The future of the European automobile industry

Low Carbon – Low Wages? China as Market and Manufacturing Base for Electromobility

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This special report provides an analysis of the changing structure of the Chinese automotive industry, its production networks, and its labor relations in the course of the transformation to new energy vehicles (NEV) as the key technology to achieve carbon-free mobility. The focus of the entire study is on the question how to minimize the employment impact of a transition to zero emissions in Europe, targeted for 2050 under EU policies. To what extent would slower or faster electrification minimize or accelerate potential job losses in the traditional car industry, and to which extent may NEV manufacturing produce new patterns of manufacturing with higher labor intensity?

China is now the global leader in electromobility, both in terms of numbers of production and use of electric vehicles, as well as in qualitative factors such as charging infrastructure or mobility services. The country has a leading position in the production and development of NEV batteries, including a strong sector of mining and production of raw materials. At the same time, China has also become a key base for multinational automakers from Europe, the U.S. and East Asia, to develop mass production of NEV and gain innovative knowledge in the world’s leading market.

Against this background, the employment effects of electrification must be assessed in the context of the structural changes in production models, production networks, and labor practices in the new segments of the automotive industry. Electromobility is driving a transformation from the traditional models of “Fordist” and “Toyotist” mass production to a modular industry structure with globalized production models, comparable to the IT industry. China has become the global hub and testing ground for this restructuring process. In the supply chains of the post-Toyotist NEV sector, new regimes of production emerge that are based on lower wages, higher labor flexibility, lower levels of automation and higher labor intensity than in the traditional core sectors of the car industry in China and world-wide.

The following chapters will analyze the key aspects of this transformation, also in relationship to relevant industrial policies and China’s particular system of policy making. Section 1 will explain the basic aspects of the transformation of industry structures and China’s role within it. Section (2) traces China’s industrial policy in the NEV sector with special emphasis on the battery segment. Section (3) examine takes a closer look at the NEV battery sector and examines the strategies of vertical specialization and integration. Section (4) traces the regimes of production in the emerging NEV sector and the implication for labor policies. Sections (5) presents conclusions and discusses challenges for global trade unions

1.) Transformation of the Chinese automotive industry in the global context

1.1 Restructuring of the global car industry

The current changes in the car industry are not merely technological in nature. They mark a comprehensive break in the production models, innovation strategies and company structures that were established with the Fordist model of mass production since the 1920s and revised under the so-called lean production revolution of the 1980s and 90s. The changes can be compared to the transformation of other mass production industries in recent decades, in which globalization and restructuring had led to a fundamental reversal of production models and value chains. Information technology (IT) and electronics manufacturing, textile and garment, footwear, and furniture have been at the forefront of such developments (Luethje e.a. 2013a).

With the transition to NEV, the automotive sector is facing similarly deep-ranging shifts in the international division of labor and the shape of global production networks. However, today major emerging economies, China in particular, are playing a leading role in this transformation. Production costs and wages are still relatively low, but China plays a leading role in process of innovation and has become an indispensable partner for industrialized countries in the transformation of the car sector.

The automotive industry has often been portrayed as the lead example of Fordist mass production and consumption, linked with relatively high wages and strong bargaining relationships between employers and trade unions. In the wake of the economic crisis of the mid 1970s, the auto industry had been at the center of restructuring of production models through lean production and modularization (Womack e.a., 1990), which enabled a refurbished model of car consumption with greater variety of models, market differentiation and segmentation, and significantly shorter model cycles. This pushed mass production and thereby capital concentration in the car industry to ever larger dimensions and limited flexible specialization as an alternative pathway of capitalist production and growth (Piore and Sabel, 1984).

Related to the basic trends of technological change, three sets of disruptive factors can be traced, which are relatively independent from each other, but interrelated. These have been broadly described in business, labor, and academic literature,

- New energy vehicles: Electrification of the car promises a solution to the major environmental problem of car-based mobility, i.e. carbon emission. It therefore offers a lifeline of survival for the established growth model of the car industry, but renders much of the know how and skills of established carmakers obsolete and radically reduces the labor content of car making (by as much as 50% according to earlier estimates, HBS, 2012). It also brings in new players from the field of new energy components, especially car batteries and power management systems.

- Digital driving and control systems: This can be seen as the most direct manifestation of information technologies becoming a key factor in restructuring. Digitalization of driving brings in the big players of the IT industry, their models of innovation and market control, and their financial power, including venture capital. This development challenges the traditional innovation cycles of the car industry and implies a potential shift of market control from brand-name manufacturers to providers of key components of digital driving systems and their related partners in big data and artificial intelligence.

- Digital mobility is the main driver breaking up the model of private car ownership as dominant norm of consumption (Tyfield 2018). It shifts the center of innovation downstream to the networks and applications that enable the shared use of cars, comparable to other industries with platform-based models of innovation, such as mobile telecommunications (Thun and Sturgeon, 2017). In such environments, the hardware and its brand name are becoming a less important element of competition, rather than software, apps and networks. At the same time, car sharing and other mobility networks de facto become public infrastructures (Srnicek 2017) that affect the requirements for the development of the hardware product.

1.2 Transformation of production networks: China as a hub and testing ground

These disruptions "from outside" are related to the internal problems of the traditional accumulation regime of the neo-Fordist car industry, accompanied by an expected new push of automation through the digitalization of car production (Pardi e.a., 2020). The industry has been plagued by structural overcapacity in recent decades, particularly in the wake of the global financial crisis 2008-09. China and other emerging economies provided the "safety valve" to maintain global growth in the face of severe disruptions in developed country markets, helping to postpone substantial restructuring of the dominant accumulation regime (Lüthje and Tian, 2015). This was backed by tacit coalitions between global carmakers, mainstream political parties and trade unions to protect the car industry and related jobs.

Today, conditions can be compared to the IT and electronics industry on the eve of the personal computer and Internet "revolutions" in the late 1980s. The existing global champions, large integrated computer, chips and telecommunications equipment makers such IBM, Siemens and Fujitsu, were challenged by newcomers such as Microsoft, Intel and Cisco. These companies not only pioneered sweepingly disruptive technologies, but they created a whole new model of innovation and industry organization that became known as "Wintelism" (Borrus and Zysman, 1997).

This model was based on vertical disintegration and specialization, industry-wide modularization of core components, and the separation of product innovation from manufacturing. Brand-name control transitioned from final assemblers to component suppliers. The "assembly-oriented model of innovation and market control" (ibid.) in mass production industries such as electronics, automotive or textiles and garments, was fundamentally challenged. Manufacturing was shifted to a new brand of vertically integrated contract manufacturers such as Flextronics and Foxconn that created massive manufacturing sites in Mexico, Eastern Europe, South East Asia and China (Lüthje e.a., 2013a).

1.3 Structure and growth model of the Chinese car industry in the post-socialist era

China’s automobile industry, now the largest in the world, has seen a double transformation during the past two decades.

The 1990s were dominated by the massive restructuring of the state-owned automobile firms of the Mao period on the one hand, and the emergence of first-generation joint ventures between local state-owned holding companies (such as Shanghai Automotive) and foreign carmakers (such as Volkswagen) on the other. The car market was relatively undeveloped during that period (Thun, 2006).

Since around 2000, a huge influx of foreign investment introduced a new series of joint ventures and a major modernization of production under various models of lean production. This surge of investment in advanced technologies and manufacturing systems has created a production base comparable with that of industrialized countries, including a growing array of design and development activities (Lüthje and Tian, 2015).

The production networks in China’s automotive sector today mirror the globally dominant model of flexible mass production of standardized car models in large varieties. It is based on modular, company-specific platforms promoted by the major producers on the side of production, and on private car ownership of large sectors of the population on the side of consumption. The joint ventures mainly have served the Chinese domestic market. The key policy goal was to transfer state-of-the-art technology and manufacturing know-how to Chinese carmakers (ibid.).

The production networks of the car industry are based on the lean-production model with relatively slim core factories for car assembly and global-local pyramids of first-tier system suppliers and second- and third-tier parts manufacturers (Zhang, 2015). In China, the automobile industry’s supply pyramid is embedded in the highly segmented structure growing out of the sector’s trajectory of capitalist transformation.

The top layers of production networks, assembly of cars and some strategic components (engines in particular), are controlled by joint ventures. The middle and lower tiers of the supply pyramid are mostly owned by private local, foreign and overseas-Chinese investors, usually with little access to high-level government resources. Multinational first-tier car suppliers have expanded rapidly in China, including sizeable research and development operations. However, the overall picture remains dominated by heavy cost competition and labor-intensive production processes with relatively limited industrial upgrading (Lüthje and Tian, 2015).

Against this background, the growth regime of China's automobile industry is split into a capital-intensive high end, dominated by Chinese SOE and their multinational partners, and a low end in which extensive strategies of accumulation prevail. The automotive industry represents a predominantly *state-capitalist mode of regulation* at the core, formed by the joint ventures of Chinese state-owned carmakers with multinational brands and top-tier global car suppliers from North America, Europe and East Asia. At the same time, a number of smaller carmakers under private or "hybrid" ownership, such as Geely, Chery or BYD, have emerged that have been able to challenge the large SOEs in some important markets. These companies have developed extensive production networks at local and regional levels and receive support from interventionist local governments to build supplier networks, infrastructure and technological resources.

Compared to the relatively coherent state-capitalist core of car making, the ownership structure of China's automotive supply sector remains scattered. Among first-tier suppliers, global firms with foreign direct investment or in joint ventures with Chinese SOE are dominant. At the lower tiers of the supply chain privately-owned and hybrid companies of all sizes can be found along with overseas Chinese enterprises from Taiwan and Hong Kong. They are mostly allied with local governments that provide cheap land, workers' dormitories and "flexible interpretations" of laws and regulations.

This oligopolistic structure was relatively efficient in guiding the massive restructuring of the Chinese car industry in the late 1990s and its great leap forward into state-of-the-art production technologies and networks. State-capitalist regulation has also been critical to support the massive geographic expansion into greenfield sites in central and Western China since the crisis 2008-09, as well as the globalization of Chinese state-owned carmakers as investors and shareholders in multinational car companies (such as Beijing Automotive in Daimler and Dongfeng in PSA, Lüthje and

Tian, 2015).

Given the challenges in the global car industry, however, serious doubts have been voiced over the efficiency of this framework. The state-capitalist model not only curbs competition and encourages oligopolistic pricing behavior, it also limits innovation. The major players put substantial resources into the adaptation of foreign car models to the Chinese market, but have shown little interest in developing indigenous innovations in car technologies, components and concepts. Chinese government policies therefore has increasingly shifted to increased support to newcomer companies in the NEV sector and also digital driving.

