained mechanics with a series of frontline management tasks – it will involve adjustment costs as many elements in the industry are rethought, such as training systems and production technology. It may even raise questions about industrial architecture for such decentralised flexible cell assembly models. Product design will also have to be partly reinvented, but those costs are partially absorbed by the fact that the introduction of EVs will almost certainly require such a product rethink anyway. And some of the high set-up costs can easily be absorbed through the low outlays for industrialisation and especially the in-

[1] NB.: Cellular assembly is sometimes also referred to as stationary assembly or flexible-cell manufacturing (FCM). All terms refer to the same concept of workshop assembly with longer cycle times and intentional lack of a moving assembly line.

creased ability to produce different models flexibly: an ambulance or police car can easily be assembled alongside highly customised or relatively standard passenger cars.

Progressive producer coalitions

Tying together these thoughts on different work organisation models, it is not difficult to see how one of these scenarios almost assures resistance by trade unions and the other almost, equally certainly, fosters cooperation. The underlying reason is simple: whereas the neo-Taylorist organisation model has many characteristics of a zero-sum game – what you win, I lose and vice versa – or even a negative sum, neo-artisanal models produce positive-sum outcomes. And that makes the neo-artisanal model logically and politically so appealing.

But there is a difference between being compelling and being right: the latter also requires favourable power relations to avoid the short-term trap associated with the neo-Taylorist arrangement. Many European car companies, and the industry as a whole, actually have such power relations. For a variety of historical reasons, the automobile industry has highly developed co-determination systems and strong, institutionalised, and often very cooperative industrial relations arrangements. Building on those, trade unions and management can, in principle at least, quite easily avoid the pitfalls of a conflictual outcome. The same cooperative power configurations that could be the cradle of conservative producer coalitions blocking the transition to EVs can also be at the origins of progressive, green adjustment models. If and how that happens, depends on what socio-economic actors do with them. People make history, to paraphrase Karl Marx, and in this case even, to some extent at least, under conditions of their own choosing.

3. The long shadow of history: Cellular assembly in Uddevalla

The introduction of EVs represents the most significant change in the automobile industry to date. Among a number of impacts, the organisation of the manufacturing process – so far dominated by the concept of lean production – might be up for grabs. The Volvo factory in Uddevalla is a good example of cellular assembly, an alternative production process. Reviewing *Enriching Production: Perspectives on Volvo's Uddevalla Plant as an Alternative to Lean Production*, this chapter summarises the experiences, systemic insights, and performance measures of the Uddevalla experience.

Why is the Uddevalla experience relevant?

The green and just transition in the automobile industry with the introduction of mass-produced battery-powered EVs is nothing short of the most radical change in the sector. It impacts the design of cars, the length of and hierarchy in supply chains, the geographical location of production, skills and tasks for workers, and, not least, the (re-)organisation of the manufacturing process. The latter, in essence, presents two possible scenarios.

As explained above, the first one, with the label *neo-Taylorist*, builds on the generic but actually Japanese version of lean production which is currently the preferred form of assembly. An alternative *neo-artisanal* scenario builds on European traditions of group work. The cellular assembly method that Volvo explored in its Uddevalla plant in the late 1980s and early 1990s is perhaps the best example of this manufacturing process design.

Uddevalla: a short overview

In the 1980s, Volvo faced growing demand for its cars that couldn't be met by their existing factories. Against the backdrop of a tight labour market, problematic levels of absenteeism and strikes, both Volvo and the responsible unions emphasised decent jobs as a precondition to ensure recruitment of competent workers, and hence, safeguard productivity. Additionally, the increased demand for complex up-market cars made the company even more dependent on a flexible and competent workforce to ensure high-quality and efficient production.

With the main focus on creating appealing workspaces to attract a motivated labour force, a working group consisting of the Volvo management and engineers, unions, and researchers embarked on a mission to re-design the manufacturing process entirely. The four-year design process that preceded the opening of the Uddevalla plant in 1989 started from the original idea of a factory of 700 workers building cars in an assembly line in two-minute cycles with narrowly defined tasks. Several iterations later, the concept for the new Uddevalla factory looked completely different and, in fact, kept evolving even after the plant was opened. In the end, instead of being positioned along an assembly line, 48 small, parallel stationary teams (with seven to ten members each) assembled whole cars in jobs cycles of approximately two hours. Additionally, due to the flat hierarchy, workers were also asked to take on managerial tasks, such as quality control, constant reviews of production technology and tools, HR, and team leadership. The human-centred "reflective production system", as it was coined, was born.

The plant was closed in 1992 officially due to local performance issues. However, many observers lauded the comparatively strong productivity and instead point to internal – ongoing conflicts between traditionalists and innovators, among unions, engineers, and management – and external pressures – a drop in demand and Volvo's planned but failed merger with Renault – as dominant reasons for the closure. In any case, much can be learnt from the unfortunately rather short-lived revolutionary production design in Uddevalla.

A human-centred and reflective production system

While the objectives of cellular assembly Uddevalla weren't all that dissimilar from modern lean production – customer-oriented and quick delivery alongside worker satisfaction and learning are also important features in the Japanese Kaizen production style – the means to get there were radically different.

The most obvious difference to a conventional lean production plant was the intentional lack of an assembly line. This decreased the capital expenditure of the project dramatically, as the investment in complicated tools and equipment was much lower than for similarly sized factories. The new production system also reduced requirements for space and technical production support for work groups. Indeed, it even allowed re-converting existing structures – a point that is made clear by looking more closely at the Uddevalla factory.

