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"Made in China 2025": The development of a new energy vehicle industry in China

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Abstract:

This paper examines how the state is able to facilitate the establishment of a domestic production network in new energy vehicles (NEVs), from the making of electric vehicle batteries and battery management systems to the manufacturing of NEVs. The case of China illustrates how a non-firm actor was able to create the largest NEV market in the world by implementing pro-active policies for market creation and new industrial regulations for cost and range parity. To facilitate the further development of domestic production networks for NEVs, the Chinese government shifted its regulatory parameters and leveraged the market size to drive the incumbent global automakers to rejig their product portfolios and form joint ventures (JVs) with domestic NEV-makers in China. This provides a *prima facie* case illustrating how a pro-active state can take a dominant role in establishing a domestic production network without coupling with global lead firms in global production networks.

Keywords: market creation, regulation, domestic production networks, GPNs, new energy vehicles, China

1 INTRODUCTION

Global automakers’ competitive advantages in technologies and economies of scale have allowed them to play a dominant role in a producer-driven global value chain (GVC) (Gereffi, 1999). Is this still the case with the development of the new energy vehicle (NEV) industry where lead firms’ propulsion systems may no longer have a technological advantage?

As a latecomer, China has increased its production and ownership of NEVs at an unprecedented rate within a few years. In 2010, passenger NEVs in China accounted for 11% of world production, while the US, Japan and Norway each accounted for 20-22%. By 2017, China had become the top country, with 40% (1.23 million) of world NEV stocks. This is (much) higher than earlier-movers, notably the US (24%), and the EU (26%) (IEA, 2018). Goldman Sachs estimates that China made 45% of world NEVs in 2016 and the figure could rise to 60% by 2030 (*Financial Times*, 3 December 2017). According to conventional Global Value Chain (GVC) or Global Production Network (GPN) analysis, the governance structure of global lead firms and their control of automotive technologies should give China little chance of initiating such rapid development of its NEV industry (Gereffi and Lee, 2016). How then could China become the top global producer of NEVs within six years? Can a domestic production network (in NEVs) be created through the implementation of pro-active state policies?

To address these empirical and conceptual questions, this paper examines how far the state was able to facilitate the establishment of a domestic production network in passenger NEVs (which included Sport Utility Vehicles (SUVs) but not commercial vehicles) through a series of pro-active policies for market creation and new industrial regulations without the (usual) coupling with global lead firms.

The development of a domestic NEV production network in China illustrates how a non-firm actor was able to create the largest NEV market in the world through pro-active state policies for market creation and new industrial regulations for cost and range parity: an inflection point at which the cost and driving range of NEVs and internal combustion powertrain-driven vehicles became equal). The policies included financial incentives to create a favourable investment environment for domestic NEV-makers, subsidies for building support infrastructures, purchase tax rebates, etc.

To facilitate the development of the domestic NEV production network, the Chinese government shifted the regulatory parameters from an emission-based CAFC (corporate average fuel consumption) to fuel efficiency with ‘NEV-quota based credit rating’. The state subsequently utilized market size to drive the incumbent global lead automobile firms to form new JVs with domestic NEV-makers so that their rejigged product portfolios could comply with the new regulations for ‘NEV-quota based credit rating’ and continue selling vehicles in the world’s largest automobile market. From the perspective of foreign automakers, this is not bargaining with extra-firm actors, as outlined in the GPN literature (Coe and Yeung, 2015), as lead firms have no choice but to follow the Chinese government’s executive orders. This is a *prima facie* example of how the dominant role of a pro-active state can alter the development trajectories of an industry, from the establishment of a domestic production network to the evolution of the existing GPN.

The next section provides a brief review of the literature on lead firms and the role of the state before an examination, in sections 3 and 4, of state policies on cost and range parity, the two necessary conditions that facilitated the adoption of NEVs by customers. The concluding section highlights the major findings and implications.

2 THE STATE BEYOND STRATEGIC COUPLING

To provide a conceptual and empirical context for the development of NEVs, this section briefly reviews the pertinent literature on the governance of production networks and outlines the role of the Chinese state, specifically, the 'Made in China 2025' policy.

2.1 State, strategic coupling and asymmetrical power relations

GVC and GPN analysis differ from the classical view of industrial policy, whereby latecomers can catch-up technologically (Veblen, 1915; Johnson, 1982; Amsden, 1989) in that lead firms play a dominant role in governance structures (Gereffi and Lee, 2016; Coe and Yeung, 2015). Yeung (2016:193) argues that inter-firm competition, rather than direct state intervention is important for strategic coupling with global lead firms, although the state can play an important role in the initial development of GPNs and in securing economic benefits for the domestic economy. To participate in GPNs suppliers and contractors must utilize local endowments to strategically link with lead firms (Yeung, 2016). This is especially the case for producer-driven chains in the automobile, electronics and shipbuilding industries where international oligopolies' competitive advantages in technologies and economies of scale allow them to play an instrumental role in connecting competent local suppliers to the GPN (Gereffi, 1999). Bollhorn and Franz (2016) specifically highlighted the asymmetrical power relationship in the automotive industry, where lead firms dominate suppliers, by portraying original equipment manufacturers (OEMs) as the visible tip of an iceberg. These asymmetrical power relationships established by profit maximizing lead firms restrict suppliers' opportunities to upgrade (Ravenhill, 2014). The state therefore has an incentive to pursue pro-active strategies to enhance the competiveness of domestic firms.