1.4 New players in the Chinese NEV sector

The entry of rapidly growing new players into China’s automotive sector is reshaping the traditional model of state-capitalist regulation. It brings in innovative firms from the non-state-capitalist sector of the car industry (independent car and NEV makers as well as component producers), from the IT industry, and from global and Chinese car suppliers. Significantly, the Chinese government relies on such new industrial actors, taking account of the success stories of the country’s IT and other industries that followed pathways different from the joint-venture model.

The IT sector provides a model for the current transformation of the automotive sector. The successful development of Chinese IT brand-name firms, such as Huawei, Lenovo and ZTE to national and global lead firms was achieved in the absence of or in competition with joint-venture strategies. In the telecommunications industry, joint ventures of SOEs with global players such as Ericsson, AT&T and Siemens were designed in the 1990s to trade technology transfer for market access. The Chinese partner firms reaped substantial profits from making and selling foreign-branded telecom equipment in rapidly growing urban markets, but they failed to develop brand-name products and services for the huge markets in rural areas. This was left to newcomer firms such as Huawei who combined expertise in undeveloped markets with rapid adaptation of leading-edge technologies from the evolving Internet equipment industry in Silicon Valley.

Since the Chinese government began to expand the NEV sector by imposing production quota of fully electric vehicles on carmakers (see section 2), a significant change in investment has taken place, while incumbent car makers suffer from sluggish sales and mounting overcapacity. In 2018, the Chinese market for passenger cars contracted for the first time in recent history, in the first half of 2019 sales of passenger cars fell by 14% (Financial Times, 2019a). The massive build up of capacity on the part of joint ventures, that has dominated the scene since 2008-9, has come to a halt. In some cases, such as Beijing-Hyundai, plant closures became imminent (Automotive News China 2019a).

On the other hand, independent carmakers and NEV producers grew rapidly. Geely in particular has opened three plants between 2017 and 2019, bringing production capacity to 1,7 million cars per year. In 2017 alone, 14 NEV startups in China were granted production licenses and most of the companies have started building factories. According to the China Association of Automobile Manufacturers, annual capacity for the production of pure and plug-in-hybrid electric cars hit 2 million in 2019, and a large number of NEV startups have started production until 2022.

In this context, new regional centers of production and innovation and new power relations between the central and the local state are emerging. Most of the new players and industry segments are located outside traditional centers of car manufacturing. Shenzhen and the Greater Pearl-River Bay Area (GBA) (with BYD, Tencent, Foxconn and a huge base of electronics manufacturing), Hangzhou (with Geely and Ali Baba), and Fujian Province (with CATV) can be seen as core locations. The government-industry relations in those regions are different from the traditional centers of the auto industry with their strong state-capitalist traditions. The new centers are governed by relatively open forms of regulation, with arms-length relationships between activist local governments and privately owned firms.

1.5 The emerging competitive structure of China’s green car industry

The emerging landscape of new indigenous players in the Chinese car industry can be grouped by technology clusters, business models and their relationship to the world-market:

Independent car and NEV makers with a background in the auto industry, such as Geely, Cheery, JAC and BYD. With its diverse product portfolio of small and medium-sized cars as well as buses and utility vehicles BYD has sold more electric vehicles than any competitor worldwide. Geely has established a highly ambitious strategy to convert its Volvo brand completely to NEV, embarking on joint internal component development and use of a low-cost production system created by Geely (Financial Times, 2017). At the end of 2020, Geely entered an alliance with Foxconn to provide contract manufacturing of cars, eyeing new entrants from top-tier global IT firms into NEV (Taipei Times 2021). Most of the independent car and NEV makers have their own factories, and are vertically integrated within Chinese-style conglomerates. They run extensive local production networks, designed to leverage cost advantages for local players.

Digital car and NEV start ups, backed by Internet giants, global venture capital and Chinese business tycoons, such as NextEV/NIO, LeEco/Faraday, and Baoneng. Most of these companies focus on development of high-end vehicles, similar and in competition to market leader Tesla. Most of these ventures are highly speculative and have received ample publicity. In the light of some spectacular bankruptcies their market and financial success still needs to be tested. Different from Tesla, these companies focus on design and development and use contract manufacturers to assemble cars, especially their electronic components. In the wake of Tesla‘s success in China after the coronavirus crisis, a new wave of speculative investment into Chinese NEV startups has occurred.

Integrated new energy (BYD) and battery producers. Here, Chinese companies clearly have the strongest position in the world market (Fraunhofer, 2016). BYD is a batterymaker by tradition, originally a supplier of Lithium-ion batteries (Li-ion hereafter) for computers and smartphones to Foxconn and other large electronics manufacturers. In 2017 the company was classified as the biggest producer of Li-ion batteries globally, leveraging vertical integration effects from various end markets such as cars, buses, IT or solar and energy management systems. The second lead firm is CATL, a previously unknown battery maker from Ningde, a rural city in Fujian province, where China’s president Xi Jinping once served as local party secretary. The company has massively expanded production with plans to become the world’s largest producer by

2020. As part of a major globalization effort, CATL announced the construction of a factory in Erfurt, Germany, with an initial capacity of 14 gigawatt-hours per year to supply BMW, VW and other major European carmakers with Li-ion battery cells (Dongfang IC, 2019). In addition, China's major electronics making areas, the Pearl-River Delta in particular, have extensive clusters of small and medium-sized battery makers with production experience from the electronics industry (IPRD 2018). This lineup is completed by large Chinese manufacturing operations of leading battery makers from Korea and Japan in China. In 2017, eight out of the thirteen major Li-ion battery manufacturing sites in the world were in China (Sanderson e.a., 2017).

Car suppliers play a key role in the transformation of innovation and production networks. The situation in this sector in China mirrors the segmented structure of supplier pyramids under the joint-venture model. First-tier transnational suppliers are engaged in the development of digital driving systems, and they are preferred partners for the Chinese big three Internet companies. Bosch has formed a strategic alliance with Ali Baba, Continental with Baidu. But there is no Chinese car supplier of significance that could play the role of system integrator and potential global champion in the NEV and digital supply chain.

Electronics contract manufacturers, most of them based in Taiwan, already play a major role in supply chains for car electronics and are moving into NEV and digital car electronics. EMS giant Foxconn has operations in car electronics including some major facilities in the United States and acts as a supplier to Tesla, among others.[1] Given the increasing commodification of NEV and digital car components, large IT contract manufacturers appear as potential mass producers for components of driverless vehicles and NEV. Contract manufacturers are also securing positions as investors in start-ups of all kinds, Ali Baba and Foxconn invested $350 million in an NEV startup named Xiaopeng (Automotive News China, 2018). In the fall of 2020, Foxconn announced a new technology platform for NEV and a network of alliances with Geely and Chinese start-up NEV makers, aiming at the replication of its contract-manufacturing model in the electric car sector (Financial Times, 2020).

[1] Foxconn CEO Guo Taiming stated that "Tesla EVs are virtually made in Taiwan" (Digitimes Jan 8, 2018)

1.6 Changing production models

Traditional carmakers – globally and in China - have recently responded with massive investments into NEV. Companies such as Volkswagen or Ford have begun to produce electric versions of most car models in the near future, VW announced that 50% of its sales in China will be NEV (Automotive News China, 2019c). VW has created its own global platform, and concentrates NEV manufacturing in two dedicated factories in Shanghai and Foshan (Guangdong Province).

Traditional carmakers try to use their manufacturing expertise to keep the old model of vertical integration intact. Yet, their production strategies for NEV are driving new forms of modularity. VW, BMW and other global carmakers source battery cells externally under large-scale contracts with CATL and other East-Asian producers and limit their own production activities to the assembly of battery cells into car frames (2019 field interviews).

At the same time, carmakers are aggressively pushing cooperation and cost sharing. In a major alliance with Ford, VW will license its newly developed MEB platform for electric vehicles to Ford and potentially to other car makers in the future (Financial Times, 2019b).

The restructuring of production systems and value chains also opens up considerable potentials of flexible specialization. Production of specialty cars, delivery trucks, buses, and public transport systems creates a large array of growth opportunities for NEV. In these markets, as well as in passenger NEV, volumes tend to remain relatively small. Changes in technology as well as government regulations and standards require frequent changes in model lineups and components.

To cope with such insecurities major Chinese firms tend to keep their operations highly integrated, but with low degrees of automation. BYD in particular, pursues a strategy to produce batteries and components for new energy systems of all kinds (including smart phones, urban grids, and solar systems), among which cars are only one downstream product. Under this model, new energy technologies are employed in a large variety of products and systems, economies of scale are mainly leveraged on the side of battery production (IPRD, 2018).

Table 1

Three predicted scenarios of restructuring

1. Refurbishing of the vertically-integrated mass production through integration of battery manufacturing by carmakers.

- Brand-name carmakers keep control of their hierarchical supplier pyramids, integration of battery makers as specialized suppliers (e.g., Panasonic, LG or CATL) but not controlling norms of production and technology.

2. Vertically disintegrated mass production with battery makers as core component suppliers with open interface to car assemblers.

- Battery makers controlling norms of technology and manufacturing competencies along the Li-battery supply chain – open interfaces with car brands complemented by independent makers of digital drive trains.

3. Flexible specialization of battery manufacturing clusters as core component suppliers of EV.

- Integrated supply chains with co-development of core technological innovations and transfer into quality manufacturing, based on smaller to medium-sized innovative firms using industry 4.0 technologies for local markets, mobility systems and communities.

2. Industrial policy

2.1 China’s national development strategy for New Energy Vehicles (NEV)

More than a decade ago, China has defined the NEV industry as one of its key strategic development domains, in order to meet the future challenges of resource, energy, environment, industrial transition and urbanization. In 2012, the State Council of China released the “Energy Saving and New Energy Vehicle Industry Development Plan (2012-2020)”, clearly setting out the phased goal: by 2020, the production capacity of pure electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) will reach 2 million units, with cumulative production and sales exceeding 5 million units.

Since then, the NEV industry in China has started its fast development, supported by advantageous industrial policies and subsidies from both central and local governments. In 2018, China accounted for more than half of the global EV sales and some Chinese traditional OEMs - BAIC, SAIC and Geely - are now among the world leading EV makers. This huge domestic NEV market backed up battery capacity growth.

2.2 Changing subsidy policies

The NEV subsidy policy in China has been a catalyzer for the rapid growth of the electric vehicle production and all its components. Concretely, the NEV subsidy policy covers different aspects, the most essential ones including technical requirements, purchase tax exemption, practical advantages - priority in registration, city drive and parking.