Located in pre-existing buildings on a ship yard land area, a central building – containing materials and components – was positioned between two clover-leaf structures consisting of three smaller buildings each. Each of these smaller buildings, in turn, hosted a product workshop in which eight production groups (with seven to ten workers in each) built whole cars. Automated transport vehicles moved carefully assorted assembly packages containing designated parts and materials from the central building to each work station and picked up the finalised car to bring it to its next destination some hours later.

In the work stations the car was in stand-still. Instead of slowly cruising past workers, the assemblers moved around the car. Though later some work stations were fitted with lift and tilt stations, to make work more ergonomic, there was no need for heavy complex machinery and almost all tasks were completed using hand-held machines. By grouping the components into functional main ("kin") and sub-groups ("family"), and viewing the production process as a step-wise uniting of families and kin, the process became organic, rather than the previously known mechanistic addition of parts. Long cycle times of about two hours in combination with the natural production approach also helped to reduce the physical and mental exhaustion that resulted from highly repetitive tasks in line production.

From a learning perspective, the human-centred approach in this reflective production system also brought a number of novelties. In line with a more natural grouping of parts and functions of a car, components' labels were re-defined from alphanumeric combinations back to meaningful descriptions such as “brakes” or “gear stick”. Together with the longer cycle times – in which workers performed a large array of steps, rather than one repetitive task – this contributed significantly to workers' holistic understanding of a car and its assembly. In fact, a pay-for-skills arrangement motivated labourers to gain qualifications to assemble quarter portions of a car – and eventually some even managed to build a whole vehicle individually. In practice, these qualifying measures were greatly facilitated by the close cooperation and open communication between a small number of workers which enabled skilled professionals to train learners directly on the job.

This cooperative approach also provided a valuable opportunity for direct feedback in the assembly process – as the team working on the car could check in with the previous team to debate variations or potential errors – and coordination between assemblers and engineers as well as designers. Allowing for shop-floor level inputs into the car's design process is a valuable productivity and quality enhancing measure, though it was never fully utilised at Uddevalla, due to a lack of specific car designs that fostered the plant's assembly system.

Last, but not least, workers' competencies were even further enhanced by fostering their managerial autonomy, which was emphasised by an elegant pay scheme. In addition to a basic wage for worked hours and bonus payments for each additional quarter of a car assemblers could put together (see above), assembly workers were remunerated for taking up managerial tasks. Each team had a (rotating) team leader position, people responsible for technological development, including assembly process and tools, HR functions, such as personnel and time management, and learning and development. Team members could hold up to two of the above extra responsibilities. The increased autonomy and personal development fostered a strong identification with efficient production and high quality of the final product, which was further increased by a combination of intrinsic and extrinsic motivation. Interestingly, though, merging traditional blue- and white-collar functions also proved attractive from a commercial perspective, as it produced a very flat hierarchy with a significantly reduced number of indirect jobs that are usually required for managerial tasks, including supervision and quality control.

Cellular assembly and comparative performance

So far, we've established that the cellular assembly approach in Uddevalla's reflective production system benefitted from relatively low capital expenditure (due to the lack of a complicated assembly line); highly rewarding work tasks, including large potentials for personal development; a valuable feedback cycle between workers and also with engineers, with the potential to contribute to product development; and cost savings due to a lean managerial structure. But how does the stationary assembly system compare to lean production plants regarding measures of performance?

As mentioned above, the Uddevalla factory was in operation for only three years after its opening in 1989. Long-term observations of the plant's productivity growth are therefore unfortunately not available. However, the productivity increases that occurred in this short time are significant and, in October 1992, Uddevalla's assembly time per car (32.8 work hours plus 6 hours of managerial tasks) was even lower than for the Volvo factory in Torslanda, near Gothenburg (45 hours) while the quality of the cars was at least as high. Some commentators attributed this increased productivity to the phenomenon of crisis-learning, i.e., workers wanted to prove a point before the factory closed down, rather than sustainable personal and organisational development. Nevertheless, anecdotal evidence indicates that several workers built whole cars in less than 20 hours, with one worker even assembling a complete vehicle in only 10 hours plus some time for managerial tasks.

Another challenge often arose from the comparison with other brands' plants – especially the ones operating under the Japanese version of lean production – which produced similar cars as Uddevalla, but faster. Here – alongside the above-mentioned short duration of the experiment – it is important to realise that the cars produced in these top-performing factories were specifically designed for their respective assembly system. This was never the case in Uddevalla; another fact that points towards potentially large as of yet unexploited productivity gains.

Two further, sometimes underplayed, performance measures are lead times for (customised) orders and flexibility regarding model changes. Uddevalla, utilising its highly parallelised production system – encountering neither line balancing issues, nor requiring a fixed product mix – decreased its total lead time (i.e., the time that passes between customer order and delivery) to four weeks by late 1992. Customers were able to change the specification of their cars up to three days before production, and Volvo Uddevalla even planned to half the total lead time to two weeks in 1993. Moreover, cellular assembly is not only quick, but also highly flexible. In conventional lean production, assembly lines often have to be adjusted to new car models. Uddevalla, on the contrary, due to its low-tech processes that were supported by a high workforce qualification, required considerably less time and capital to adapt to new models than Volvo's other Swedish plants.

