Going digital, going green: changing production networks in the automotive industry in China

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Abstract: The article analyses the changes in production and innovation networks in the automobile industry in China resulting from the transition to new-energy vehicles and digital driving technologies. This transformation is seen as a fundamental break with the present neo-Fordist growth model in the car industry and a rise of new forms of network-based mass production, comparable to the IT industry since the 1990s. The article traces the complex politics of this transition embedded in different modes of regulation in the Chinese automotive sector, its impact on work and regimes of production, and the perspective of a broad-ranging 'Foxconnisation' of car manufacturing.

Keywords: China; auto industry; new-energy vehicles; value chains; production models; work; labour relations.

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1 Introduction

The digitalisation of the automobile, the rapid emergence of new energy cars and of new mobility systems are beginning to drive a massive restructuring of production models and value chains in the global automotive industry. China is at the centre of this process. Guided by its 'Made-in-China-2025' industrial strategy, the Chinese government had

initiated a set of policies to rapidly develop new energy cars and new mobility systems (Muniz et al., 2019). The goal is to leapfrog industrialised countries in technologies, innovation networks and value chains of future mobility (Wang and Kimble, 2011). Will the government-driven big leap forward in car technologies and mobility be disruptive to the existing model of post-Fordist mass production in the Chinese automotive industry?

This paper proposes a conceptual framework and basic empirical arguments to understand the structural changes in production models, value chains and innovation strategies. We want to link this analysis to the context of China's complex socio-economic rebalancing (Lüthje et al., 2013c) and transcend narrow perspectives of 'market vs. institutional forces' (Chen and Midler, 2016) underlying most mainstream analysis of China's new energy vehicle (NEV) industry. The concepts refer to regulation theory (Aglietta, 1979), theories of global production networks (Lüthje et al., 2013a) and newer concepts of China's political economy as an emerging variety of capitalism (McNally, 2008). The goal is to provide an integrated analysis of changes in technology, industry structure, and the labour process. Under this perspective, two sets of arguments are proposed:

1 The existing model of hierarchically modularised mass production in the automotive industry (the 'post-Fordist' or popularly 'Toyota model') is challenged by a host of new players in new-energy cars, digital driving systems and mobility services, most of them with background in the information technology (IT) industry. Volume manufacturing of 'green' and 'digital' vehicles is driving the vertical disintegration of car production towards a structure of relatively independent industry segments led by producers of core components, as prevalent in the IT industry since 1990. This model of production and value-chain governance has been analysed as 'Wintelism' (Borrus and Zysman, 1997) or network-based mass production (Lüthje, 2001; Lüthje et al., 2013a).

2 This transition engenders a major shift in the forms of socio-economic regulation and political power relations within the Chinese car industry, from a primarily state-dominated model ('refurbished state capitalism', McNally, 2013) to a structure in which highly innovative private or semi-private firms from the new-energy and IT sectors and the related government agencies, especially at the local level, play a key role (referred to as 'network capitalism'). This development also engenders major changes in the labour process and working conditions: the state-dominated production regimes of the leading Sino-foreign joint ventures with relatively high wages and stable jobs for core workers, experience increasing competition from electronics and new energy firms and their low wages and flexible regimes of production.

Based on ongoing empirical studies, this paper will trace the emerging shifts in the Chinese automotive industry. In the first section the conceptual perspective of this analysis related to theories of global production networks, varieties of capitalism and socio-economic regulation will be explained. Section two will provide an analysis of the mode of regulation that has governed capital accumulation and production in the Chinese car industry since the 1990s. Section three will trace today's disruptive forces emerging from independent carmakers, producers of NEV, digital car technologies and batteries, car suppliers and electronics contract manufacturers. The fourth section looks at the regimes of production and work in the emerging sectors and their potential impact on

incumbent carmakers. The conclusion will summarise possible scenarios of future development and points to alternatives for industrial policy making in China, centred on strategies of flexible specialisation.