Other scholars have examined the important role of the state. Focusing on state-capital relations, inter-state relations, and state-GPN accumulation strategies, Smith (2015) and Pickles and Smith (2016) proposed a strategic-relational framework to examine the ways in which the regulatory and accumulative roles of the state shape the configuration and restructuring of GPNs. This framework was enhanced by Horner's (2017) identification of four state roles (facilitator, regulator, producer (state-owned enterprises) and buyer (public sector procurement)), while G Yeung (2016) pressed for its operationalization. Horner and Nadvi (2018) argued that we have to examine the multiple production networks at different geographical scales to account for the role of domestic actors and markets in developing countries and the emergence of polycentric trade. Yang (2014) has called for further research on the recent restructuring of lead firms and the emerging domestic market-oriented production networks in China. More specifically, Gruss and ten Brink (2016) and Butollo and ten Brink (2018) demonstrated that proactive local state policies and a booming domestic market are crucial for the development of Chinese photovoltaic and LED lighting industries, respectively. This research on the role of the state in GPNs raises the question as to whether the importance of the state as an extra-firm actor is actually diminishing vis-à-vis inter-firm competition, as argued by Yeung (2016:193).

With high entry costs in terms of capital investment, technological capabilities, and complex uncodified industrial architectures (rather than an industry-level standard), the development trajectories of automobile industry latecomers are determined by a combination of investment by global lead firms and state intervention (Sturgeon et al., 2008, 2009). With a minimal level of state intervention in Spain, global lead automotive firms took full control of the whole supply network (Lagendijk and Knaap, 1993). Although states are able to help domestic firms couple with the automotive GPNs, foreign lead firms control the development trajectories of domestic firms, including the parts suppliers in the Czech Republic (Pavlínek and Janak, 2007) and Turkey (Özatağan, 2011). The rapid development of the automotive industry in Slovakia is arguably the reflection of a spatial fix by VW, PSA and Kia (Pavlínek, 2016). Mexico is another example of such development (Sturgeon et al., 2010), but Contreras et al. (2012) reported that socio-professional networks and market relations contributed to the emergence of knowledge-intensive domestic suppliers in the Ford's automotive cluster in Mexico. A few countries with more pro-active industrial policies, such as South Korea, have managed to develop domestic automotive industries (O'Brien and Karmokolias, 1994; Park, 2003). There is no consensus on the effectiveness of pro-active industrial policies on the development of domestic automotive industries, partly due to different national institutional environments.

China is another example of the adoption of pro-active automobile industry policies. The development of automobile industry has been embedded in the Chinese institutional environment: the state implemented a 'market for technology' strategy with the intention of using the vast Chinese market to attract foreign investment in the 1980s. The local-content (until 2004) and technology transfer requirements, and restrictions on the import of complete- or semi-knocked-down (CKD/SKD) vehicles resulted in a high level (more than 80 percent) of localization in Sino-foreign JVs (Sit and Liu, 2000; Qu, 2009). Although there is evidence of firm-level upgrading (in lower value-added activities), the competitiveness of completely built-up (CBU) vehicles in Chinese state-owned automakers is still low, partly due to high protective import tariffs of up to 80% and local government procurement policies (Liu and Dicken, 2006; Holweg et al., 2009). Although Chinese automakers and their local suppliers strategically couple with global lead firms (illustrated by the internal combustion engine-GPN with broken line in Figure 1), they have little incentive to invest in research and development (R&D): in 2010 their R&D intensity was less than 2% compared with 5% or higher in Toyota, Volkswagen (VW), and General Motors (GM) (Li et al., 2016).

[Insert Figure 1 about here]

In contrast to conventional GPN analysis, this paper focuses on two specific roles of the state in China in establishing a domestic production network and how the state leverages the domestic market to ‘pull’ global lead firms to cooperate with domestic firms. A pro-active state with strategic industrial policies can facilitate the formation of a domestic production network and the subsequent connection with a GPN in NEVs through applying a set of regulatory parameters (Figure 1). These regulatory parameters are largely supply push, which in turn stimulate market demand (demand-pull) and the size of NEVs. Market creation through this combination of state-driven supply push and demand pull enables NEVs to reach cost and range parity. Once the NEVs market has been developed, the state can adjust the regulatory parameters to accelerate the development of domestic production networks (illustrated by the circle with solid line). To access the large emerging NEV market, global lead firms are then ‘forced’ to establish JVs with selected NEV-makers in the domestic production network.

This research makes three specific contributions to the literature. First, it highlights the importance of the domestic market for the establishment of a domestic production network. The significance of market size is recognised neither explicitly as a component of the regional assets (such as technology and knowledge) identified by Coe et al. (2004) nor as one of the four explanatory variables in Coe and Yeung (2015). Second, it examines a specific form of ‘forced marriage’ between global lead firms and local NEV-makers which differs from the indigenous coupling documented in the GPN literature (Coe and Yeung, 2015:184). This research shows that strategic industrial policies do play an important role in the rise of new lead firms or national champions. In contrast to existing GPN concepts, global lead firms do not choose (inside-out rather than outside-in as in structural coupling) to join local actors to establish a GPN, and are not in a dominant bargaining position. Third, this research affords a framework for analysing the relationships between various firm and non-firm actors in an established GPN (for internal combustion engine driven-automobiles) and newly established domestic production networks (of NEVs), showing that the formation and boundary of the NEV-GPN (illustrated by the dotted lines) is partially shaped by the incumbent lead firms and actors in the Chinese domestic production network.