4. Vertical re-integration of supply chains

While EVs are complex products, their complexity pales in comparison with cars with internal combustion engines (ICEVs henceforth). Alternators, gearboxes, drive trains, mechanical brakes, cylinders, engine cooling and ignition systems disappear or dramatically change in character. Many dedicated suppliers of these subsystems thus face an uncertain future as a result of the shift in the underlying technology. But the relative simplicity heralds a potentially far more dramatic shift in the relations between suppliers and car makers (usually called original equipment manufacturers or OEMs). Depending on the degree of standardisation, which can actually be quite high in EVs, many OEMs may decide to start making or supplying parts themselves. In the limiting case, as we will see, an amateur car builder – i.e., our staff at PEACS, dear reader – could find many of the necessary parts in a relatively standard electronics store: a computerised controller, a few electric engines, a serious battery pack, etc. The rest could be found in junk yards: second-hand seats and lights. In fact, technically speaking, a Tandy or Radio Shack store (do these still exist?) would probably stock the bulk of what you need: a large electric car is, in many ways, the same as a small remote-controlled electric car, but simply scaled up to carry two or more adults. And that basic simplicity, combined with the ready availability of many parts, changes the entire calculation for OEMs and suppliers.

The building blocks: Asset specificity and product architecture

When thinking about supply chains and degrees of vertical integration, the key guiding concept is the degree of asset-specificity that OEMs and suppliers bring to the relation. The crucial distinction here is between *generic* and *co-specific* (specific assets are, in a way, not particularly interesting, since the supplier is a monopolist, which leaves relatively little for the buyer to decide). Generic assets are best thought of as standardised, off-the-shelf parts and services, while co-specific assets can only be realised as a result of the simultaneous presence of both (examples in a different but related area are specific skills and dedicated machines, which are quite useless on their own but powerful in combination).

Asset specificity, in turn, is related to the underlying product architecture. The lean production revolution of the 1990s has privileged modular product architecture (versus holistic or integrated product architecture), in which OEMs acquire relatively generic parts, often designed to detailed technical as well as performance specifications. As a result, OEMs have increasingly 'fragmented' their operations, outsourced production of parts and services, and selected suppliers primarily on cost after fierce competition and tough contract negotiations – in many cases without much regard for geographical location. This resulted in global value chains, where every link in the chain is optimised in light of the central requirements that the OEM has set – which could be cost, quality, flexibility, R&D capacity, etc., or any combination of these.

By the time the need for EVs had manifested itself, most car manufacturers concentrated on final assembly on the tangible side of the business, and on design, sales and marketing on the intangible side, leaving much of the conception, production and delivery of parts to their suppliers. Despite a very small number of notable exceptions – BMW has adopted something closer to a more holistic, concurrent product design, and Mercedes retained in-house production of a large share of its parts throughout the 1990s – the dominant modular product architecture led to a generalised preference for relatively generic parts and services, selected on the basis of cost and organised solely around the wishes of the OEM.

The economics and political economy of vertical integration

EVs can very easily be associated with increased standardisation of parts: many of the subsystems in electric cars are reasonably well-understood technologies and in simple forms have been around and combined in many durable consumer products over the last half century. Necessary but standard parts such as electrical engines, batteries, semi-conductors and software, for example, show up in electric drills, hi-fi chains, mobile phones, washing machines and even small electric vehicles, from bicycles via scooters to cars. The core parts of an electric car therefore have very few technical secrets. Non-core parts such as seats (or by extension interior systems) or lights (or front ends) are not fundamentally different from electric cars to ICEVs and have been subject to fierce cost competition for many decades now. Finally, it is far from clear if all the specialised electric functions that steer an internal combustion engine (injection, timing, etc.), and that are provided by sophisticated suppliers such as Bosch, will automatically be transferred to EVs. As this suggests, electric cars lend themselves disproportionately to modular product architectures, in which parts are generic and cost is the main selection criterion. There is, therefore, in principle nothing that stands in the way of simply copying the long supply chains that are currently so prevalent in the industry, and in which only the first-tier system supplier has direct links with the OEM.

But that speaks against another crucial economic principle: if parts are indeed extremely standardised (and, lest we forget, considerably fewer in number), nothing stops car manufacturers from buying in the simplest building blocks themselves and organising assembly in-house rather than through suppliers. Vertical disintegration became a guiding principle in the 1980s because car manufacturers concentrated on core competencies. Functions beyond that were bought in along the lines of the principle of specialisation that has guided economic thought since Adam Smith. The parts produced by suppliers were, in other words, considered to be superior to anything that the OEM could ever produce. However, in a world in which parts are relatively standardised and their operation well-understood, supply chains can be a lot shorter with vertical (re-)integration as the central principle. The more a car comes to resemble an IKEA package – the technical term in the automotive industry is a CKD (for complete knock-down) – the more its actual production, parts as well as final assembly, can be (re-)integrated.

This, then, opens the door to a novel production paradigm in the industry, along the lines of the neo-artisanal work model discussed earlier in this dossier. It is often ignored that standardisation and re-integration, accompanied by clever 'design for assembly', also allows for extremely decentralised forms of production. While it may be hard to imagine a new car being built in a cost-effective way in a local garage, with CKD-type assembly of standardised parts such an idea becomes a considerably more imaginable possibility. In the extreme case, a customer could order a new car in a dealership (or online); the dealer orders the parts right away over its computer links to generic suppliers, receives them per mail order and the local mechanic puts the car together with a few twists of parts that slot easily into one another. Once the few necessary fluids are topped up and the battery charged, the car can be collected a few days after the (more or less customised) order was placed. Replace the dealership with a decentralised production arrangement in autonomous teams in small workshops and you have an idea of how the production system might evolve.