2 Vertical disintegration and competing modes of regulation in the Chinese car industry

The current changes in the car industry are not merely technological in nature. They constitute a comprehensive rupture in the production models, innovation strategies and corporate structures that were established with the Fordist model of mass production since the 1920s and revised under the lean production paradigm of the 1980s and 90s. These changes can be compared to the transformations of other mass production industries in the recent three decades, where post-Fordist restructuring had led to a more comprehensive reversal of production models and value chains, such as in IT and electronics manufacturing (Borrus and Zysman, 1997; Lüthje, 2001), textile and garment (Bair, 2002), footwear, and furniture (Gereffi and Korzeniewicz, 1994). As in those older cases, the present changes in the auto sector imply deep-ranging shifts in the international division of labour and the shape of global production networks.

Today's technological changes appear to be highly disruptive for the established industry model, as has been stated by a growing number of business analysts (e.g., McKinsey, 2016).

- *Electrification* of the car promises a solution to carbon emission, but it renders much of the know-how and skills of established carmakers obsolete, especially in assembly, and it radically reduces the labour content of car making [by as much as 50% according to earlier estimates (HBS, 2012)]. It brings in new players from the field of new energy components, especially car batteries and power management systems.
- *Digitalisation* of driving through AI-based systems is the most direct manifestation of ITs becoming a key factor in restructuring. This attracts the leading platform providers from the IT industry, challenges the traditional innovation system of the car industry, and shifts market control from established car manufacturers to providers of digital driving systems and their components (McKinsey, 2016).
- Last but not least, *shared mobility* based on large-scale internet platforms is the main driver to break up the model of private car ownership as dominant norm of consumption (Tyfield, 2018).

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 digitalisation of car production (Pardi et al., 2019). The industry has been plagued by structural overcapacity in recent decades, particularly in the wake of the global financial crisis 2008–2009. 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 its jobs. The delayed restructuring of the recent decade resulted in the

political crisis of the emission-cheating scandals of Volkswagen and other global carmakers in 2015/16, often referred to as the 'Fukushima of the car industry'.

In the wake of these developments, 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 incumbent global champions, vertically integrated computer, chips and telecommunications equipment makers such as 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 organisation that became known as 'Wintelism' (Borrus and Zysman, 1997). The new model was based on vertical disintegration and specialisation, under which rapidly growing providers of core components created standards that were 'open-but-owned' (ibid.), such as Intel's microprocessor architecture and Microsoft's Windows operating system.

The new constellation was characterised as *network-based mass production* (Lüthje, 2001). Brand-name control transitioned from final assemblers to component suppliers, the "assembly-oriented model of innovation and market control" in Fordist mass production industries such as electronics, automotive or 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. Vertical disintegration at the top of production networks resulted in vertical re-integration at the bottom, i.e. at the level of manufacturing. In the course, product innovation on the part of lead firms such as Apple, Nokia or Cisco became more and more separated from manufacturing (Lüthje et al., 2013a).

At the time, almost 20 years ago, the question was raised whether vertical disintegration and contract manufacturing could become a model for the production of cars and components as well. A broad literature discussed the modularisation of car manufacturing and the global restructuring of the supply sector (e.g., Boyer et al., 1999; Jacobides et al., 2016). But there remained consensus that the dominant model of vertical integration in the car industry, i.e. modular supplier pyramids dominated by final assemblers and their production architectures, would basically stay intact. The key factor was that the core technologies of cars, engines and drive trains in particular, would not become 'open-but-owned', but remained under proprietary control of global carmakers (Jürgens and Sablowski, 2004; Lüthje et al., 2013b).

Seen from this perspective, the current restructuring of the car industry may appear as some kind of late revenge of the Wintel over the Toyota model. IT and internet giants as well as some NEV carmakers and car suppliers are driving new forms of productive organisation that mark a break with the refurbished Fordism of global carmakers. Similar to the 'PC revolution', restructuring is driven by massive financialisation of innovation that pushes the logic of 'vertical fragmentation and centralisation' (Ernst and O'Connor, 1992) into the car industry. And the core components of NEV – batteries, chips for self-driving and battery systems, and the core software for future digital driving platforms – are developed to become architecture-defining components with 'open-but-owned' characteristics, potentially controlled by major chip and internet companies such as Google, Apple, Nvidia, Baidu or Ali Baba.