From 2010 to 2019, China has issued more than 70 regulations at the national level regarding the NEV industry, more than any other country. Importantly, there has been a tightening of technical requirements enabling the allocation of subsidy. At the beginning the only requirement to qualify for a subsidy was a minimum energy capacity for the power battery of at least 15 kWh. Today, the requirements are much broader, they encompass vehicle performance (maximum speed and minimum range), battery density as well as vehicle energy efficiency (Alochet M., 2020).

Parallel to the tightening of technical requirements, the Chinese government announced to fully cancel its direct financial subsidy by the end of 2020 and has been gradually doing so since 2016, with a yearly reduction rate of about 20%. In April 2020, due to the continued NEV market slow down and a severe economic situation caused by the Covid 19 epidemic, the Chinese government decided to postpone the full cancellation of subsidy to 2022, allowing longer time of adjustment.

The government's plan is to substitute the direct financial subsidy by a market-based credit mechanism, which combines a NEV quota and a credit trading system for carmakers. The New Energy Vehicle Mandate, which came into force on April 1, 2018, imposed NEV credit targets as 10% of the conventional passenger vehicle market in 2019 and 12% in 2020 (with continued gradual growth for following years) for any carmaker with over 30 000 vehicles manufactured locally or imported yearly in China (ICCT, 2018).

For the moment, this mechanism is at its initial period of deployment, and the trading system still in construction. The NEV credits mechanism aims to stimulate intensification of R&D and technological densification in the Chinese automotive industry, from battery power, to electric range and finally to the electric range + battery power + energy consumption tripod. The MIIT announced that it will continue to intensify requirements in the future (Muniz e.a., 2019).

However, with the gradual phasing out of buyer subsidies, the NEV market in China has visibly slowed down since the second half of 2018. Especially for the second half of 2019 - due to the continued subsidy reduction at both national and local level as well as the and complete elimination of subsidy for vehicles with a driving range under 250 km - the total sales of NEV were only about 1.2 million units, decreasing 4% compared with the same period in 2018. With the impact of Covid 19 on consumption power, the NEV sector has further suffered from a very weak demand for the first half of 2020.

Taking out the consequences of the pandemic, NEV producers are still facing big challenges with the full cancellation of direct subsidy in view. One solution is to reduce the sale price of the vehicle in order to win a bigger market share and at the same time guarantee a minimum production volume to reach the economies of scale. As battery represents over 50% of the overall cost of an electric vehicle, battery firms are also among the most impacted in the NEV value chain.

OEMs generally requested battery firms to reduce the price by 20% to 40% during 2019. In the same year, the average battery pack price in China reached $147/kWh, which was the world’s lowest. Price pressure has become a major structural market feature.

2.3 Environmental policies in the NEV battery sector

The tightened subsidy policies (2.1.2) themselves had an upgrading effect on quality and environmental standards. However, health and safety supervision and environmental regulations on lithium-ion batteries are relatively loose in the Chinese market. It’s not that there are no industrial policies in this area, but that the results of policy implementation have large deviations. According to China Automotive Technology & Research Center, the total number of retired power batteries in China was about 200,000 tons in 2020, of which a large number flow into informal black-market channels such as small workshops, causing potential pollution risks to water, land resources, and human safety (Xinhua News 2021).

“Top-level design” of policies occurred only recently. In July 2021, China’s major economic policy decision-making body, i.e., the National Development and Reform Commission published the “Circular Economy Development Plan during the 14th Five-Year Plan Period”, highlighting the importance of NEV batteries recalls for the first time in a general national development plan. Four tasks were identified in the development plan: 1) to promote the establishment of standardized recycling service outlets through NEV manufacturing enterprises, battery recycling enterprises or their collaboration; 2) to promote the standardized cascade utilization of power batteries, and improve the technical capacity of residual energy detection, residual value evaluation, as well as restructuring and utilization; 3) to strengthen the application of complete sets of advanced equipment for the recycling and cascade utilization of power batteries; 4) to improve the standardization of power battery recycling.

The main administrative body for environmental and safety regulation of NEV batteries is the Ministry of Industry and Information Technology (MIIT). The ministry issued several directives on industrial standards regarding lithium-ion battery based on technological advices from the major enterprises in the industry. In addition, policy coordination is also emphasized by the regulatory authorities. The MIIT led to organize a technical committee to coordinate the management of cascade utilization of NEV batteries. In principle, the State Administration for Market Regulation mainly supervises the quality of battery products. The Ministry of Ecology and Environment is in charge of environmental pollution prevention and control in the production process of cascade utilization of batteries; the Ministry of Commerce carries out supervision on enterprises that dismantle scrapped NEV vehicles. In reality, the fragmented nature of Chinese administrative system places considerable difficulties on policy coordination.

2.4 NEV battery recycling

In 2018, the MIIT, together with four other relevant ministries, issued the “Interim Regulations on the Management of the Recycling and Traceability of Electric Vehicle Power Batteries”. It proposed to implement an extended producer responsibility system and full life cycle management of NEV batteries. In its Regulations, the MIIT stipulates that the vehicle manufacturing enterprises should be the main responsible parties for the recycling of batteries. As a matter of fact, there are not so many things that these vehicle manufacturers can do in terms of battery disassembly, recycling and reuse. Currently, battery manufacturing companies and third-party recycling companies are usually authorized to carry out battery recycling.

According to the Regulations, information collection is required for the entire process of power battery production, sales, use, scrapping, recycling, and re-use. A traceability management system and a national platform was proposed for enterprises to upload product information in the form of manufacturer code. This integrated traceability management system (www.evmam-tbrat.com) is based at the Beijing Institute of Technology. Three modules are included on the platform, which are vehicle management module, recycling management module, and local traceability supervision module.

In 2021, the MIIT issued the “Administrative Measures for the Cascade Utilization of Electric Vehicle Power Batteries”. In order to utilize used NEV batteries, enterprises are encouraged to develop technologies applicable to areas such as base stations and energy storage productions. They are forbidden to apply the used batteries to products that cannot be further recycled and to areas that pose high environmental or safety risks. A number of pilot projects were established to encourage the cascade utilization of NEV batteries. Five companies were on the list of the first batch of enterprises that meet the industrial standards specified by the MIIT; twenty-two companies were in the second batch.

In March 2021, an online platform for retired battery trading was launched in Nanhai District of Foshan City in Guangdong. On this platform, traders are able to find a list of NEV power battery recycling service stations across China. They can also publish purchasing and selling information of retired batteries and seek power battery performance evaluation and laboratory testing services. According to the website, a total number of 16555 NEVs have been decommissioned and 28264 power batteries have retired as of November 2021 in China. Guangdong has the greatest number of decommissioned vehicles in the country, which amounts to 10175 NEVs and 11098 power batteries. [2]

[2] https://dianchizhijia.com/home/retireBattery

3. NEV battery production as emerging core sector

3.1 Rapid growth, but looming overcapacity

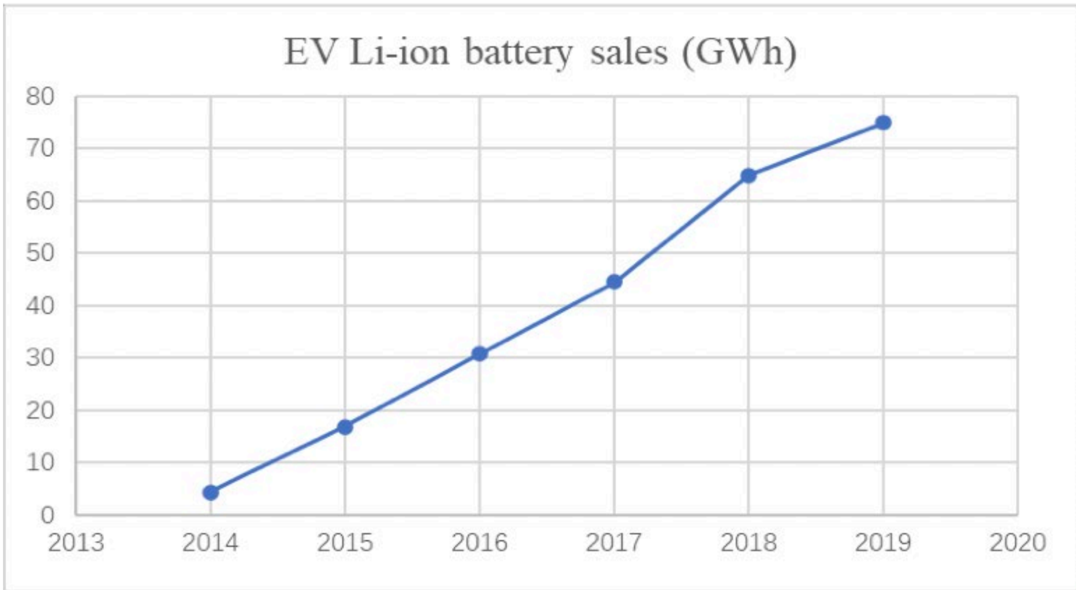
Largely due to the domestic NEV industry development, the LIB industry in China has also experienced a fast growth since 2014. Benefiting from favorable policy and generous subsidies of the Chinese government, many firms have entered different positions along the value chain of the LIB sector in a very short period. BYD planned to reach 90 GWh production capacity by the end of 2020. CATL, representing 50% of the domestic market in 2019, would have 54 GWh production capacity by the end of 2020. Other leading battery firms (Gotion Hi-Tech, Tianjin Lishen, Farasis Energy, National Energy, BAK) are also increasing their apacity to 20-40 GWh for the same period[3]. Besides using specialized battery firms, most OEMs are vertically moving to battery self-supply or building joint ventures with battery firms.

According to the adjusted growth targets proposed by the MIIT (Ministry of Industry and Information Technology) in December 2019, by 2025 NEVs will contribute to about 25% of annual vehicle sales in China, instead of the initial 20% in the 2012-2020 NEV Development Plan. The main reasons for the adjustment are increasing production capacity, improved technological level, growing global demand, as well as providing a guide to further investments and technology upgrading. Under the government's plan of 8.75 million NEVs sales by 2025, power LIB demand will reach more than 500 GWh from China alone.

Even though the NEV sales slowed down in 2019, the power LIB sector still registered a significant annual growth: total sales reached 75 GWh, with an increase of 15.3% compared to 2018; installed capacity reached 62 GWh, representing an increase of 9.2% compared to 2018. In 2019, 73 % of the global total LIB capacity was located in China, compared to the second place of the US with 12% share (Rapier, 2019).