Rethinking the company

That links the question of jobs and tasks to the question of company organisation. If supply chains shorten, managers and owners face a strong incentive to consider neo-artisanal models of assembly, not only to redistribute work within the company, but also between companies. For vertical re-integration must imply that with the parts, jobs in the supplier companies are also transferred into the OEM's operations – or disappear. If cellular assembly on a neo-craft basis is more cost-effective on a total cost basis because of the reduction in non-salary costs, the model could easily accommodate the increase in the workforce that would follow from a reorganisation of work practices. In the limiting case, such a vertical re-integration would therefore also transcend the dual insider-outsider labour market that has increasingly emerged in the industry.

5. Vertical reintegration, regional economic governance and comparative advantage

If OEMs redesign supply chains and if they shorten substantially along the way, a new dynamic kicks in, which pulls all companies involved into a different vortex. Imagine a three-tier supply chain. A chip is manufactured in China; that chip is integrated into a simple steering unit – a small computer – elsewhere in the country, from where it then finds its way in an engine control system produced by a little-known subsidiary in Central Europe fully owned by a sophisticated car electronics company in southern Germany. Finally, that unit is integrated into an electronic control system that connects all functions in an engine and sold to a luxury car producer in the area. This is how cars are made these days: the network of parts and their producers spans the entire globe – or close.

The shift to EVs has huge implications for the geography of production. If indeed OEMs shorten their supply chains, the steps between China and southern Germany all but disappear. In fact, a proper carbon accounting of global value chains on its own would spell the death of such international arrangements; combined with the possible shift in supply chains, the pressures are inescapable. All other things equal, the new system heralded by EV assembly will require a more geographically concentrated supplier network, with knock-on effects on production and especially wage costs. Unpacking this problem involves a few steps. What exactly is at stake? Who will win; who will lose? Are there mitigating considerations?

Carbon accounting and vertical re-integration

Before setting out the contours of this problem, it is important to bear in mind that even if nothing else changed, production costs were likely to rise anyway, because a geographical re-concentration of this kind was almost certainly on the cards once transport costs rose because of proper carbon accounting. The possible increases in cost of decentralised assembly with concentrated supplier networks will therefore be relatively small compared to the shadow future built on the necessarily regionalised production systems rather than the dispersed global value chains that supplanted the re-emergent regional systems in many countries.

Regional economies: from strong to weak

This process of vertical reintegration is likely to put tremendous pressure on local production systems that grew around the production of ICEVs – and, ironically, particularly on those regions where luxury cars were produced, supplied by high-powered, sophisticated suppliers. Imagine a regional economy built around a single car assembly plant as the hub, with spokes consisting of highly sophisticated, specialised suppliers of complex functions. If most of those functions (can) disappear in the transition to EVs – think of fuel, oil and water pumps, cooling units, cylinders and other elements in the engine, but also of drive trains, axles and brakes, which will be a very different underlying product – the suppliers of those systems and parts will face significant adjustment problems. In the limiting case, such a regional economy might collapse entirely, with only relatively generic subsystems such as seats, headlights and paint shops surviving.

The point is not that these suppliers cannot adjust – they will have to; but they face the challenge that they have to do so in technologies that are, at best, only tangentially related to current ones. Very few of them, especially among the smaller firms, will have the financial capacity and technological ability to make that jump. This inter-company adjustment and the shifts in products will, in turn, produce different task profiles, jobs, training systems, staffing requirements and employment regulations. In sum, it is unlikely that the wealthy regions of yesteryear (let alone the weaker ones) will be able make the transition into this new world without a loss in regional income and social cohesion.

Regional economic governance

This turns the problem at least in part into one of regional political governance, whereby local political actors have to negotiate a transition with local industries and trade unions. The ability to build coalitions that steer regional economic development in a positive-sum direction is central to this governance problem, but solutions are possibly far from obvious and will depend in large measure on how the past prepared the actors for their new role. (Ironically, such a regional strategy was part of the DGB unions' work on the future in, of all years, 1989 and which was effectively destroyed by the 'Fordist' turn that was forced upon German unions after the collapse of the Berlin wall).

What we do know, though, is that regional economies that are heavily dependent on the car industry, its suppliers and possibly, by extension, much of the engineering sector beyond the automobile sector, will face a serious shock. The successes of the past – as in southwestern Germany, parts of north-eastern France, the Spanish and Italian car-industry dependent regions, and Flanders, the Ruhr and Lower Saxony with several car plants and their suppliers – will not necessarily be reproduced in the future. In fact, the deep technological and organisational shifts documented in this dossier thus far, may mean a dramatic change of track, but against a background of deep path-dependencies that make such a change very hard to pursue.

The regional adjustment trajectories will therefore have to reassess some of the conditions for economic development. One, regional re-industrialisation will have to compensate some of their costs disadvantages by relying on more complex organisations, a more highly skilled and therefore flexible workforce, and innovative abilities beyond individual firms. That will imply new roles for all actors involved. Companies will have to develop more permeable boundaries so that supply functions can be integrated and externalised, as production develops. Workers will need to acquire not only new production skills but a whole array of, for lack of a better word, management skills to organise and support cellular assembly and vertical re-integration. Trade unions and employers will need to rethink local labour market governance (including wage setting) to reflect the new skills and flexible organisations.

Comparative advantages and international trade

As a result, comparative advantages are likely to shift as well. De-carbonisation must imply that supply chains shorten and that some activities are, therefore, repatriated. Low wages, at least one of the drivers of global value chains (GVC) over the last three decades, will become less important, because carbon accounting will raise transport costs to debilitating levels. Softer attributes, which will often exist outside the market will be even more central in future comparative advantages: the availability and production of local competition goods such as education, cooperation and innovation; and the sophistication and flexibility – both in terms of numerical and functional adjustment – of the local production networks. In other words, vertical re-integration will therefore also imply a shift toward high-value added, relatively cost-insensitive production arrangements, with competition between companies and regions organised along 'good' dimensions, such as productivity and developmental capabilities.