2.2 Made in China 2025

How did the Chinese government overcome the capital and technological barriers to the development of NEVs? In May 2015 China announced the ten-year ‘Made in China 2025’ action plan to upgrade production networks in prioritized sectors by fostering Chinese brands, enhancing the service sector, and improving manufacturing efficiency by 2025. To this end the government committed US$3.1 billion, including US$1.6 billion to be spent by local governments (*South China Morning Post*, 23 March 2018). China aims to compete with the world’s manufacturing powerhouses by 2035 and to be at the forefront of world manufacturing by 2049.

The NEV sector is one of ten high-tech manufacturing sectors identified by the Chinese central government as ones in which China aims to become a dominant global player (State Council, 2015). NEVs include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel-cell electric vehicles (FCEVs). Specifically, the government set targets for sales of one million domestic NEVs by 2020 (70% of market share) and three million by 2025 (80% of market share). Domestic automakers are targeted to be in the top 10 models by 2020 and the top 10 NEV-makers by 2025, while domestic suppliers are scheduled to account for 80% of the domestic market for electric vehicle batteries and electric motors by 2020 (MIIT, 2015). These are very ambitious targets for a new mobility device with an alternative source of propulsion power, as sales of NEVs were a tiny 50,000 in 2014 (CPCA, 2108).

Given the existing low value-added of the automotive industry (it only accounts for 1.53% of GDP compared with 4% in countries with major automakers), and the dominance of global automotive giants in the core technologies of internal combustion powertrains and their supply chains, the Ministry of Industry and Information Technology (MIIT) explicitly identified low carbon emissions (in terms of fuel efficiency and electrification), digitization (and connectivity), and autonomous driving as the most feasible ways to establish domestic production networks. Strategically, the development of NEVs could improve the energy security and environment of China by reducing its carbon emissions and dependence on oil imports. China has to import 60% of the oil it consumes, of which one-half is for transportation, with 80% used by vehicles (MIIT, 2015).

In addition to not approving any new projects for fossil-fuel vehicles, the Chinese government have implemented a set of pro-active policies to achieve cost and range parity, the necessary condition for the development of the NEV industry.

3 THE INITIAL DEVELOPMENT OF DOMESTIC PRODUCTION NETWORKS IN NEVs: COST PARITY

Financial incentives and industrial regulations are crucial for NEVs to reach cost parity with combustion powertrain-driven vehicles, i.e., the inflection point where the ownership and running costs of the two types of vehicle are equal. To achieve cost parity, the Chinese government has acted as both a facilitator and regulator establishing market creation policies and new industrial regulations.

3.1 Initial supply push through financial incentives

The first market creation policy was to provide financial incentives to assist automakers to decrease the high development costs of a new powertrain for NEVs. Importantly, the subsidies are paid to the automakers directly (supply-push), and not to the buyers. A trial NEV programme was introduced in 2010 in five cities (Shanghai, Shenzhen, Hangzhou, Hefei, and Changchun) before the Chinese government formally included it in the Twelfth Five-Year Plan (2011-15). An earmarked budget of 100 billion *yuan* (US$15 billion) was established. This budget provides incentives for buyers/automakers and electricity utilities and mean that a buyer can obtain a grant of up to 60,000 *yuan* (US$8,600) to buy a locally made BEV (imported BEVs do not qualify), 35,000 *yuan* for a plug-in hybrid electric vehicle, and up to 500,000 *yuan* for an electric bus (Table 1). Local authorities are able to provide additional grants worth up to a maximum of 50% of the state subsidy.

[insert Table 1 about here]

To facilitate technological progress in domestic NEV production networks, the central government reduced the ceiling of subsidies for automakers of NEVs with shorter driving ranges every year from 2014. In January 2017, the government reduced its buyer subsidies by 20%, to 44,000 *yuan* for BEVs with a driving range of 250 km and above (Table 1). In 2018, the maximum subsidies are only payable for BEVs with a driving range of more than 400 km. A 10% rebate on the purchase tax for NEVs was due to expire in 2017, but was extended to

2020 (*South China Morning Post*, 5 December 2017). By the end of 2020 the subsidy scheme for automakers will be replaced by 'NEV-quota based credit scores' (see below). The government spent 59 billion *yuan* on subsidies in 2015, 83 billion *yuan* in 2016, and a similar amount in 2017 (*China Daily*, 18 January 2018).

In addition to financial incentives, a number of city governments have implemented a 'green licence plates' policy for NEV owners since December 2016. Initially a pilot programme in five cities, it was extended to all cities in 2018. In major cities, buyers of NEVs are less subject to the quotas and prolonged registration processes for conventional cars. For example, in Beijing and Tianjin the restrictions on the issue of new licence plates that limit the sale of new vehicles and are designed to reduce air pollution are much less strict for NEVs. NEVs are also exempt from rules that bar conventional vehicles from driving in major cities on a certain number of days per week, while being allowed free parking for up to two hours in selected controlled areas (*South China Morning Post*, 12 December 2017).

3.2 Demand pull: a massive rise in NEV sales

Under the subsidy scheme, NEVs have almost reached cost parity with city micro-cars in China. Some of the cheapest BEVs are selling at below 40,000 *yuan* (US$6,100) with the subsidy, e.g., the post-subsidy price of a Chery QQ3ev (120 km range) is effectively equal to that of a QQ3 (with a 1L combustion engine). BAIC's EC180, a BEV with a 200 km range, is selling for around 50,000 *yuan* (US$7,600) after subsidies and discounts: the recommended retail price of 151,800-157,800 *yuan* is reduced by the 36,000 *yuan* and 18,000 *yuan* of state and local government subsidies, and the discount from BAIC of 48,000 *yuan*. Such aggressive pricing made the EC180 the top selling model in the world within a year (see below). Cost parity, the 'green plate' policy and the improved infrastructure in major cities have led to a massive increase in NEV sales since 2014. The importance of the domestic market for Chinese BEV-makers cannot be underestimated as it allows them to gain market share and information (Brandt and Thun, 2010).