[3] Author's calculation from company reports and announcements

Figure 1: Market growth of NEV-used Li-ion battery in China



Source: Gao Gong Industry Institute (GGII), March 10, 2020

The rapid power LIB capacity expansion by Chinese battery producers, however, has resulted in a relatively low utilization rate, as NEV sales still present only about 5% of the total vehicles sales annually, thus causing the problem of overcapacity. According to the statistics published by Gao Gong Industry Institute (GGII), the total production of power LIB in China reached 44.5 GWh in 2017, 8.1 GWh higher than the actual demand; the overall inventory accounted for about 18.2% of the total output; the national power battery capacity utilization rate was only 40%.

In 2018, only the leading firm CATL's production capacity utilization rate reached a higher level of 76%; BYD's capacity utilization rate was only 54%; the capacity utilization rates of the next eight biggest Chinese power LIB firms were even lower, ranging from 6% to 34% . Behind the exciting electric vehicle market development, the data indicates on the contrary that the power battery sector is already suffering from severe overcapacity.

3.2 Sectoral policy: from infant industry protection to market competition

Back in 2016, in order to prevent foreign competitors and protect its nascent Li-ion battery industry, the Ministry of Industry and Information Technology (MIIT) introduced the catalogue of “Regulations on the Standards of Automotive Power Battery Industry”, commonly known as the “white list”. According to this document, only battery models fully-owned by local battery makers were included in the list and by consequence qualified to receive government’s NEV subsidies.

Since all the recommended NEV battery-cell suppliers were domestic, this measure in fact pushed the Japanese and South Korean battery firms, such as Panasonic, LG Chem and Samsung, out of the Chinese local market. This regulation provided a window period for Chinese firms to build their own comparative advantages, through methods including technology absorption, economies of scale, supply chain lock-up effects, etc.

On May 22, 2018, the new “white list” for the first time included three Chinese Joint Ventures of foreign battery leaders, namely Samsung (50%), LG Chem (50%) and SKI (40%), releasing a strong signal of reducing protectionism and promoting stronger market competition. At the same time, China has effectuated the full opening up of its automotive market for foreign investors; no form of joint venture is required anymore when foreign companies invest in the Chinese auto sector. Tesla was the first to fully invest and own its Gigafactory in Shanghai.

Since then, foreign battery firms, especially leaders from Japan and South Korea, have made a strong comeback in the Chinese market, investing in new battery plants aiming to supply to OEMs of their own nationality and also Chinese ones.

- Panasonic has planned to build up to 9 GWh/year battery capacity in Dalian (Liaoning), about 35 GWh/year battery capacity in Suzhou (Jiangsu) and 30 GWh/year in Wuxi (Jiangsu);

- LG Chem has planned to build in Nanjing (Jiangsu) 23 GWh/year battery capacity by 2023;

- Samsung SDI wants to reach a total of over 35 GWh/year battery capacity in Xi’an (Shaanxi), Tianjin and Wuxi (Jiangsu) by the year of 2021;

- SKI has opted for the form of battery joint ventures, one with BAIC in Changzhou (Jiangsu) of 7.5 GWh/year capacity and another with EVE Energy in Yancheng (Jiangsu) of up to 28.5 GWh/year capacity .

Currently, these foreign battery firms are mainly supplying foreign owned OEMs or joint venture OEMs. LG Chem sells its battery to Tesla and the former joint venture of Dongfeng-Renault (now fully owned by Dongfeng). SKI supplies to the joint venture of BAIC-Benz. Panasonic and Sanyo supply to the joint venture of GAC-Toyota. Samsung SDI is the supplier of SF Motors. With the progressive market opening, the foreign suppliers will compete with Chinese battery firms both in the domestic and overseas markets.

As the protectionist policy changed and entry barriers were lifted, one big challenge for Chinese battery firms now is the strong competition from foreign battery firms, which still have some comparative advantages in the core technologies and quality management. Besides traditional strategies including stronger R&D efforts to improve battery technology - larger production scale to reduce the unit price, better battery system solution to reinforce overall performance -, Chinese battery firms are also considering other strategies for downstream integration and cooperation, such as forming alliances and joint ventures with OEMs or Tier-1 car suppliers.

We will describe more examples in the following section. These different strategies will accelerate the consolidation of the battery sector and lead to deeper industry evolution.

The market opening goes along with the reduction of subsidies, showing a typical Chinese pattern of industrial policy adaptation. In the LIB sector, the industry policy evolved throughout different development stages. After the intial phase of protecting the nascent industry, a sufficient number of domestic players had been established. With a potential risk of overcapacity, policy support changed to stimulating core technology innovation and consolidation among battery makers. Chinese policy makers hope that market selection will promote firms that offer the best performance, have better innovation capacity, and show higher competitiveness.

3.3 Value-chain strategies of Li-ion battery firms in China

As macro-industrial policy initially enabled the rise of China's electric vehicle battery industry, firm-level strategies and choices progressively relayed to this impetus. Indeed, battery firms in China quickly deepened their capabilities in mass production and R&D of battery technologies and products. Driven by demand, a large quantity of products became available in the market, and production capacity has kept increasing fast. Strong user (NEV car) – producer (NEV battery) – supplier (NEV components) linkages and interactions are created through the active development of mainstream firms, further strengthening the localization of NEV battery value chain in China.

CATL has set up battery joint ventures with all big Chinese OEMs, including BAIC, Dongfeng, Changan, SAIC, GAC, Geely and FAW. Large capacity of production and vertical-horizontal consolidation within battery industry are creating big Chinese firms in a short period of time (CATL, BYD, Gotion High-Tech, Tianjin Lishen, EVE Energy, etc.).

As a result, the number of battery firms has significantly decreased, from about 240 in 2015 to only 69 by the end of 2019; this number will continue to decrease in the coming years. At the same time, a trend of internationalization, through different strategies (greenfield investment, M&A, strategic cooperation, etc.), is also observed among leading Chinese battery firms, which demonstrates China's deepening insertion into the global value chain.

CATL is building its first overseas battery plant in Germany, with a planned capacity of 14 GWh by 2022, in order to supply to European OEMs such as BMW, Volkswagen, Daimler, Jaguar Land Rover and PSA. CATL also formed a long-term strategic cooperation agreement with Bosch to produce Bosch 48-volt batteries. Gotion Hi-Tech's wholly owned subsidiary and Tata AutoComp from India signed an agreement to jointly design, develop and produce LIB cells, packs and BMS. BYD is considering building a battery cell factory in the UK to supply Jaguar Land Rover. Envision AESC, the battery industry fund of Envision Group (a Chinese pioneer in energy internet of things), has acquired 80% of Nissan's power battery business.

The dominant practice of core firms in the Chinese LIB sector can be analyzed as a value chain strategy. Table 2 summarizes the strategic moves of all relevant players in terms of their activities. The horizontal axis represents value chain segments, the vertical axis the different types of relevant firms, and the in-tables describe the firms' strategic positioning and entries.

This value chain strategy is characterized by two combined aspects:

- **Growing through vertical integration.** Except some firms in specific niche segments such as equipment and support parts, almost all firms in the LIB sector grow their business through vertical integration. Upstream firms integrate forward to downstream segments, including battery recycling and energy storage. Downstream firms integrate backward to upstream segments such as materials or components. Midstream firms undertake both forward and backward vertical integration. New entrants are active in various segments, with preferences to battery making and complete NEV assembly. Vertical integration is realized by acquiring or creating new assets by means of mergers and acquisitions, strategic alliances, industrial co-operations, and greenfield investment.

- **Competition based on industrial specialization.** When LIB firms grow through vertical integration in the value chain, they do not abandon their original segments and business (the grey colored areas in Table 1). On the contrary, firms continue to compete in their original market and try to become more specialized in their original segments as bases for further market expansion and growth. Through rapid scaling up of production capacity and progressive technological development of new products, they gain more resources and capabilities by exploiting and augmenting their existing assets.

Table 2: Firms' strategies for NEV battery value chains in China

Value chain segments / Firm category	Raw material mining and refining	LIB materials producing	LIB cell, module, pack, and BMS manufacturing	Electric powertrain system production	NEV assembly and production in China	Battery charging station	Reuse and recycling of LIB	Diversified energy saving and storage segments
(1) Mining and refining firms	Minmetals Jinchuan Huayou	Minmetals Jinchuan Huayou	Minmetals				Jinchuan Huayou	
(2) LIB materials producers		Corun Shanshan GHTECH Tinci	Corun Shanshan Tinci				Corun Shanshan GHTECH Tinci	
(3) Incumbent LIB manufacturers	CATL BYD Sunwoda	CATL BYD Sunwoda	CATL BYD Gotion Lishen EVE Farasis BAK Sunwoda	BYD Sunwoda	BYD Sunwoda	BYD Sunwoda	CATL BYD Gotion Lishen BAK Sunwoda	CATL BYD Gotion Lishen EVE Farasis BAK Sunwoda
(4) OEM producers of NEVs			(a) BYD, Geely, FAW, National New Energy, VW, Weltmeister, Great Wall (b) BAIC, Dongfeng, Changan, SAIC, GAC, Geely, FAW, Daimler (c) VW (Gotion), Daimler (Farasis), Geely (LG Chem), Wanxiang (A123)		BMW Tesla VW		BYD Geely BAIC SAIC BJEV Dongfeng Changan VW Daimler	
(5) Specialized recycling and dismantling firms	GEM	GEM					GEM Brunp Haopeng Miracle	GEM
(6) Startups and new players in NEV & battery industry			GREE Zhongli Evergrande Envision Baoneng		Baoneng		Baoneng Weltmeister China Tower	Baoneng Weltmeister China Tower ZTE

Source: authors' data collection from industrial news and company announcements

As a common characteristic of the behavior of different firms, the strategic moves take place mostly within the boundaries of the LIB value chain. The field of specialization is around the battery-related technologies. The vertical integration and entry mainly are directed at various segments the segments of the battery sector, from upstream to downstream. Even for the more diversified downstream activities, they are all based on specialized production, service, and technology of power batteries for

NEV. The framework of the value chain has become the major reference point for the strategy choices of firms at different chain stages of LIB in China.

As we have explained in part 1, the boundary between LIB makers and OEM carmakers is still relatively open. Our findings in China show that not only OEMs, but all players in the LIB value chain adopt vertical integration strategies at various levels of production networks. In China, the adoption of vertical integration strategy by all major firms in the battery value chain resulted in the emergence of a bundle of specialized players who quickly occupy every stage of battery value chain, capable to supply OEMs with lower costs and flexibility. Thus, the Chinese pathway of development is highly complementary to the vertical integration strategies of OEMs. It supports an NEV industry based on vertically specialized mass production of various interacting industry segments, similar to the electronics and other high-tech industries.