But there is no such thing as a free lunch. While you can reintegrate suppliers' operations into OEMs, reorganise links between companies and retrain workers, the repercussions on international trade and therefore on economic development outside the advanced capitalist countries are significant. Vertical re-integration, against the background of free trade within supra-national, regional blocs, has far-reaching implications for emerging economies. Imagine what would happen if a four-tier GVC turns into a two-tier local production system in which all important activities were repatriated to the continent from, among other places, Asia. Somewhat schematically China and other emerging economies that have grown fast as the world's workshops will need a new economic development model, one less based on cost advantages in the international division of labour and more on a growing middle class and rising domestic demand.

6. Industrial Relations and Political Economy in EV Production

The shift to EVs, and the accompanying reorganisation of industry, work and firms, will wreak havoc on existing industrial relations arrangements. Workers, trade unions, households and regions in the global north(-west) will see their life chances, economic growth, and the conditions under which they secure a decent living change dramatically. With the gradual disappearance of the blue-collar worker trade unions will be weaker and, alongside this, the evolution of the industry will erode the stable industrial relations systems that underpinned the Taylorist-Fordist production model on which the automotive and related sectors were based. If sophisticated industry-specific skills were the organisational basis for workers' power in the industry in its fossil-fuel past, a potentially radical shift in production model towards neo-Taylorism is likely to undermine that power basis.

Mutual dependence of capital and labour

Against this background, the mutual dependence of highly specific skills and highly specific capital at the basis of the car industry's social model – wages by and large following productivity, with workers and unions incentivised to work towards higher productivity as a result – is likely to come to a reasonably abrupt end. The reason is simple. Converting assembly lines from standard ICEVs to newly designed EVs is a 'lumpy' process: we do not simply gradually add a single electric car at a time on an existing assembly line but face an all-or-nothing transition, whereby we drive down ICEV production to zero before converting the plant to produce EVs. As we have argued throughout this dossier, EVs are not simply standard cars with an electric engine but are based on different engineering and design principles.

Yet significant workforce reductions, combined with new skills that are not built on or may even be compatible with existing skills, spell a social bloodbath. No employee, and no union representing employees, will take such a dramatic shift lying down. Since the car industry is populated by strong unions, this political set-up everywhere heralds many and long social conflicts, and the possibility of a European car industry which disappears as a result. Unless things move away from the arrangements we know today, the alternative to extinction of the industry is that of a very conservative producer coalition between workers with specific skills (and their unions) and capitalists with specific investments in machines and factories. A coalition with the political clout to slow down the introduction of EVs and green cars in general, may be socially more palatable but comes at the expense of the environment.

The role of industrial relations in the transition

If, however, supply chains shorten while old and new OEMs start with a tight vertically integrated production, the industrial relations background is very different. Faced with the potentially disastrous possibility of expensive social plans and social conflict over adjustment costs during the transition, companies will be inclined to upgrade their workforce skills (probably through a combination of social plans and activation policies), which would allow them to retain much of their existing workforce.

Relying on industrial relations institutions to push through socio-economic change is not new: From the 1950s to the 1990s, the Swedish trade union confederation LO used centralised wage bargaining to construct a more dynamic economy, while Wolfgang Streeck's analysis of Germany industry's adjustment to the second oil shock talks about beneficial constraints in this regard. The combination of constraints on unions and employers, and workers and companies, on the one hand, and opportunities offered by robust labour relations systems on the other, allows for optimism beyond the doom scenarios – but it will require careful management of the transition because of the veto powers of some of the players.

Integrated production and a fragmented workforce

One of the central problems is the trade-off between the plight of the workforce in different sub-sectors of the car industry. While a vertical reintegration and workforce adjustment would certainly smoothen the transition within the OEMs, it will mainly shift the adjustment costs to sectors where suppliers are currently active. While non-core functions in the car such as seats or lights are likely to remain with existing specialised supplier functions that are directly related to the new mechanics of the electric car are very likely to end up in the OEMs' operations – at least at the start. Since these are often among the most valuable functions, even sophisticated suppliers of these functions today will find themselves facing significantly reduced demand and increased competition on cost in such a scenario.

Industrial relations and the political economy of adjustment

In that case, the political economy conflict associated with the distribution of costs and benefits of the adjustment moves to first-tier and perhaps second-tier suppliers. While third-tier suppliers probably make sufficiently generic widgets that will allow them to find new markets, the first- and second-tier suppliers are saddled with extremely high sunk costs in industry-specific competencies, which makes the transition to a new technology potentially impossible to digest.

As a result, the just transition becomes the core of the green transition, not a sideshow that we need to address because it would be socially unreasonable. If workers can feel secure in the transition, they will help industry make the move into productive investment in EVs as well. In fact, if the possible increase in wage costs is off-set by a decrease in all other costs associated with product and process development, the prospects for a new social pact between labour and capital are much better than if adjustment happens after conflict and losses for one (or both) of the parties. Industrial relations institutions, which might harbour the potential for such zero-sum (or negative-sum) conflicts, can also be turned around to become areas and arenas to negotiate a feasible future.