However, such changes in the productive structure of capital occur within complex economic and political power structures, embedded in the political system and the underlying social relations in the respective national or regional context. The state plays a

decisive role in shaping production networks, a factor often overlooked by theories of global value chains (Lüthje et al., 2013a). But the driving forces are much more complex than just government subsidies or ambitious goals of industrial upgrading (Chen and Midler, 2016). In the case of China, our analysis has to be related to the political economy of China's variety of capitalism (Ten Brink, 2019) and the complex structure of the Chinese state, with its multiple layers of decision-making and its contradictory top-down and bottom-up dynamics (McNally, 2013, 2018).

Based on previous research (Lüthje et al., 2013c; Lüthje and McNally, 2014, 2015; Lüthje, forthcoming) we distinguish three different modes of regulation within China's emergent capitalism, which also govern certain segments of the automobile industry. These modes of regulation are conceived as generic types of government-industry relationships that combine different forms of capital ownership with certain regulatory and industrial policies on the part of the state and party, constituting characteristic practices of decision making and socio-economic hegemony at local and sectoral levels.

- The first can be called 'refurbished state capitalism' (McNally, 2013): it describes the historic core sectors of Chinese industry such as steel, machinery, shipbuilding or petrochemicals, in which state-owned enterprises have been transformed into dynamic corporations with strong profit orientation that retain close relationships with the government and the Chinese Communist Party. In the automotive industry, this segment is mostly represented by the joint ventures between Chinese state-owned carmakers and their foreign partners.
- The second can be called 'network capitalism': It refers to the newer, technology- and capital-intensive industrial sectors that developed in recent decades mostly under private or hybrid combinations of state and private ownership, such as IT, household appliances, new energy technologies, as well as internet, e-commerce and logistics. Those enterprises maintain arms-length relationships with the state and are supported by activist local governments with targeted industrial policies. However, party and state do not play a prominent role in company management. In the automotive sector this segment is represented by the independent carmakers such as Geely or Cheery and most NEV producers.
- The third mode of regulation is called 'market despotism'. It is typical for the vast labour-intensive industries at the low ends of production networks that feed global supply chains and increasingly China's massive domestic e-commerce networks. Cut-throat competition between small and medium enterprises is the norm, leading to constant downward pressure on wages and working conditions. 'Flexible interpretations' of labour, safety and environmental regulations with complicity of local governments are frequent, innovative capacities are low. In the automotive industry, this mode of regulation is represented by a large number of suppliers at the middle and lower ranks of the pyramid.

As we will explain in the following sections, these diverging modes of regulation are shaping the vertical restructuring of the Chinese car industry today. Competition between traditional and new carmakers and the suppliers of key components for digital and green cars is embedded in the competition between various modes of regulation at the local and sectoral levels. The neo-Fordist model supported by the refurbished state capitalism in the core sectors of the car industry becomes increasingly undermined by the vertically disintegrated forms of network-based mass production prevalent in the emerging centres

of the 'new' car industry and their network-capitalist forms of regulation. This produces strong dynamics towards Wintelist forms of production and their typical forms of employment with a low-paid and highly flexible workforce, mostly composed of migrant workers. More sustainable forms of vertical restructuring based on flexible specialisation and digital manufacturing do not find much room in this scenario, but may offer alternatives to the future development of car production.

3 Triple alliances and refurbished state capitalism

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 by 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 (Thun, 2006). Since around 2000, a huge influx of foreign investment introduced a new series of joint ventures and a major modernisation of production under various models of lean production. This surge of investment in advanced technologies and manufacturing systems created a production base comparable with that of industrialised countries, including a growing array of design and development activities (Lüthje and Tian, 2015).