4. Production regimes and labor policies

The changes in value chains have a potentially huge impact on work and employment in the car industry, which have hardly been researched yet. Early estimates and beginning job reductions at global car makers indicated that substantially fewer workers will be needed for NEV manufacturing and that the traditional mechanical skills of car workers and engineers will be devalued (HBS 2012). The impact from changing value chains and relocation are not included in most studies, however. As the electronics industry demonstrated, the revolutions in technologies and business models in the 1990s initiated a massive transformation of manufacturing. In its course, most traditional computer and telecommunications production was closed down or sold to contract manufacturers and relocated to emerging economies (Lüthje e.a. 2013a).

4.1 Foxconnization of car manufacturing?

In the Chinese car industry, massive state-of-the art production bases have been developed during the recent two decades. However, job losses among core global carmakers and their home regions have been less severe than in comparable industry, e.g. electronics. Most carmakers duplicated their production networks rather than using China as a location for low-cost export production. However, this may change in the course of the current transformation towards NEV.

As we have explained already this implies a break in the existing competitive structure and production models in the Chinese car industry - between the incumbent joint ventures with relatively upscale wages and working conditions on the one side, and their competitors from independent car makers and the IT industry on the other. The latter mainly rely on low-wage manufacturing workforces with high proportions of rural migrant workers.

The sectoral transformation of China’s car industry traced in the preceding sections also involves a complex restructuring and recombination of the existing regimes of production (Lüthje e.a., 2013b).

In the **joint ventures** of leading OEM the globalized model of state-capitalist regulation is aligned with regimes of production that combine the practices of transnational automakers with the party-based management systems of their Chinese partners. This has resulted in the characteristic twin structure of Western and East Asian corporate lean management and state-bureaucratic practices on the shop-floor (Lüthje and Tian, 2015). Today, the core factories of the JVs suffer from increased cost competition and slower market growth. Workforce reductions and plant closures have been seen in major centers of car manufacturing in China.

Most carmakers have started to incorporate manufacturing of electric or hybrid vehicles into their existing production lines, adding new flexibility requirements for factory organization and workers. Increased pressures have led to workers' dissatisfaction over deterioration of pay, benefits and employment prospects, especially for temporary workers. In one case, FAW-VW in Changchun, this caused in 2017 a major labor conflict with temporary workers over principles of equal pay for equal work.

Independent carmakers, NEV and battery producers: Most of these companies rely on vertically integrated production with high flexibility and workforces with wages substantially lower than in the joint ventures. The rule of thumb among industry experts is about 9 US-dollars as a standard hourly wage at the top joint ventures compared with 4-4,50 dollars at independent carmakers such as Geely and BYD (Automotive News China, 2017). The lower wage scale is especially prevalent among companies with a background in the electronics industry such as BYD and most battery makers.

Their regimes of production represent a high-performance type of labor relations, which has been adapted from Korean, Taiwanese and U.S. models. Wages and employment conditions are fairly decent, but the system is highly incentive-based. Skilled employees can achieve considerable extra income and promotions, but work organization is based on relatively low base wages and salaries, usually less than 50% of regular monthly incomes. Production workers, many of them migrants, are forced to work overtime to achieve a living income (Lüthje e.a., 2013b). The production systems of these companies are very flexible, but rely on a core of relatively experienced skilled or semi-skilled workers. One of the leading firms of this kind maintains its operations in two large industrial parks in South China, one employing

20.000-30.000 and the other one over 70.000 workers (2017/18 field research and interview data, and IPRD 2018).

Electronics contract manufacturers in China are notorious for their poor working conditions and low wages. Their very large factories, many of them with 100.000 or more workers represent a regime of flexible mass production that draws its unique characteristics from China's system of internal labor migration (Lüthje e.a. 2013b). It is based on large-scale employment of rural migrant workers in coastal provinces or big-city inland locations with base wages at the local legal minimum wage and massive overtime work, often beyond legal limits. Work is extremely segmented and deskilled, designed to facilitate mass recruitment and lay-offs according to market conditions. Workers are mostly housed in dormitories, often with harsh living conditions. With the increasing role of EMS contract manufacturers in NEV and digital car production such working conditions are expected to penetrate supply chains. Trade unionists in developed countries, therefore, speak of the "Foxconnization of car manufacturing".

Car suppliers have diverse regimes of production, reflecting the segmented structure of the industry and their positions in the supply chain. First-tier multinational car suppliers have high-performance type of production regimes, while those in joint ventures with state-owned Chinese carmakers have state-bureaucratic forms (Lüthje e.a., 2013b). The car supply industry in China generally works at wages much lower than in the core joint ventures, including first-tier multinationals such as Bosch or Denso. The lower levels of the car supply sector in China are typically traditional low-wage industries, comparable to the flexible-mass-production regimes in the IT industry or to the "classical" low-wage environment of labor-intensive small and medium enterprises.

A recent study of the car supply sector in South China indicated that the shift to NEV car manufacturing and automation have not yet caused major restructuring among car suppliers at the middle and lower tiers, since most of the car manufacturers in the region still focus on traditional car technologies (Yang e.a., 2019). Automation, however, does have potentially heavy impact at the low ends of the supply chain. Recent studies of metal-related manufacturing industries in Guangdong province found that relatively simple forms of automation (mostly with Chinese-branded low-cost robots) lead to massive replacement of manual labor, often affecting the most experienced workers in physically challenging labor processes such as machining of metal or polishing of stainless parts (Huang and Sharif, 2017).

4.2 Automation and digitalization of production

The transition to NEV manufacturing and its impact on employment and production regimes must be seen in the context of the technological and organizational changes in automotive manufacturing through digitalization and automation, often described as “the fourth industrial revolution”. In China this agenda has been mainly promoted under “Made in China 2025”, the national core program to promote advanced manufacturing in advanced industries.

As has been mentioned above, the car industry as a whole is not a strategic sector under Made in China 2025. Only New Energy Vehicles (NEV) is among the ten emerging industries of this program. Some carmakers, from Germany especially, take part in highly publicized promotions of German-Chinese collaboration in industry 4.0. But in reality, industry 4.0-type manufacturing schemes are not significant at the shop-floor. The prevailing tendency of rationalization is to solidify and optimize methods of lean production and to improve efficiency under the conditions of China’s “new normal” with much lower growth rates than in the previous two decades (Luethje and Tian 2015).

The situation reflects the general tendency in the global car industry: since the level of automation in the core sectors of the car making generally is high, there is no significant incentive to implement radically new schemes of digital manufacturing. In China, state-of-the-art technologies have particularly been promoted through the massive construction of new car plants in the wake of the global financial and economic crisis 2008-09. Most of these factories have been set up in green-field locations in central, western and southern China outside the established centers of the car industry. These factories have been built on the bases of the most current platform, production and supply-chain strategies of global car makers, some of them as global model factories for the respective company (ibid).

This investment rush was heavily subsidized by central and local governments, as well as by the massive construction of road and highway infrastructure. It resulted in a massive expansion of production capacity, which often remained underutilized in the face of slower growth rates and shifting demand to cheaper Chinese cars and NEV. The main goal of rationalization in these factories is to increase efficiency of the existing production processes in order to improve profitability under declining rates of profits. However, major restructuring of production schemes and value chains is currently happening in the NEV-sector and among car suppliers at the mid- and lower ends of supply chains.

In *NEV*, manufacturing volumes are still rather low and subject to frequent changes of models, technical standards and government requirements. Against this background manual assembly prevails among indigenous Chinese carmakers. Major global car firms so far have mostly integrated electrified models into their existing assembly operations, based on the platforms for their traditional cars. The recent upsurge in NEV production (starting from the NEV-production quota imposed by the Chinese government in 2018) has not changed this situation significantly. Major multinational carmakers recently have dedicated entire factories to volume production of NEV, such as FAW-VW with its ultra-modern plant in Foshan, Guangdong province, using VW's new dedicated platform for electric vehicles[4]. However, the slow growth of sales of VW and other incumbent car makers' electric vehicles and the preference of Chinese consumers for Chinese-branded NEV so far have not allowed foreign carmakers to play out their leadership in mass production and to set the benchmark for new production models in China.

4.3 Uneven development along production chains

A major drive for automation and digitalization is underway in battery production. The challenge here is to master mass manufacturing of large-scale Lithium-Ion batteries for electric vehicles. Up to now, volume production of such type of batteries has been confined to small batteries for IT products such as smartphones or laptops. Chinese

[4] 2017-18 field interviews; *VW Group doubles capacity of South China plant;* Automotive News China, June 26, 2018

manufacturers command ample experience in this field. South China, the leading center of IT manufacturing, hosts the largest supply base of Li batteries in the world. The transition to volume production of large-size batteries requires substantial automation and highly capital-intensive equipment. Especially in the mechanical parts of the production process and in materials handling are massive potentials for digital automation, promoted under Made in China 2025. Battery factories, therefore, are seen as model applications for advanced manufacturing under the related national and local programs (IPRD 2018).

In the *car supply industry*, automation and digitalization is driven by two factors. Major Chinese second- or third-tier car suppliers, such as CITIC Dicastal in wheel alloys or Desai in car electronics, have developed extensive automation projects in production and supply chain management. Some of them host model projects for factory automation under Made in China 2025. These companies represent the type of mid-market mass manufacturer described above, that is transforming large-scale assembly operations from mainly manual to semi-automated processes. However, the nature of this rationalization is rather conservative, with a strong focus on cost cutting, quality improvement and expansion of manufacturing databases. In car electronics, this development intersects with the transformation to NEV production, since some of the major Chinese of producers also engage in the manufacturing of battery control systems or battery packs and cells[5].

At the lower ends of auto supply chains, basic processes of metal parts manufacturing, such as grinding, milling and polishing, are the typical application fields for low-end robots. The companies mostly use relatively cheap equipment from Chinese producers, some of them also imported robots from top international brands, such as ABB, Kuka or Yaskawa, configured by local Chinese firms. The purchase of Chinese-made or -configured robots is heavily subsidized by local governments (usually between 30-60% of investment costs); investment strategies are short-term, usually with a return-on-investment target of less than three years. Such robots are typically used to displace semi-skilled migrant workers with long work experience and relatively high wages, who are difficult to find in local labor markets. Automation of this kind

[5] 2017/18 company interviews

replaces the best-paid groups of migrant workers, but usually there is no retraining to qualify them as operators or programmers for automated equipment (Butollo and Luethje 2017).