7. The road to green cars has many twists and turns

The just transition to a car industry that produces (primarily) green EVs is a long journey. As has become clear in this PEACS dossier, this is a road with many forks – decision points – where car makers, unions and (regional) governments must decide if and how the European automobile sector operates in the future. This concluding section brings together the many explicit and implicit trade-offs that we introduced in this dossier. Diagram 1 guides our discussion: each branch in the graph represents a conceivable turning point for the transition. Making those branching points explicit will allow policy-makers to understand the trade-offs, risks and potential for conflict and resolution. We will analyse them along three dimensions, which also guided us in this dossier, and will be the framework for our future research and consulting in this area:

1. **Micro: Tasks, jobs, and work organisation in the firm.** What are the jobs and skills required in the future, how will they be structured in (new) assembly systems (e.g., flexible cell assembly), and (how) can the automobile industry continue to offer decent workplaces?

2. **Meso: Supply chains and cooperation/competition in the sector.** What impact will the increase in EV production and automation have on existing supply chains? Will we see a shortening of the supply chains and what does that mean for supply chain hierarchies? How are the tier 1, 2, and 3 suppliers going to cope with the transformation?

3. **Macro: Industrial relations in the political economy.** What are the social aspects of the green transition? What are strategies for unions, employers, and (regional) governments to deal with the risks of industrial adjustment and/or de-industrialisation and subsequent job losses? What are the trade-offs? Where can we find over-

laps and potential coalitions? Do these lead to a positive push for a green and just transition or could we experience hold-ups?

Is Europe willing to transition to EV production?

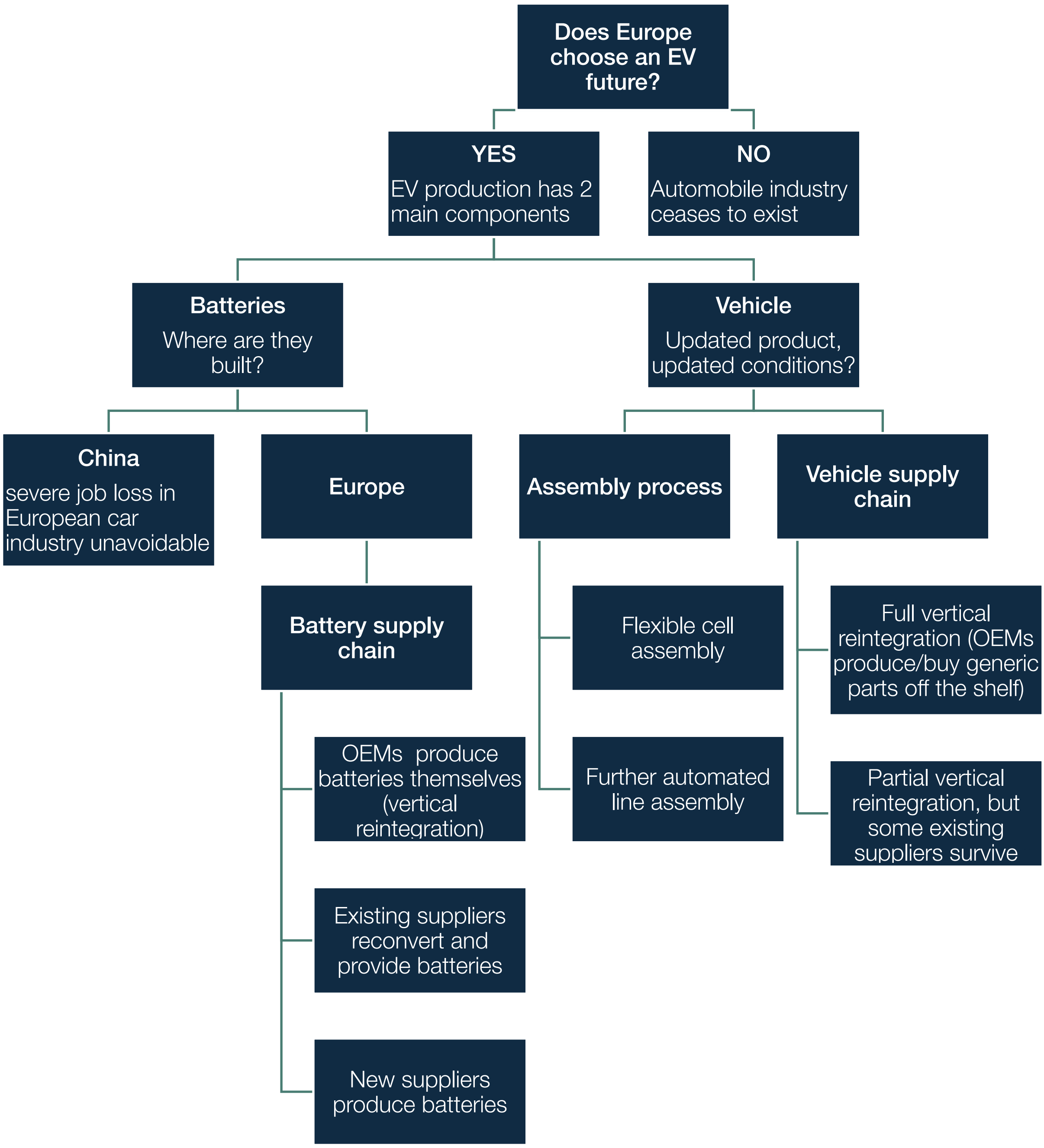
With these analytical dimensions in mind, let us take a closer look at the pathways outlined in Diagram 1. The green transition in the car industry is predicated on alternative energy sources – ICEVs are a product of the past and EVs are poised to become the alternative of choice in mass consumer markets, especially if governments further their adoption with taxes and subsidies (alternatives such as hydrogen are much better-suited for large-scale commercial transportation modes). The European automobile industry, therefore, faces an existential choice: go green or go home.