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. However, the growth of the auto industry in China is not a replay of the success story of the automobile in the West during the golden days of Fordism. Mass car ownership remains restricted to urban middle classes with incomes above the level of most manufacturing and agricultural workers. The growth of the industry cannot rely on rising income levels of large sectors of the working population. It is heavily dependent on extensive investment in infrastructure, subsidised fuel prices and accelerated urbanisation (ibid.). The auto industry thereby reflects the general accumulation model of China's emergent capitalism, which favours fixed-capital investment over the growth of mass incomes and consumption (Hung, 2016).

The domestic 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 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 labour-intensive production processes with relatively limited industrial upgrading (Lüthje and Tian, 2015).

Against this background, 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 challenged the large SOEs in some important markets. These companies receive support from interventionist local governments to build supplier networks, infrastructure and technological resources – a manifestation of China's emerging *network capitalism*. 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 associated with localised *market despotism* under township and village governments that provide cheap land, workers' dormitories and 'flexible interpretations' of laws and regulations.

This 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 2008–2009, as well as the globalisation 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)].

However, serious doubts have been voiced over the efficiency of this framework. The state-capitalist mode of regulation does not only curb competition and encourages oligopolistic pricing behaviour; it also limits innovation. The major players put substantial resources into the adaptation of foreign car models to the Chinese market, but show little interest in developing indigenous innovations in car technologies, components and concepts. These points to systemic contradictions between the overall goals of government policies on the one side and the profit-making strategies of individual capitals and the interests of the state as a shareholder on the other – an aspect often overlooked in standard economic literature. Most problematic, however, is the fact that this structure is reproducing the bi-furcated industry structure with high profits at the top and massive pressure on suppliers. It leads to continuing heterogeneity of supplier networks and impedes the development of a technologically viable component industry (Lüthje and Tian, 2015).

4 Disruptive forces: the challenge of network capitalism

The disruptive forces reshaping the global car industry in China manifest themselves within the segmented regulation of the automotive sector and within China's emergent variety of capitalism in general (McNally, 2013). The entry of rapidly growing new players potentially undermines and reshapes the present model of state-capitalist regulation, since it promotes innovative firms from the non-state-capitalist sector of the car industry, the IT industry, and component makers. 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 trajectories different from the joint-venture model.

Again, the IT sector provides the key reference for the changes of industry structure and the fundamental shifts in China's innovation system in recent decades. 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 (Thun and Sturgeon, 2017).

Huawei's success story has become a blueprint for China's industrial policy of recent years, especially under the 'Made in China 2025' – program of 2015, which is geared at the expansion of strategic future industrial sectors (Butollo and Luethje, 2017). The push to expand NEV by imposing production quota of fully electric vehicles [10% per carmaker in 2018, 12% in 2020 (Muniz et al., 2019)] follows this approach, and has already produced a significant change in investment. In 2018, the Chinese market for passenger cars contracted for the first time in recent history, but new production capacity was added rapidly by independent carmakers and NEV producers. In 2017 alone, 14 NEV startups in China were granted production licenses and most of the companies have started building factories. A large number of EV startups is expected to start production until 2022 (Automotive News China, 2019).

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. All of them are related to models of network-capitalist regulation in their respective industry sectors and localities.

- *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). Most of the independent car and NEV makers are vertically integrated within Chinese-style conglomerates (jituan), but pursue important strategic partnerships with foreign car makers. They have their own factories and run extensive production networks in China with considerable cost advantages.

- *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 systems.

- *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 Li-batteries for computers and smartphones to Foxconn and other large electronics manufacturers. In 2017, the company was classified as the biggest producer of Li-batteries globally, leveraging

vertical integration effects from various end markets such as cars, buses, IT or new energy systems. The second lead firm is CATL, a hitherto 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 is massively expanding its production with plans to reach a capacity of 50 gigawatt hours by 2020, which would make it the world's largest producer. As part of a major globalisation 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-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. This lineup is completed by large manufacturing operations of leading battery makers from Korea and Japan in China. In 2017, eight out of the 13 major Li-battery manufacturing sites in the world were in China (Sanderson et al., 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 (Automotive News China, 2017). 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.

  And most smaller suppliers remain locked into market despotic conditions at the low end of centralised supply chains, with not much opportunity for higher-value specialisation in the emerging supply chains for NEV.