A recent study of the automation and labor policies of car suppliers in South China confirms the dynamics of catch-up automation under the conditions of China's "new normal" (Yang e.a. 2019). The study included ten tier-one and tier-two suppliers for Chinese-Japanese joint ventures in the Pearl-River Delta. All of them had been involved in a major wave of labor conflicts in 2010 and subsequently participated in the introduction of democratic union elections and collective bargaining at plant level, seen as a model for China. Production processes in those companies have been continuously automated in recent years and became more capital intensive. Automation, however, is mostly gradual in nature, designed to improve quality, efficiency and to lower labor costs. Digital technologies and robots do not play a prominent role in the rationalization strategies of those companies, Made in China 2025 and the related local policies cannot be seen as a major driver for shop-floor change. Automation clearly has an impact on workplaces and workers, but in no way as dramatic as the political slogan "robot replaces men" would suggest.

On the whole, the employment effects of both the transition to NEV and of automation and digitalization in the Chinese car industry are difficult to measure in quantitative terms. Obviously, the shift of NEV production networks into the electronics sector, as well as the relatively low level of automation in the assembly of NEV and their components (with the exception of batteries) can be seen as a trend towards higher labor intensity in automotive manufacturing. This may offset some of the job losses in the car industry resulting from the less complex manufacturing processes in NEV production. On the other hand, digitalization and automation will continue to progress rapidly in electronics manufacturing and in NEV production networks. Therefore, job reductions through automation are to be expected as a long-term trend for NEV manufacturing, especially in its more labor-intensive segments.

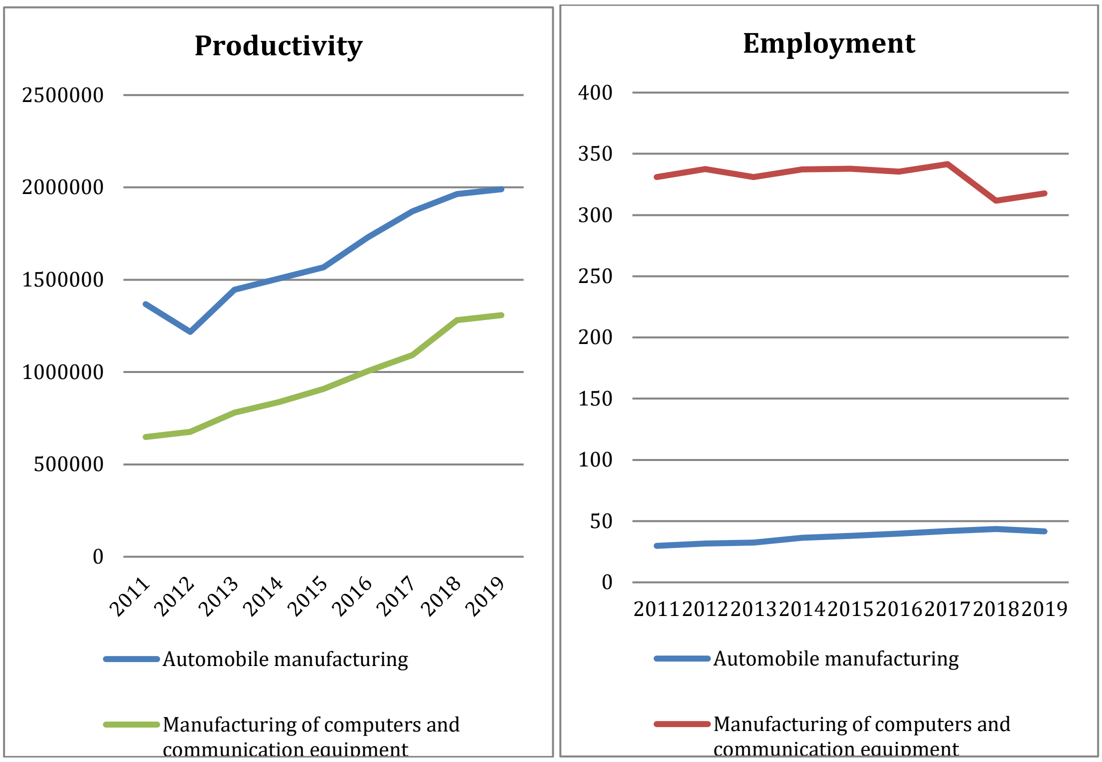
These tendencies can be assessed through a comparison of productivity and employment data of automotive and electronics manufacturing in China. Recent data from Guangdong province, China's largest manufacturing region and a core location for the global electronics industry as well as for the production of NEV and traditional cars, shows divergent trends for both sectors.

- *Automobile manufacturing* has very high productivity measured in output per worker. But productivity growth was only moderate, around 45.5%, between 2011 and 2019, and employment grew slightly during that period. These figures reflect the fact that the main car factories in the region, namely of the joint ventures of Toyota and Honda (with Guangzhou Automotive) and Volkswagen (with FAW), have only been established between 2007 and 2012 as greenfield facilities with very high degrees of automation.
- *Manufacturing of computers and communication equipment (IT)* has the second highest productivity, but significantly lower than automobile manufacturing. However, overall labor productivity grew much faster, more than 101.7% between 2011 and 2019, whereas employment remained largely stable. Traditionally, IT manufacturing included a high proportion of manual assembly, but the sector saw massive automation during the last decade (particularly in labor-intensive assembly shops at the lower end of supply chains, see below).

With more than 3 million employees the IT industry remains the largest industrial sector in Guangdong, whereas employment in the automotive industry is much lower (under 500.000 including car suppliers). Therefore, the potential for automation-related job losses is much higher in electronics manufacturing than in the highly automated car industry. However, NEV production will certainly add new products and production lines to the electronics industry. But whether this will compensate for job reductions through automation remains to be seen.

Figure 2

Productivity and Employment in Automobile and Electronics Manufacturing in Guangdong Province 2011-2019



Data Source：Guangdong Statistical Yearbook

4.4 Work processes in Li-ion battery manufacturing: observations from factory visits

The work process in Li-ion battery manufacturing has not been studied systematically yet. It is very different, however, from the manufacturing of traditional lead-acid batteries, which had been notorious for severe toxic health hazards for workers, especially in developing countries including China. The manufacturing of Li-ion batteries is highly automated in most core processes, and includes printed circuit board and mechanical assembly as known from the electronics industry. In the absence of systematic studies, we provide a first description of manufacturing processes along the industrial chain from factories in the Pearl-River Greater Bay Area (GBA) that we visited between 2017 and 2019.

In general, Li-ion battery manufacturing is highly automated and usually does not require large factory workforces as in traditional car or electronics production. According to figures published by the companies (see Appendix 1), China's largest battery maker, CATL, has a total workforce of roughly 20.000, distributed over 9 factories (including the newly established one in Erfurt, Germany) and R&D facilities, mostly located at its headquarter in Ningde, Fujian province. The workforces of other battery makers appear to be much smaller.

Some of the leading battery makers concentrate their production in large industrial campuses that include up- and downstream production processes like cell or electronics assembly, or the manufacturing of electric vehicles or electronics products. BYD has most of its production in three large campuses in Shenzhen and Huizhou, each of which with several ten thousand employees. Battery factories are located within these industrial parks, which also include R&D facilities, logistics and large dormitories and apartment buildings for workers.

Similarly, the joint-venture battery factory of CATL and Guangzhou Automotive Corporation (GAC) is located in GAC's large new energy car industrial park in the Panyu district of Guangzhou City. The presumably largest battery factory in the GBA manufacturer is located in Huizhou and has been developed as an integrated industrial park in a rural greenfield locations. The workforce consists overwhelmingly of migrant workers housed in dormitories.

Along the production and industry segments identified above, the following profile of the work process can be drawn (this does not include refining, production of basic materials, and recycling, since we did not have the opportunity to visit relevant facilities).

Production of anodes and cathodes is an industrial manufacturing process that includes metallization, metal forming and die casting. It is performed in small-to-medium sized factories with smelter ovens and similar equipment. It includes heavy physical work with high impact from noise, fumes and high temperatures.

Production of battery cells, the core process**,** is highly automated and occurs in large cleanroom-like facilities. It involves the preparation and processing of micro-thin copper foils, from which the battery cells are made, several stages of metallization and galvanization, and the final rolling of the material into small cylindric battery cells. The quality, calibration and maintenance of the equipment is crucial for the production process, which must maintain highly uniform quality of millions of battery cells. Most of the equipment is from first-tier providers from Japan and South Korea. Due to the highly automated character of the process, the workforce inside the cleanrooms is very small, mostly skilled or semi-skilled equipment operators and maintenance workers. Outside of the cleanrooms, most work is in logistics and warehousing.

Packaging and assembly of batteries occurs in facilities of different sizes according to production volumes and product characteristics. Cells are inserted into metal casings and frames, usually by medium-skilled assembly workers with some experience. In larger facilities this is done on assembly lines with some automation, smaller facilities mostly use hand assembly. In cooperation projects between carmakers and large battery providers, parts of the battery assembly may also be located in or near car plants.

Electronics assembly (battery management systems) consists of the generic work processes of electronics manufacturing, i.e. assembly of printed circuit boards (usually with program-controlled SMT and soldering equipment), hand assembly of certain non-standardized parts and enclosures, and final testing. According to volumes and product characteristics, this work is performed in facilities of different sizes, some of them integrated in electronics factories with varieties of other products.

Production of battery frames and casings occurs in specialized factories of different sizes and involves standard processes of metal manufacturing such as cutting, drilling, welding etc. Production is becoming more and more automated, leading companies in the GBA use imported high-precision equipment and robots to improve production quality and save labor costs.

Final assembly and configuration for car frames mostly occurs at the facilities of the car makers that use externally produced battery cells. The work organization differs according to the products and the production models of the various car makers. As has been explained above, the division of labor between car makers and battery providers are still relatively unstable. The largest car factory in South China, a Sino-European joint venture, has built a battery assembly plant on its factory campus. This plant configures the batteries for the multinational’s traditional car platform and models. This process is relatively labor intensive, because platforms for combustion-engine vehicles are not suited to receive large Li-ion battery assemblies. With the transition to a specific platform for electric vehicles, standardization and modularization of this process is expected with potentially fewer workers. The testing of the batteries requires extensive safety checks. Workers have to acquire special training and certification, which the company provides through its highly developed internal vocational training system.

In general, the work process in Li-ion battery manufacturing is relatively differentiated in its various stages and segments, but its basic characteristics are similar to industrial production known from in the metal and electronics sectors. Much of the existing knowledge on practices of decent work, workforce training and occupational safety and health can be applied to this field. For the core process of battery cell manufacturing, there exist no viable studies on the chemical and toxic risks for workers. The existing Chinese and international literature on health hazards in battery manufacturing only mostly deals with traditional lead-acid batteries.