Being a second mover in the EV market is not necessarily a drawback, as we argued. Classic car companies can build on their established brand name, sales and after-sales services that produce brand loyalty, a vast network of dealerships across the globe, strategic links with sophisticated suppliers to weather technical surprises, and on co-operative industrial relations in the industry. And they can learn from EV pioneers' mistakes and achievements, including bottlenecks in technology and production and regulatory challenges. The industry starts from a very propitious point; but being lucky is not enough. The transition needs to take into account a series of collective action problems and related political-economy bottlenecks.

The stakes are high, therefore: unless the European car manufacturers actively work towards the transition, the industry as we know it today will cease to exist. As obvious as it might seem, the choice is a delicate one (see the introduction). Refitting factories that are built on dedicated capital, specific workforce skills, and rusty technology and design legacies is not easy. Conservative capitalists and unionised workers may thus end up in a veto coalition, able to influence regulators to go slowly. If they succeed to do so, this is bad news for the environment; if they fail, it can either mean that the sector vanishes completely, or – if capitalists push forward without the unions' consent – it could spell, first, a deep social conflict and, then, a social collapse – with all the associated political and social problems.

Crucially, while the decision to transition towards EV production is conceptually the first one on the agenda, it is by no means inevitable or even irreversible. In fact, it will be under constant re-evaluation; opposition against the transformation can only be averted if all trade-offs in the decision tree are acknowledged and reorganised as positive-sum outcomes; and if negative-sum results are counteracted by social plans or other compensatory measures. EVs may produce a collective gain, but it is built on individual pain – and that trade-off makes the process tricky.

Diagram 1: The decision tree of Europe's green transition in the car industry



EV – what's new?

If European carmakers decide to embark on the EV path – as many of them indeed already have – they are facing an updated product that creates its own environment and choices. First, an EV has considerably fewer parts than an ICEV (down from about 20,000 to about 6,000), though the labour input that goes into production isn't necessarily much lower. Roughly speaking, an EV has two main components. First, batteries, and by extension, battery packs that power the vehicle. Second, a simplified version of today's parts makes the EV a fully-fledged car.

Batteries - who makes them?

Though not a main part of this dossier, it is important to note that establishing a sufficiently large European battery production capacity is a crucial element of a sustainable industrial policy in the automobile sector. If, on the contrary, China maintains or even extends its lead as battery producer, providing this critical input to European OEMs, the consequences for the domestic labour market could be drastic. The Chinese takeover of the formerly prosperous European solar photovoltaics industry should serve as example, and it would be wise to prevent a repeat of such mistakes in the battery sector. The EU Commission's early push to create European Battery Alliance, an industry consortium, shows that this matter is being taken seriously, currently resulting in the development of a sizeable number of battery factories across the continent.

Battery supply chain

If we assume, moving down the decision tree in Diagram 1, that the European automobile industry indeed manages to create a healthy battery sub-sector, we can analyse the resulting conditions and trade-offs along the three dimensions outlined in the beginning of this subsection.

Let us start with the micro level. Regardless of who ends up supplying the batteries, all producers face the challenge of having to either newly establish, extend, or reconvert their workforce's skills to produce the relatively novel goods. While batteries have obviously existed for a while and various forms surround us in our daily lives, the range and power requirements alongside the quest for cost and size minimisation require deep technological knowledge and highly skilled workers in the field of chemical and electric engineering.

The meso dimension, or the question about cooperation and competition within the supply chain, is concerned with three rough outcomes of the transition. If OEMs pursue a strategy of complete vertical reintegration, meaning they start producing virtually all major parts, including EV batteries themselves (as Tesla has done), or take over smaller firms to acquire the required production capacity, the market will be too small for existing or new suppliers to enter. If existing suppliers manage to reconvert their machine and workforce skills to manufacture important parts of the battery or its environment (e.g., Bosch), they could be able to survive the transition and prosper in the new world. The question, however, how many of them have sufficient strategic and financial resources to achieve such a successful reconversion remains open. Lastly, the battery market could attract new firms (either subsidiaries of existing, mostly Asian, battery producers or start-ups) which could become individual players or operate as joint-ventures with established OEMs.

Looking at the importance of batteries for EVs can give us a further interesting insight about the supply chain dynamics, assuming there is no full vertical integration by OEMs. The hierarchy between OEMs and suppliers is largely dependent on the importance of the intermediate inputs for the final product. Batteries (at least in the medium-run) make up a large portion of the value of an EV and will remain one of its most important parts. EV batteries might of course become simple commodities (viz. smaller batteries) but that requires radical technological innovations which are unlikely to occur in the foreseeable future. Battery suppliers (regardless if old or new), therefore, have a chance to reposition themselves and can potentially break OEMs' dominance.

The macro dimension assesses the decision points against a backdrop of industrial relations in the wider political economy. The most important impact on regional economies will come from the location of the battery producers. Existing ICEV suppliers of heavy or sophisticated goods are usually geographically concentrated around their OEMs, but if they fail to remain part of the supply chain, the consequences for regional labour markets will be dire, as it is far from certain that new suppliers will choose the same locations. Another crucial element for the analysis of industrial relations is the question if and how the workforce in new battery producers will be unionised. This is not only important for representation and wages, but – in combination with existing regional workforce capabilities – the formation of newly required skills.