- *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 USA 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).

Overall, it can be said that the forms of vertical integration, production models and value chains are in rapid transformation and highly unstable. Obviously, the NEV industry in China is evolving along a modularised structure, composed of a set of subindustries that provide the major components and systems. In this context, new regional centres 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 centres of car manufacturing. Shenzhen and the Pearl-River Delta (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 of China's emerging network capitalism.

Incumbent carmakers – globally and in China - have recently responded with massive investments into NEV. Companies such as Volkswagen or Ford are planning 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, 2019). 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 market control, but their production strategies for NEV are driving new forms of modularity, such as VW's global platform for NEV. Most 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).

The restructuring of production systems and value chains also opens up considerable potentials of flexible specialisation. 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).

5 Regimes of production: Foxconnisation of car manufacturing?

The move to network-based mass production has potentially huge impact on work and employment in the car industry, which has hardly been researched yet. Early estimates and beginning job reductions at global car makers indicate that substantially fewer workers will be needed for NEV manufacturing, and that the traditional mechanical skills of car workers and engineers will be devalued to a considerable degree (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 et al., 2013b).

In the car industry today, massive state-of-the art production bases have been developed in China and other emerging economies already. Job losses due to transnational relocation have been less severe than in electronics, since most carmakers duplicated their production networks rather than using China as a location for low-cost export production. However, the transformation of industry structures to a large extent now is played out within the emerging economies. In China, this implies a break in the existing competitive structure and production models - 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 (Lüthje et al., 2013b).

In the leading *joint ventures* the globalised 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, resulting 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. Massive workforce reductions and plant closures are imminent in major centres 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 organisation and workers. Increased pressures have led to workers' dissatisfaction over deterioriation of pay, benefits and employment prospects, especially for temporary workers (China Labour Bulletin, 2017).

- *Independent carmakers, EV 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 labour relations, which has been adapted from Korean, Taiwanese and American 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 organisation 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 et al., 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).

- *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 labour migration (Lüthje et al., 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 (Lüthje and Butollo, 2017). 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 'Foxconnisation 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 et al., 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 market-despotic environment of labour-intensive small and medium enterprises.

Our recent study of the car supply sector in South China indicated that the shift to NEV car manufacturing and automation has 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 et al., 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 labour, often affecting the most experienced workers in physically challenging labour processes such as machining of metal or polishing of stainless parts (Huang and Sharif, 2017).

6 Conclusions

This article developed a conceptual framework to help understand the 'green' and 'digital' transformation of the Chinese car industry and its implications for production models and value chains. Current changes are clearly disruptive for the established production models and its forms of political-economic regulation. This process is not merely a result of heavy-handed government policies and subsidies to create 'national champions' and Chinese global leadership, as the rhetoric of today's 'trade wars' suggest. Rather, these transformations reflect deep-ranging structural problems of the post-Fordist growth model in the global car industry and its revival in China in the wake of the financial and economic crisis 2008–2009. The shift in China's industrial policies to NEV and digital car technologies can be seen as a strategic break with the existing mode of regulation based on the triple alliances of multinationals, Chinese state-owned carmakers and government. The joint ventures are no longer undisputed 'national champions' in the automotive sector.

A large array of new players has emerged that command core knowledge in NEV and digital car technologies and their components, but the structure is very much in flux and highly dispersed. In spite of rapidly rising production volumes and the impressive scale of some Chinese firms, there are no companies that appear to be potential 'system integrators' of far-flung technology chains and production networks. The strongest players in hardware components are based in the field of battery production (CATL and BYD), with differing strategies of vertical integration. At the same time, there is a widespread separation of technological innovation from manufacturing, especially among the NEV start-ups. All this favours vertical disintegration – albeit in uncoordinated and sometimes chaotic fashion – and uneven regional distribution of various industry segments.