Chinese NEV-makers have reached all the government's quantitative sales targets so far. Sales of NEVs have increased by a massive 90 fold, from a lowly 6,051 units in 2013 to 50,115 units one year later, and 547,564 units in 2017 (Table 2). BEVs make up most of these sales, accounting for 80% of NEV sales in 2017 (D1EV, 2017a). If commercial NEVs are included, the total sales figure reached 768,023 units in 2017 (CAAM, 2018), and the annual sales of domestic NEVs is on course to reach the ambitious target of one million by 2020.

Chinese NEV-makers dominate the domestic market, accounting for 90% of sales compared with a market share of 50% for Chinese branded vehicles with combustion powertrains. This exceeds the government's aim of 70 and 80% market share by 2020 and 2025 respectively.

[insert Tables 2-3 about here]

In addition to producing China's top 20 selling models in 2016 and the first ten months of 2017, four Chinese NEV-maker models (BYD, JAC, BAIC and Know Beans) have been consistently among the top ten NEV sellers in the world since 2015 (Table 3). The EC180 launched by the BAIC in January, sold 49,191 units in the first ten months of 2017, outselling the popular Nissan Leaf and Toyota Prius Prime plug-in hybrid electric vehicle, thus becoming the top selling NEV in the world. In terms of total sales, BYD has been the top NEV-maker by volume since 2015, and Zotye and BAIC have been among the top ten NEV-makers since 2016 (D1EV, 2017a). These outcomes far exceed the government's target of that Chinese domestic producers make one of the top 10 models by 2020, and become one of the top 10 NEV-makers by 2025.

3.3 Sustained supply push through shifting regulatory parameters: fuel efficiency and 'NEV-quota based credit rating'

To sustain the supply push of a domestic NEV production network, the Chinese government shifted regulatory parameters from corporate average fuel consumption (CAFC) to fuel efficiency with 'NEV-quota based credit scores' (Figure 1).[1]

Until recently China used an emission-based CAFC for its automobile industry. Based on this system, all vehicles, whether produced or imported into China, had to meet a pre-determined set of emission parameters, largely mirroring those implemented by the European Union. For instance, all vehicles had to meet the Euro 4 emission standards by 1 July 2011, with earlier deadlines for Beijing and Shanghai, and more stringent Euro 5 and 6 emission standards had to be met by 2018 and 2020, respectively (Table 4). Specifically, the government aimed to improve the CAFC of all new vehicles with combustion powertrains to a level of about 5 litre/100 km (equivalent to 120g CO_2/km) by 2020. Any automaker with a CAFC above the specified level will face penalties (Delphi, 2017:76).

[1] AFC is calculated by $T_{CAFC} = \sum_{i=1}^{N} T_i \times V_i / \sum_{i=1}^{N} V_i$; where *i* is the serial number of the automaker vehicle type, T_i is the vehicle fuel consumption target of a single type *i* and V_i is the annual quantity of the single type of vehicle *i* (Delphi, 2017:76).

[insert Table 4 about here]

Following a consultation document produced by the MIIT in 2016, the State Council issued a document on credit rating in June 2017. The new regulations apply to automakers and importers with an annual output of 30,000 vehicles and will be effective from 2019 onwards (delayed from 2018) (*China Daily*, 16 October 2017; *Financial Times*, 17 November 2017; CAAM, 2017b). The eligibility of automakers and importers to operate in the Chinese market is determined by their credit rating, a composite indicator incorporating two separate scores: (i) a CAFC-based fuel efficiency score for vehicles with combustion powertrains; and (ii) a quantitative score, largely based on sales of NEVs.[2]

The most contentious regulation in the credit rating system is the so-called '8-10-12' rule to regulate the number of NEVs sold as a proportion of the automaker's sales of vehicles with combustion powertrains. To gain a positive overall credit rating, NEV sales must equal at least 8% of their traditional vehicle sales by 2019, with two percentage points added to the NEV quota each year until it reaches 12% by 2021. In other words, to stay in the Chinese market, by 2021 automakers' sales of NEVs must equal 12% of conventional vehicle sales, unless they can purchase credits from other automakers.

The size of the Chinese market and the massive rise in NEV sales driven by this combination of supply push and demand pull policies leave foreign lead firms with no choice but to comply with Chinese NEV initiatives.

3.4 Narrowing the technological gap through 'forced marriage'?

The main point of contention in the '8-10-12' quantitative credit rating rule is that there is very limited room for automakers to manoeuvre their existing portfolios. Compared with a decade long preparatory period in California, the transitional period in China from the initial consultation in 2016 to the delayed implementation in 2019 was just three years. In 2016, the market share of NEVs in major cities, such as Beijing, Shanghai, and Guangzhou, was about 3.6 percent, and a negligible 0.31% in other areas.