According to our observations, working conditions and workforce in the battery industry resembles those of other manufacturing industries such as electronics or automotive supply. The majority of workers are lower- to medium-skilled who are paid according to the general local standard wages in the GBA (around 5000-6000 RMB per month for lower-skilled and 6000-8000 medium to higher-skilled assembly workers and equipment operators). Skilled maintenance workers are relatively few, since maintenance and calibration of equipment is mostly performed by engineers with college degrees.

As in the GBA in general, most workers including the higher-skilled ones and engineers have a migrant background from rural areas of Guangdong or other provinces. Production workers are housed in dormitories, either on company premises or in rental facilities in industrial areas. Higher skilled workers live in apartments provided by the companies or in private housing areas. Under the existing rules and regulations, migrant workers have no long-term residency in the cities of employment and have only limited access to social services, schools and government subsidies for housing etc. Therefore, the turnover among the local industrial workforce remains high, also among higher-skilled employees.

4.5 Worker rights and trade unions

In the broader context of the restructuring of the Chinese car industry, the work regimes in battery manufacturing can be considered as one element of the “Foxconnization” of car manufacturing described above. Battery production and the related areas of electronics manufacturing have adopted indigenous Chinese regimes of high-performance production or flexible mass production as known from electronics contract manufacturers. Only in the final assembly and configuration facilities that are connected to core carmakers and their joint ventures it can be assumed that working conditions and pay are at the level of established first-tier car companies.

From this perspective, the battery industry reflects the divisions along the production chains of the automotive industry in China, which have been analyzed in the literature quoted in this report. Official trade unions have an established presence in state-owned car makers and their joint ventures, but they do not play a strong role in setting the standards of wages and working hours. Collective contracts and bargaining procedures only exist at company level, there are no industry-wide labor contracts or wage standards. However, the wages and benefits at state-owned car makers are comparatively high, auto workers are among the highest paid industrial workers in China. Also, the state-owned car makers have comprehensive vocational training systems and internal labor markets. Wages and wage classifications are linked to workers’ achievements in education and training.

Under the labor regimes prevalent among private car makers and electronics firms, wages and benefits for production workers are much lower. Trade unions exist in most of the larger companies, but their position is still weaker than in SOE and joint ventures, where the trade union normally is integrated into the management structure. As we have mentioned already, under the rapid expansion of the NEV sector in general and battery manufacturing in particular, these conditions may rapidly become the ‘new normal’ in automotive manufacturing in China.

In general, the employment in these companies represents lower- to middle-standards of work and pay in China. Working conditions in foreign-investment enterprises and joint ventures are significantly higher, these companies are seen as preferred employers among Chinese workers. On the other hand, conditions at Chinese private companies in the car sector such as BYD, Geely or bigger battery makers are significantly better than in labor-intensive smaller and medium enterprises, which represent the lower end of supply chains of the automotive and electronics industries.

Major labor conflicts or publicly known violations of worker rights in the NEV-battery industry could not be detected in the course our research. In the respective locations in the GBA and other areas in China, several cases of severe poisoning of workers in the production of traditional lead batteries have become known between 2005 and 2015. There are no such reports about Li-ion battery facilities or related electronics factories. We cannot say much about working conditions and wages in the mining, materials processing and recycling segments. Since most of the facilities are located in rural mining districts in northern and central China, one may assume similar conditions as in coal and other mining industries.

In the particular case of the car suppliers cited above, automation is used to compensate for higher labor costs supported by the newly established collective bargaining system in these companies, but it is not part of an overall assault on workforces and their improved collective rights. Rather, cooperative labor relations based on “moderated mobilization” prevail (Yang e.a. 2019). The workers experience intensification of work and stricter control, but they do not see their jobs immediately threatened. However, they do expect higher wages and a fair share in productivity gains and economic profits, as well as a more rational structure of the wage system that would remunerate the skill improvements and greater efforts required from the workers. Collective bargaining, so far has not much addressed these topics, and remains relatively weak due to its limitation to single factories. But definitely, there is room for qualitatively oriented bargaining strategies as well for industry-wide bargaining at local level.

5. Conclusions and policy recommendations

5.1 Industry structure and global supply chains

As we explained in the first section of this report, the automotive sector is undergoing a massive transformation that historically can be compared to the break-up of Fordist and Neo-Fordist production models and the subsequent globalization of major manufacturing industries in the 1980s and 1990s, electronics in particular. Vertical disintegration and re-integration are at the core of this process. On the one hand, the existing production systems of global car makers and their hierarchical supplier pyramids (commonly known as the "Toyota model") may gradually lose their core role in the automotive sector. New sources of production know-how are emerging, which is no longer exclusively controlled by traditional car makers. NEV batteries are a key element in this transformation.

Compared to the 1990s, the conditions of what we call "globalization" have changed considerably. Emerging economies have not only developed as low-cost production bases and "extended work benches". Rather, they have accumulated substantial technological and production know-how at various stages and become important players in global innovation. In the NEV and battery sector, China is the global lead market, the major producer and a key innovator. Global supply chain development, therefore, no longer is a top-down process, controlled by the leading global brand-name companies in industrialized countries, but multidimensional in the sense of distributed centers of innovation and industrial players controlling different segments. The global car makers are no longer the undisputed leaders of industrial development in the auto sector.

China caught the opportunities of impeding disruptive transformation and gained a leading position as a first mover in NEV battery making. This development was based on a large sector of battery suppliers for consumer electronics, computers and mobile phones. China now has a complete Li-ion battery value chain for NEV, from upstream materials production to midstream manufacturing of cells, modules, BMS, and packaging, as well as downstream applications in mobility and various other fields, such as grid storage, lighting, solar energy, and movable storage. Within the automotive sector, Chinese battery producers are becoming important players as providers of core components, reaching out into other battery technologies such as fuel cells.

The dominant strategy of Chinese firms can be described as **specialized vertical integration** across the industrial chain, including Li-ion battery cell production, mining and refining, cell materials and components, electronics assembly, packaging, final assembly of NEV and building of charging stations. Major firms expand and integrate their activities into various stages of the production system, but vertical integration remains within the battery value chain and around the specialized field of battery or electricity storage. This ongoing recombination secures the dominant role of Chinese firms in global production networks in the battery industry and within the NEV sector in general.

5.2 Environmental and social sustainability

In the environmental field, China has established a comprehensive framework of laws and regulations connected to national and regional industrial policies to promote NEV and "green" mobility. As we have explained, the industrial policies to upgrade NEV manufacturing have important effects of upgrading for battery manufacturing, both with regard to product safety and recycling. China's current effort to build a comprehensive system of NEV-battery recycling are ambitious and advanced compared to similar efforts in developed industrial countries. One reason is that the unexplored negative environmental consequences of NEV-based mobility, such as rising electricity consumption, shortage of raw materials and growing electronic waste, have become more visible in China than elsewhere.

Reports about these and related problems have been rare and the potential environmental problems of NEV mass production are hardly present in Chinese mainstream media. However, there remain a number of open questions, which should also be raised with major carmakers.

- The environmental impact of Li-ion battery manufacturing has not been systematically studied in major industrial countries, including China. Given the size and scope of the industry in China, a systematic review of environmental impact studies of battery plant location could give important insights on this field.

- The same can be said for recycling facilities and the environmental impact of materials mining and refining. Since these industry segments are mostly located in rural and less developed regions in China, the impact on rural and environmental development should be studied, also in other developing countries.
- Unregulated recycling facilities have been a problem in China. The government recently has promoted efforts to eliminate unregulated recycling and to promote recycling platforms. The question has to be raised how effective these policies are and whether battery makers and recycling still use unregulated recycling facilities. On the other hand, new initiatives in this field, such as the online trading platforms for used batteries, should be studied.

In the field of labor relations, the "Foxconnization" of car manufacturing through the rapidly growing NEV segment brings lower wage and employment standards to the Chinese automotive industry, which has been dominated by state-owned enterprises and joint ventures. Whether this development will induce a general trend to lower wages in core automotive manufacturing in China, or whether there the existing segmentation of employment conditions between some first-tier car makers and the lower tiers of the supplier networks will be increased, remains to be seen. Certainly, this will depend on the degree to which official trade unions and government labor bureaus will be involved at the local level, and whether existing labor laws and standard are properly implemented.

Consequences on global supply chains may be different from the electronics industry, since the emerging NEV sector does not yet have a clear division of labor between technology-defining brand-name firms (such as Apple, Dell or Huawei) and manufacturers (such as Foxconn). Also, the motives to relocate factories and build global production network are not only in lowering labor costs, rather than strategic considerations concerning market proximity, co-operation and co-innovation with end users, global carmakers in particular. Electronics contract manufacturers themselves are becoming important players in production networks for NEV with substantial technological resources. Some of them have already established joint ventures with global car makers in China, such as Foxconn with Stellantis.

The open questions to assess labor standards in the production regimes of major NEV firms and of global carmakers are mostly related to the general framework of labor relations in China.

- Do companies comply with existing labor laws and health-safety regulations?
- Are those regulations implemented properly at the local level?
- Do companies pay living wages and decent benefits according to existing laws and regulations?
- Do companies accept trade unions and collective bargaining regulations, such as the collective bargaining guideline in Guangdong province?
- Do the wage systems of companies relate to workers' skill levels and do they provide incentives and remunerations for learning and skill development?
- Do the companies provide quality vocational training, and how is skill development at company level related to vocational education in public schools and institutions?
- Working conditions and OSH in battery cell production: given the scarce knowledge of health hazards in Li-ion battery manufacturing, there remains a wide array of open questions which should be studied systematically. Studies should also be based on data from the manufacturing of Li-ion batteries for consumer electronics and IT products, which has existed for several decades.
- Working conditions in mines, refining and smelter facilities. Little is known about the situation in lithium and metal mining facilities, but it can be assumed that there exist similar issues of OSH, wages and working conditions as in coal and other sectors of China's large mining industry. Those industries have been relatively well studied and can serve as reference.