Vehicle side of things

Turning to the second stylised main component of an EV, i.e., all non-battery vehicle parts, it is worth remembering just how much their complexity pales in comparison with ICEVs. Alternators, gearboxes, drive trains, mechanical brakes, cylinders, engine cooling and ignition systems disappear or dramatically change in character. This has far-reaching consequences for both assembly processes and supply chain.

Assembly processes

As explained in chapter 2 of this dossier, the imminent introduction of EV assembly across the European and worldwide automobile industries will likely force an adjustment of jobs, tasks and their combination in work organisation. In essence, two possible extreme scenarios are presenting themselves. The first one, which we called neo-Taylorist is an extension of the short-cycle assembly model that has dominated the industry since the early 20th century. The other, labelled neo-artisanal, build on small groups of highly skilled workers who collectively build cars, without assembly line and in very long cycles.

The choice of the assembly system, though part of our micro perspective, also has implications for the meso level of the discussion. It is often ignored that standardisation and re-integration, accompanied by clever 'design for assembly' and flexible cell assembly, also allows for extremely decentralised forms of production. In the limiting case, large assembly workforces in OEM factories in dedicated geographical areas might therefore be replaced by smaller decentralised teams assembling cars directly in the dealer's location; a scenario many regional governments should consider.

There is little doubt that unions (and workers) prefer the neo-artisanal route; there is also little doubt that this route, while not necessarily unprofitable, will require major shifts in conception, heuristic and logic from engineers, managers and unionists who grew up under and were trained in the old model. We know from the demise of Uddevalla in the early 1990s that overcoming these obstacles is at least as important as experimenting with alternatives.

Vehicle supply chains

As outlined above, the relative simplicity of non-battery EV parts heralds a potentially far more dramatic shift in the relations between suppliers and carmakers. Vertical disintegration became a guiding principle in the 1980s because car manufacturers concentrated on core competencies. However, depending on the degree of standardisation, which can actually be quite high in EVs, many OEMs may decide to start making or supplying parts themselves.

If supply chains shorten, managers and owners face a strong incentive to consider neo-artisanal models of assembly, not only to redistribute work within the company, but also between companies. For vertical re-integration must imply that with the parts, jobs in the supplier companies are also transferred into the OEM's operations – or disappear. If cellular assembly is more cost-effective on a total cost basis, as we show in section 2, the model could easily accommodate the increase in the workforce that would follow from a reorganisation of work practices.

Moreover, de-carbonisation must imply that supply chains shorten and that some activities are, therefore, repatriated. Low wages – one of the main drivers of GVC over the last three decades – will become less important, because carbon accounting will raise transport costs to debilitating levels. However, as explained in section 5, if most of the sophisticated functions (can) disappear in the transition to EVs the local suppliers of those systems and parts will face significant adjustment problems. In the limiting case, some European regional car economies might collapse entirely, with only relatively generic subsystems such as seats, headlights and paint shops surviving.

From a macro-perspective, first- and second-tier suppliers face extremely high sunk costs in industry-specific competencies and deep path-dependencies, which makes the transition to a new technology potentially impossible to digest. Regional governments, trade unions and employers will need to consider regional re-industrialisation and rethink local labour market governance (including wage setting) to reflect the new skills and flexible organisations. Therefore, the social element is not just a nice-to-have, but the crucial core component for the transition's economic and environmental success.

Further suggested reading

BCG, (2018). *Will flexible-cell manufacturing revolutionize carmaking?* Accessed online 10/12/20: https://www.bcg.com/de-de/publications/2018/flexible-cell-manufacturing-revolutionize-carmaking

BCG, (2020). *Shifting gears in auto manufacturing.* Accessed online 10/12/20: https://www.bcg.com/de-de/publications/2020/transformative-impact-of-electric-vehicles-on-auto-manufacturing

Boudette, N. E., (2020, July 22). In electric car market, it's Tesla and a jumbled field of also-rans. *New York Times.* Accessed online 10/12/20: https://www.nytimes.com/2020/07/22/business/tesla-electric-car-audi-polestar.html?referringSource=articleShare

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of international political economy*, *12*(1), 78-104. Accessed online 10/12/20: https://edisciplinas.usp.br/pluginfile.php/3257635/mod_resource/content/1/Gereffi%20(1).pdf

Pasaoglu, G., Fiorello, D., Martino, A., Scarcella, G., Alemanno, A., Zubaryeva, A., & Thiel, C. (2012). Driving and parking patterns of European car drivers-a mobility survey. *Luxembourg: European Commission Joint Research Centre*. Accessed online 10/12/20: https://setis.ec.europa.eu/system/files/Driving_and_parking_patterns_of_European_car_drivers-a_mobility_survey.pdf

Sabel, C. F. (1989). *The reemergence of regional economies*. Berlin. Accessed online 10/12/20: http://www.academia.edu/download/52613032/Post-Fordism.pdf#page=106

Sandberg, A. (1995). Enriching production. *Perspectives on Volvo's Uddevalla plant as an alternative to lean production*. Accessed online 10/12/20: https://www.researchgate.net/profile/Ake_Sandberg/publication/23543035_Enriching_Production_Perspectives_on_Volvo's_Uddevalla_Plant_as_an_Alternative_to_Lean_Production/links/5447607c0cf2d62c3050628e.pdf

Trefis (2020, July 23). Behind Tesla's profits. *Forbes.* Accessed online 10/12/20: https://www.forbes.com/sites/greatspeculations/2020/07/23/behind-teslas-profits/

UAW Research (2019). *Taking the high road: Strategies for a fair EV future.* Accessed online 10/12/20: https://uaw.org/wp-content/uploads/2019/07/190416-EV-White-Paper-REVISED-January-2020-Final.pdf