It is conceivable that the rapid change from an emission-based CAFC to 'NEV-quota based credit rating' is a part of the Chinese government's specific strategy to force global automakers to rejig their production and marketing strategies to make them consistent with the overall NEV policy in China. The policy facilitates the transfer of state-of-the-art BEV

[2] The exact calculation of the quantitative-based scoring favours BEVs. For example, a BEV with a driving range of 300 km gains 4.4 credit points while a plug-in hybrid electric vehicle gains 2 points.

technologies and their affiliated control modules to domestic production networks through Sino-foreign JVs and can ultimately help domestic NEV-makers emerge as lead firms and even leapfrog their global counterparts (Figure 1). China, arguably, could justify this policy by referring to the protectionist measures for domestic automotive industries implemented by other countries. For example, the United States forced Japan to implement voluntary export restraints in the 1980s (Mair et al., 1988).

The above speculation is supported by circumstantial evidence, specifically, the relaxation of long-standing restrictions on Sino-foreign JVs in the automobile sector, and foreign automakers' rush to establish JVs in China. Since June 2017, when the State Council issued the document on credit rating, foreign automakers have been allowed to form more than two JVs with Chinese automakers for NEV production.[3] This could be coincidental, but one could also argue that this new policy encourages foreign automakers to form JVs with Chinese partners for NEV production. Subsequently, various global and Chinese automakers announced a US$90 billion investment in BEVs: US$19 billion comes from automakers based in the US, US$21 billion comes from automakers in China and US$52 billion from those based in Germany. Importantly, a large proportion of these new investments are earmarked for JVs in China and this contributes to the further development of domestic NEV production networks in China (*South China Morning Post*, 16 January 2018).

The product portfolios of the VW Group illustrate the urgency foreign automakers feel. VW is the world's top selling brand, and China is its most important market, accounting for 40% (4.17 million) of VW Group worldwide sales of 10.7 million vehicles in 2017 (*China Daily*, 14 March 2018), VW has to sell 83,400 BEVs to sustain its credit rating.[4] It is estimated that VW has to sell 100,000 BEVs by 2020 under the '8-10-12' rule. VW has only marketed a single plug-in hybrid electric vehicle (Golf GTE) in China and its sales volume is not even reported by the China Passenger Car Association (CPCA) (CAAM, 2017b).

VW already has two JVs with SAIC and FAW (SAIC Motor, FAW Group, Changan Automobile and Dongfeng Motor are the so-called 'Big Four' Chinese automakers). SAIC is

[3] The Chinese government eventually eliminated the 50% ceiling for JVs and allowed foreign automakers to establish wholly-owned subsidiaries making plug-in hybrid and BEVs in 2018, commercial vehicles in 2020, and other passenger vehicles by 2022. It also reduced its import tariff on imported vehicles and parts from 25 to 15 percent (*China Daily*, 17 April 2018).
[4] The estimate of 83,400 BEVs is based on an assumption that all BEVs sold have a driving range close to 300 km to get an average of 4 credit points/BEV: 83,400 BEVs x 4 points = 333,600 points, which fulfils the quota of 8 percent of 3 million conventional cars. China accounted for 39 and 24 percent of GM and Ford's global unit sales, respectively, in 2016 (*Financial Times*, 30 May 2018).

one of the top three selling NEV brands in China, with sales of 44,000 NEVs (176,000 credit points, assuming 4 points/NEV) (Table 2). SAIC needed 76,784 points for its own brands of vehicles with combustion powertrains (8% of 959,800 units sold in 2017). The remaining credit points could be used by SAIC to cover 1.25 million vehicles, leaving a massive credit point shortfall of another five million vehicles with conventional powertrains sold by its three JVs: 2 million with VW and 4 million with the GM in 2017. This explains the urgency of the scramble by VW and other leading automobile firms to form JVs with new, rather than existing, JV partners to jump-start their NEV outputs to fulfil the requirements of the credit rating system. In other words, global lead firms are forced to team up with 'strategic' domestic JV partners to help them to plug the huge gap in their credit rates under the '8-10-12' rule in China. The forming of such JVs is similar and yet different from the concept of 'obligated embeddedness' proposed by Liu and Dicken (2006), which attributed the formation of Sino-foreign JVs by global lead firms to avoid high import tariffs on vehicles into China. In this case, however, lead firms can no longer leverage their technological advantages in powertrains and production scales in internal combustion engines. Chinese NEV-makers and their supply networks may not have state-of-the-art technologies but they have the largest production capacity in the world. From the perspective of the power relationships between firm actors and the implementation timeline for 'credit ratings', global lead firms are arguably forced rather than 'obligated' to form JVs in China.

To counter the effect of NEVs-based scores, VW raced to form a €10 billion 50-50 JV with Anhui Jianghuai Automobile Group (JAC Motors) in the very month of June 2017 when the credit rating document was published. JAC, an earlier mover in BEVs, launched the J3 EV back in 2010, and is one of the few ideal 'strategic partners'. JAC's aim is for NEVs to account for 20% of its total vehicular output by 2020, double the proportion required by the credit rating system. With sales of 28,000 NEVs in 2017 (Table 2), and a projected growth rate of 30% per annum (sales growth rates were 72% and 55% in 2015-16 and 2016-17 respectively), JAC could sell 36,400 NEVs and get 145,600 credit points in 2018. With a target production of 400,000 conventional powertrain vehicles, JAC needs 32,000 points and could thus have a surplus of 113,600 credit points that VW could use. These surplus points are equivalent to 1,420,000 cars, which is still short of the 2 million sales recorded at SAIC-VW in 2017. This partially explains VW's decision to invest US$17.4 billion in 40 locally manufactured NEVs models by 2022 and the establishment of the Ezia brand to provide intelligent mobility services in China.