5.3 Policy recommendations

a) Decent work in NEV manufacturing is a key issue to make the new-energy vehicle industry sustainable and to ensure social standards in the green transformation of the automotive sector and the global economy. Trade unions are key actors in this field and should develop their activities based on systematic analysis of supply chains and industry structures. Crucial lessons can be learned from previous transformations of manufacturing industries, electronics in particular. Industrial unions should develop proactive policies to secure social and environmental standards in global supply chains and to support industrial policies to reshape the automotive sector along the lines of shared prosperity between emerging and industrialized economies.

b) Industrial unions should develop **industry-wide perspectives** of securing labor, environmental and safety standards in battery manufacturing. As the development in China shows, NEV-battery production is emerging as a diversified industrial sector with different types of firms and specialization and with a high degree of local clustering. Such an environment provides the conditions for industry-wide organizing, collective bargaining, and industrial policies. However, union strategies for the automotive sector must go beyond securing the traditional interests of core car makers and their workers. It must rather define new strategic goals that include workers in the battery industry and along the global supply chain of mining, refining and materials production as well as the strategically important recycling sector.

c) Industrial unions should promote industrial policies that support **diversity** within the NEV sector, rather than engaging in a global technology race based on the creation of mega factories with large amounts of government subsidies. The current policies in Europe and the U.S. to catch up with battery cell producers from China, Japan and Korea support such a technology race in the name of "supply chain security". The experiences from local industry clusters in China offer strategic perspectives of diversified development, that may also be conducive to the conditions of industrialized countries, especially to small and medium-sized enterprises in the electronics and automotive supply sectors. Such industrial policies can also help to counterbalance an emerging oligopoly of global battery makers in conjunction with large car makers.

d) Industrial unions should support open markets together with strong **multilateral social and environmental standards** for battery manufacturing. Given the global structure of supply chains and the position of China and other emerging economies in innovation, "decoupling" and protection of national or regional markets is not possible and not practical for workers and trade unions. This is also true for the mining and materials sector, which needs viable global standards and enforcement within multilateral institutions and agreements. Transnational agreements on trade, investment, and technology should include such standards, international trade unions should actively engage in relevant negotiations. The investment agreement currently under negotiation between the EU and China, for example, should not only contain protections for investors, but also for workers and communities.

e) The representation of workers and trade unions in the Chinese NEV industry apparently is weak. The labor standards in the emerging sector and its relevant locations have been shaped by the electronics industry, which mostly employs migrant workers and provides low or very low wages. However, in global perspective this situation seems to represent the norm, rather than an exception. **Organizing** the fast-growing NEV industry, obviously, has to be a top priority for industrial unions. As known, Chinese trade unions do not engage in such activities and labor relations are mostly dominated by the state. But industrial unions could promote the organization of employees of newly-built factories of major producers from China and South Korea in North America and Europe, especially in batteries. Recent experiences from companies with Chinese ownership in Europe show that many Chinese multinationals accept local labor laws and standards, including works councils and trade unions.

f) Industrial unions should seek **cooperation with Chinese trade unions** and experts from government, companies and relevant organizations. The joint ventures of international car makers can provide an important platform, some of which have developed regular communication between trade unions at company level. The facilities of Chinese battery makers in Europe could create similar channels in the future. Given the scarcity of information on key questions of industrial, environmental and social development of NEV manufacturing, we need further studies of production models, supply chains and labor process. Industrial unions should initiate **health and safety studies** on core processes of battery manufacturing and establish communication with Chinese trade unions and experts on questions of working conditions and work safety. The situation in the **mining and materials secto**r requires special attention, since little is known about working conditions in relevant facilities in China and in developing countries in Africa and South East Asia.

g) Supply-chain monitoring and due diligence by stakeholders at multinational car makers can play an important role to raise awareness and promote communication. In China, this would require communication with and through the joint ventures of the respective companies. The joint venture partners and their union representatives should be actively involved. Communication should be built on extensive knowledge of Chinese laws, regulation and practices. Precise questions have to be developed regarding the locations, health and safety standards, union representation and the local implementation of relevant labor laws and regulations.

References

Alochet, M. (2020). Are Chinese regulations shaping the global deployment of the EVs industry? Paper presented to Gerpisa colloquium 2020.

Borrus, Michael, and John Zysman (1997); Wintelism and the Changing Terms of Global Competition. Prototype of the Future? BRIE Working Paper 96b, Berkely Roundtable on the International Economy, Berkeley CA.

Dongfang IC (2019). "Ningde Shidai de quanqiuhua kuozhang, goujian dianchi chanye de da geju (CATL's global expansion, creating the battery industry's big pattern)", *Yan Zhi qiche jianwen (Yan Zhi Automobile Insight). Market Report.* Author: Beidu Nangui. WeChat Offical Site http://mp.weixin.qq.com/s/SJ4RJqUrl

Financial Times (2017, October 15). Geely and Volvo jointly develop components. *Financial Times*.

Financial Times (2019a, July 10). China's car market set for second year of falling sales. *Financial Times*.

Financial Times (2019b, July 12). Ford and Volkswagen to share costs on electric and self-driving cars. *Financial Times*.

Financial Times (2020, October 17). Foxconn accelerates electric vehicle drive with new tech platform. *Financial Times*.

Financial Times (2021, January 8). Foxconn ramps up EVs push via deal with Chinese start-up. *Financial Times*.

Fraunhofer ISI (2016). Energiespeicher Monitoring 2016: Deutschland auf dem Weg zum Leitmarkt und Leitanbieter? *Frauenhofer ISI Research Report*. Karlsruhe: Fraunhofer-Institut für System- und Innovationsforschung ISI.

Gao Gong Industry Institute. (2018). Top 10 Chinese Lithium-ion Battery Makers in 2018. GGII, January 10, 2019. https://www.gg-lb.com/asdisp2-65b095fb-35935-.html, retrieved on 4 November 2020.

Gao Gong Industry Institute. (2019). Top 10 Chinese Lithium-ion Battery Makers in 2019. GGII, March 10, 2020. https://www.gg-lb.com/art-39878.html, retrieved on 4 November 2020.

Gao Gong Industry Institute. (2021). Top 15 Chinese Lithium-ion Battery

Makers in 2020. GGII, February 26, 2021. https://www.gg-lb.com/art-42311.html, retrieved on 17 August 2021.

Gereffi, G., & Korzeniewiczs, M. (Eds.) (1994). *Commodity Chains and Global Capitalism*. London and Westport Ct.: Praeger.

Hans Böckler Stiftung (HBS) (2012). *Elektromobilität und Beschäftigung. Wirkungen der Elektrifizierung des Antriebsstrangs auf Beschäftigung und Standortumgebung (ELAB)*. Düsseldorf: Hans Böckler Stiftung.

Huang, Y, & Sharif, N. (2017). From 'Labour Dividend' to 'Robot Dividend': Technological Change and Workers' Power in South China. *Agrarian South: Journal of Political Economy*, *6*(1), 53–78.

International Council on Clean Transportation (ICCT). (2018). China's New Energy Vehicle mandate policy (final rule) [WWW Document]. International Council on Clean Transportation. https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111, retrieved on 28 October, 2020.

International Energy Agency (IEA). (2019). Global EV Outlook 2019 - Scaling up the transition to electric mobility, IEA Technology report, May 2019. https://www.iea.org/reports/global-ev-outlook-2019, retrieved on 4 November 2020.

IPRD (Institute for Reform and Development of the Pearl River Delta) (2018). Huizhou shi chanye he chengshi fazhan yanjiu baogao (Industrial and Urban Development in Huizhou City). *IPRD Policy Consulting Report*, Unpublished Manuscript. Guangzhou: Sun Yat-sen University.

Lüthje, B. (2001). *Standort Silicon Valley: Ökonomie und Politik der vernetzten Massenproduktion*. Frankfurt and New York: Campus,.

Lüthje, B. (2021b). Going digital, going green: changing production networks in the automotive industry in China. *International Journal of Automotive Technology and Management*, *21*(1-2), 121-136.

Lüthje, B., & Tian, M. (2015). China's automotive industry: structural impediments to socio-economic rebalancing. *International Journal of Automotive Technology and Management*, *15*(3), 244–267.

Lüthje, B., Hürtgen, S., Pawlicki, P. and Sproll, M. (2013a). *From Silicon Valley to Shenzhen – Global Production and Work in the IT-Industry*. Boulder, Co.: Rowman and Littlefield.

Lüthje, B., Luo, S. and Zhang H. (2013b). *Beyond the Iron Rice Bowl: Regimes of Production and Industrial Relations in China.* Frankfurt/New York: Campus.

Muniz, S.T.G., Belzowski, B.M. and Zhu, J. (2019). "The trajectory of China's new energy vehicles policy", *International Journal of Automotive Technology and Management,* Vol. 19, Nos. 3/4, pp. 257-280.

Pardi, T., Krzywdzinski, M. & Lüthje, B. (2020). Digital manufacturing revolutions as political projects and hypes: evidences from the auto sector. *ILO Working Paper 3*: *The Future of Work in the Automotive Industry*. Geneva/Paris: International Labour Organisation.

Piore, M. J. & Sabel, C. F. (1984). *The Second Industrial Divide. Possibilities for Prosperity.* New York: Basic Books.

Rapier, R. (2019). "Why China is Dominating Lithium-ion battery Production", *Forbes*, August 4, 2019.

Rosina, M. (2017). "Status of the Rechargeable Lithium-ion Battery Industry Report", *Yole Développement*, July 2017.

Sanderson, H., Hancock, T., & Lewis, L. (2017, March 5). Electric cars: China's battle for the battery market. *Financial Times*. https://www.ft.com/content/8c94a2f6-fdcd-11e6-8d8e-a5e3738f9ae4. Accessed 07 July 2021.

Srnicek, N. (2017). *Platform Capitalism*. Cambridge UK: Polity Press.

Taipei Times (2021, January 14). Hon Hai to set up vehicle joint venture. *Taipei Times*. https://www.taipeitimes.com/News/biz/archives/2021/01/14/2003750511. Accessed 07 July 2021.

Thun, E. (2006). *Changing Lanes in China, direct investment, local government, and auto sector development*. New York: Cambridge University Press.

Thun, E., & Sturgeon, T. J. (2017). When Global Technology Meets Local Standards. Reassessing China's Telecom Policy in the Age of Platform Innovation. *MIT-IPC Development Working Paper 17-001*. Cambridge, MA.: MIT Industrial Performance Center.

Tyfield, D. (2018). *Liberalism 2.0 and the Rise of China: Global Crisis, Innovation and Urban Mobility*. London: Routledge.

Womack, J. P.，Jones, D. & Roos, D. (1990). *The Machine that Changed the World*. New York: Rawson Associates.

Xinhua News. 2021. 20 万吨退役电池，大量流入“黑市”——新能源汽车电池回收乱象调查 (200,000 tons of used batteries into ‘black market’——an investigation on the chaos of recycling NEV vehicles) . http://www.xinhuanet.com/politics/2021-04/12/c_1127321334.htm, retrieved on 10 November 2021.

Yang, T., Luo, S., & Lüthje, B. (2019). Machine Replacing Man? Upgrading and Transformation of Car Suppliers in the Pearl-River Delta 2010-2017. *Friedrich-Ebert-Stiftung Discussion Paper*. FES Office China.

Zhang, L. (2015). *Inside China's Automobile Factories, The Politics of Labor and Worker Resistance,* New York: Cambridge University Press.