Will this transformation finally lead to a 'Wintelist' restructuring of the car industry in China and globally? Two scenarios can be derived from our analysis:

a *Refurbishing of the vertically integrated mass production models of global carmakers*. This strategy is underlying the present drive of traditional carmakers to 'electrify' their products and to integrate large-scale manufacturing of NEV into their existing networks of production. This trajectory can build on the enormous capacity of global carmakers in R&D and production, but it may lead to distinctively new forms of modularity under which key components will no longer be developed and produced by the carmakers themselves. Vertically integrated component suppliers such as Panasonic, LG or CATL in batteries or some tier-one car suppliers and their Chinese internet-platform partners in digital driving systems can become new system suppliers. Carmakers will remain potential system integrators or flagship firms, but this type of shared control over production networks will be substantially different from the Fordist or Toyotist model of vertical integration.

b *Emergence of a vertically disintegrated mass-production model similar to the electronics industry.* Such a model would consist of layers of vertically specialised high-volume production separated between brand-name carmakers, providers of core components and contract manufacturers. For green and digital cars China now controls technologies and advanced mass-production capabilities in core hardware components, system software and artificial intelligence, as well as key infrastructure architectures (5G). At the same time, China is home to large-scale chains of network-based mass manufacturing, especially in electronics with notoriously poor wages and employment conditions for the majority of the workforce. However, the viability of such a 'Wintelist' scenario in the automotive industry would critically depend on the establishment of 'open-but-owned' standards for core components (Borrus and Zysman, 1997) and platform-based innovation systems in the various industry segments (Thun and Sturgeon, 2017).

Further development of this transformation will depend on the political and social power relations that shape it. The challenge for China's industrial policy is twofold. On the one hand, government policies have to further emancipate themselves from the innovative pitfalls of the joint-venture model and the related strategies of post-Fordist mass manufacturing. On the other hand, a replication of the 'Wintel' story under Chinese leadership, as currently pursued in the battery sector, has the potential to create segmented systems of mass production, in which product innovation remains disconnected from innovations in manufacturing processes and low-wage working conditions prevail (Lüthje and Butollo, 2017; Piore and Sabel, 1984).

Flexible specialisation clearly appears as a strategic alternative. The challenge is to create integrated supply chains with co-development of core technological innovations and rapid transfer into quality manufacturing. Smaller to medium-sized innovative firms with high-quality products, management and workforces seem to be the appropriate form of organisation. Given the continuing insecurity about the future patterns of industry organisation, as well as the relatively small production volumes in the NEV industry, the creation of interconnected clusters of specialised suppliers and component and software producers could be a reasonable strategy for combining flexibility with quality, and for overcoming China's notorious weakness in transforming innovations in product architectures into high-value manufacturing (Brandt and Thun, 2010).

Such industry networks could leverage the potentials of flexible specialisation in new mobility technologies and create opportunities of decentralisation of car manufacturing directed to the needs of local markets, mobility systems and communities (Lüthje, 2019). Conditions for such an approach exist at the local level, particularly in the aforementioned high-tech centres and its regional affiliates (IPRD, 2018). An important step (and topic for future research) would be strategic industrial policies to elevate lower-tier car suppliers from the conditions of market despotism and upgrade their innovative capabilities, management and workforce development. The upgrading of work and vocational training appears as a core issue, since it remains a blind spot in most regional development strategies – even in locations that have seen advances in collective bargaining, workplace representation, and trade union reform (Luo and Yang, 2019).

Further research on this agenda would also imply major theoretical and conceptual challenges. Theories of global production networks still have not fully taken account of how China and other large emerging economies increasingly are becoming leaders of transnational production networks in new industries. Theoretical discussions on this fundamental change have only begun, the impeding green and digital transformation of the automotive sector certainly provides a major example. At the same time, the complex political economy of such transformation in the respective countries requires new efforts to relate theories of production networks to a more elaborated framework of state and political theory. Analysis of competing modes of regulation as in the automotive sector can be applied to understand 'varieties of capitalism' within China's political economy and to elaborate theories of comparative capitalism in this perspective (cf., McNally, 2018; Ten Brink, 2019).

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Notes

1 Foxconn CEO Guo Taiming stated that "Tesla EVs are virtually made in Taiwan" (DIGITIES, January 8, 2018).