3.5 Costs of supply push: excess production capacity

The formation of Sino-foreign JVs could be an 'interim solution' to enable global lead firms to fulfil the EV quotas, and could exacerbate excess production capacity in domestic production networks. The construction of excess production capacity, the duplication of investment and even fraudulent subsidy claims have occurred as inexperienced investors jump onto the bandwagon of domestic NEV production networks, partly due to the lower entry costs and partly due to the potential rewards of a share of the huge state-subsidised NEV market.

More than 200 Chinese companies have been approved by the authorities for the manufacture NEVs, including about 70 planning to make electric passenger vehicles (*China Daily*, 6 November 2017). With around 25 new EV models introduced in 2016 alone, consumers have a choice of 75 EV models, much more than in any other country (*South China Morning Post*, 28 November 2017). The former secretary-general of the Chinese Association of Automotive Manufacturers (CAAM), Mr. Shulin Zhang, said that less than 20 of these companies have the capacity to manufacture NEVs in volume: 'Only a few manufacturers have long-term plans and are trying to develop new energy vehicles; the rest focus solely on the government subsidies and don't have any long-term development plans' (*China Daily*, 6 November 2017).

In 2017 alone, commitments to more than 70 new NEV projects involving the investment of 450 billion *yuan* were made by 21 provinces, in particular, Jiangxi, Jiangsu, Zhejiang and Guangdong provinces. Should all of these projects come into full production, projected annual capacity is a staggering 11 million NEVs, which is equivalent to 45% of the annual sales volume of passenger vehicles in China (the existing NEVs account for 2.26% of the 24.2 million passenger vehicles sold in 2017) and on a par with the annual sales volume of passenger vehicles in the EU. With a registered capital of 1.1 billion *yuan* (in 2017), Zhuhai Yinlong, a manufacturer of EV lithium-titanate (LTO, $Li_4Ti_5O_{12}$) batteries, earmarked almost 100 billion *yuan* of investment on NEVs with various partners in nine provinces, with a total production capacity of 880,000 NEVs per annum. With this projected volume of output, if every major automaker pushes forward the planned production of BEVs, the shortage of lithium-ion batteries will escalate (CAAM, 2017c).

Compared with the targeted volume of one million by 2020 and three million by 2025 and the limited export market potential (the existing sales of NEVs in China already accounts for 60% of global sales), excess capacity could reach more than 70% of these 70 new NEV projects alone. Given the phasing out of the state's financial subsidies in 2021, the extent to which the rapid growth in the sales of NEVs can be maintained is questionable.

Various efforts by the central government to encourage consolidation in the sector have failed to slow down the momentum of investment in NEVs because of strong opposition from local authorities anxious to increase GDP. As local authorities can provide additional subsidies of up to 50% of the central grant, it is possible that some local governments could protect their home NEV-makers by selectively delaying the approval of subsidy applications.

Moreover, production capabilities and capacities do not equal sales. According to the CPCA, the source of the most complete and consistent sales data of passenger NEVs, only 43% (30) of the 70 NEV-makers recorded any sales between 2014 and 2017 (Table 2). The fragmented market is dominated by ten NEV-makers who accounted for practically all the sales in 2017, occupying 87.74% of the market. The top five NEV-makers accounted for 60% of the market, and the top three for 47%, with BYD accounting for 21% of the Chinese market. An examination of product segments reveals the dominance of BYD even more clearly. In the first 10 months of 2017, BYD accounted for 70% by volume of mid to high-end market segment sales, defined by the 130,000-300,000 *yuan* (US$19,700-45,500) price range. Importantly, more than half the company's NEVs were sold in cities that do not restrict conventional vehicle plate registration (*China Daily*, 27 November 2017). All this evidence points to the unavoidable restructuring of the sector.

Furthermore, there are cases of fraud committed by automakers. After inspections of 90 major NEV-makers in 2016 (involving subsidies for 401,000 NEVs sold between 2013-2015), the Ministry of Finance penalized five NEV-makers for exaggerating their sales by pre-registering unsold NEVs and defrauding the subsidy programme out of almost 10 billion *yuan* (*South China Morning Post*, 12 September 2016). The Ministry of Finance revoked the production licence of the bus manufacturer, Suzhou Gemsea Coach Manufacturing, as it had received subsidies, but not produced any NEVs (Xinhuanet, 2016; MIIT, 2016).

4 SUSTAINABLE DEVELOPMENT OF DOMESTIC PRODUCTON NETWORKS IN NEVs: RANGE PARITY

A sustainable development of domestic NEV production networks depend on the availability and costs of supporting infrastructure (charging poles and charging speed) and battery technology, all of which are essential for range parity (where NEVs have the same driving range as average vehicles with combustion powertrains).

4.1 Supporting infrastructure and domestic NEV production networks

The spatial distribution of charging poles and stations is one of the most important factors to resolve range anxiety for BEVs. Compared with combustion powertrain-driven vehicles where petrol/diesel stations are widely distributed and refilling takes only a few minutes, recharging BEVs normally takes hours (selected models of the next generation of BEVs could recharge batteries at 800-volts to 80% capacity in 15 minutes) and the density of the spatial distribution of charging poles is much lower.

As one of the strategic emerging industries in the Thirteenth Five-Year Plan (2016-2020), the central government subsidizes electricity utilities to build charging networks, and its focus is on key technological advancements in battery energy density and battery thermal adaptability for NEVs (NDRC, 2016:chapter 23). With this massive investment, charging networks have proliferated in major Chinese cities during the last two years. In 2016, more than 100,000 charging poles were installed, ten times the number built in 2015 (CAAM, 2017a). The pace of installing charging facilitates has accelerated further and reached 446,000 poles (about 214,000 public and 232,000 private charging poles) by the end of 2017. Foreign automakers are joining the building frenzy, e.g., BMW aims to increase its charging poles in 100 Chinese cities by 120% to 145,000 in 2018 (*China Daily*, 19 January & 26 March 2018). Compared with 44,000 charging outlets and 16,000 electric stations in the US, China has leapfrogged the earlier mover and become the country with the largest number of charging facilities in the world. A further 124 billion *yuan* (US$19 billion) will be invested by the government to build a nationwide network of 4.8 million charging outlets and stations by 2020, and range parity is a realistic target in the near future (Hensley et al., 2018). This significant improvement in the spatial distribution of the charging infrastructure sustains growing market demand and the development of domestic NEV production networks.

4.2 Indigenous innovation in supply networks of NEVs

BEV drivetrains involve far fewer components than combustion powertrains. BEV's major components include an electrical drive module (electric motors with an integrated single-speed transmission), a power module (electric vehicle batteries (EVBs) and battery management system (BMS)) and a power distribution module (PDM). For instance, a Chevrolet Bolt BEV has 35 moving and wearing parts in its drivetrains, only 21% of the 167 wear and tear parts in a VW Golf (which has a much more complicated combustion engine with 113 parts plus another 27 parts in the 6-speed automatic transmission (gearbox with clutch and differential)) (USB, 2017:27). On top of that, a combustion powertrain-driven vehicle also has to be equipped with an emission control system (catalyst and particulate filters plus the muffler).

There are at least two major types of BEV-motor. Conventional BEVs (Tesla) use asynchronous/induction motors, while newer BEVs normally use more efficient permanent-magnet synchronous motors. In 2016, there were 200 BEV-motor makers, mostly making permanent-magnet synchronous motors, with about 18% making asynchronous/induction motors. Importantly, only 5% (ten) BEV-motor makers had the capacity for large-scale production (GGII, 2017a).

Electric vehicle batteries are important for achieving range and cost parity as the battery pack is not only the most costly component, accounting for 40-50% of BEV costs (Hensley, 2018), but its size, weight, energy intensity and thermal characteristics (including heat dissipation during recurrent discharge cycles) also determine the range (including the recharging and cycle times) of BEVs. Certain variants of lithium-ion battery technology are normally adopted for electric vehicle batteries. The overall efficiency, voltage and thermal stability of the battery cell stack in each battery module as well as its recharging (including when coasting or braking) and degradation are monitored and regulated by the built-in battery management system.

Under the pro-active policies to encourage the adoption of NEVs, the massive increase in BEV production has obviously led to a corresponding jump in the production of electric vehicle batteries in domestic production networks. The total capacity of installed batteries in China reached 30.8 GWh in 2016, and the installation of lithium-ion batteries reached 18.1 GWh during the first ten months of 2017. It is expected that the installed capacity of lithium-ion batteries will reach 141 GWh by 2020 (ITDCW, 2017). With the exception of BAK, major Chinese battery-makers such as BYD, CATL and Guoxuan High-tech lead the world in terms of volume/voltages but their expertise is in lithium ferrous phosphate (LFP, $LiFePO_4$) batteries. Low-cost, low-toxicity, and high thermal stability are the advantages of LFP batteries, but they also have comparatively lower energy density (150-200Wh/kg versus 260Wh/kg in NCA batteries) due to their low operating voltage and low electrical conductivity at low temperatures. Although these companies have achieved comparable energy intensity (300Wh/kg) to the safer lithium nickel manganese cobalt oxide (NMC,

$LiNiMnCoO_2$) batteries in laboratories, they have yet to demonstrate their ability to scale up their production capacities to cater for the expected demand (DIEV, 2017b).

Japan and South Korea currently have the technological and production edge in electric vehicle batteries. For instance, Japanese battery giants, such as Panasonic, Murata and GS Yuasa, are supported by well-established supply networks, comprising advanced lithium-ion battery-makers and specialist materials and chemicals suppliers (Toray, Nichia, Nippon Carbon and Kanto Denka Kogyo as well as Mitsui Chemical, Mitsubishi Chemical, Asahi Kasei and Ube Industries which are leading companies in cathode, anode, separator and electrolyte supplies for batteries, respectively). In an analysis of the leading global players in the battery supply chain by CLSA Securities, half of the 36 companies named were Japanese.

Although all major battery manufacturers have had plants in China since 2014, they control the core technologies as their 50-50 JV partners in China are non-battery makers and have limited capacity to absorb battery technologies. In this case, forming JVs was simply to fulfil the Chinese government's regulations. This lack of indigenous innovation could have significant implications for the long-term competitiveness of domestic NEV production networks.

In 2016, there were 145 electric vehicle battery-makers and about 100 suppliers of battery management systems (GGII, 2017a). Similar to the NEV market, the fragmented battery market is dominated by a few vertically integrated BEV-makers and large battery-makers. In 2016, the top six battery-makers in China were CATL, BYD, OptimumNano, Guoxuan High-tech, Lishen, and BAK. CATL, the largest battery supplier in the world, and BYD alone accounted for 23.3% and 22.5% of installed capacity (ITDCW, 2017). In battery management systems, BYD alone accounted for 26.85% of the market, and another top five suppliers (all battery-makers) accounted for another 28%, leaving about 45% accounted for by other specialized battery management system suppliers with limited integration into domestic NEV supply chains. A number of specialized battery management system suppliers could exit the market during the industrial consolidation (GGII, 2017b).

As the core component of NEVs, electric vehicle batteries also exhibit signs of excess production capacity. Between 2016 and the first half of 2017 123 new battery and related raw materials' projects with a total investment of 230.7 billion *yuan* were announced. Sixty projects have so far materialized with an investment value of 130.6 billion *yuan*. In the third quarter of 2017, the production capacity of the top 20 battery-makers reached 102.2 Gwh, which is 5.6 times higher than the installation of lithium-ion batteries, at 18.1 GWh (CNEnergy, 2017). Should all battery-makers are operating at full production capacity, there could be up to five times overcapacity for the top 20 battery-makers in 2018. The number of battery-makers decreased 30% year-on-year to 100 by 2017 (*China Daily*, 25 April 2018).[5]

5 CONCLUSIONS AND IMPLICATIONS

This research examined the role of the state in the establishment of a domestic NEV production network. Specifically, it examined how the state utilized regulatory parameters to create a domestic production network before leveraging the domestic market to ‘pull’ global lead firms to team up with domestic firms. The case of China illustrates how a non-firm actor was able to establish a domestic production network in NEVs and create the largest NEV market in the world by implementing pro-active policies (incentives for domestic NEV-makers, infrastructure construction subsidies, ‘green’ licence plates, purchase tax rebates, etc.) for market creation and new industrial regulations for cost and range parity.

To facilitate the development of domestic NEV production networks, the Chinese government shifted the regulatory parameters from an emission-based CAFC to fuel efficiency with ‘NEV-quota based credit rating’. The incumbent global lead firms were forced to alter their timeframe for the introduction of NEVs in China by collaborating with new domestic JV partners to make and sell enough NEVs to allow them to continue selling vehicles with combustion powertrains in the world’s largest automobile market. In other words, the state used market size (for both NEVs and conventional vehicles) to drive incumbent global automobile lead firms to work with domestic automakers and in turn, facilitate the transfer of NEV technologies to their JVs. These policies facilitate the further development of domestic NEV production networks, from the making of electric vehicle batteries and battery management systems to the manufacturing of NEVs in China. From the perspective of foreign automakers, this is not really bargaining with extra-firm actors, as outlined in the GPN literature (Coe and Yeung, 2015), as they have no choice but to conform with Chinese government regulation in order to stay in the world’s largest market. This case

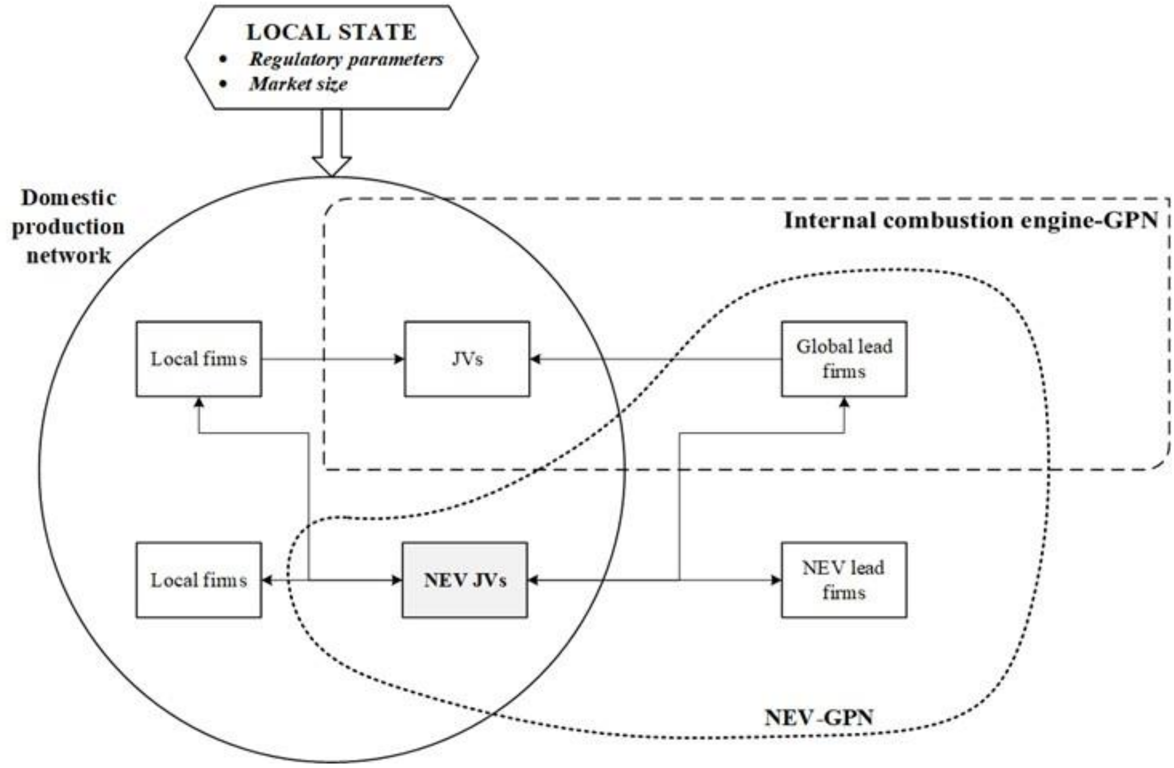
[5] Although it will change the point of emission (tailpipe Vs power plant emission), whether the massive deployment of NEVs will lead to significant environmental improvement is questionable as coal-fired power plants still contribute 66 percent of electricity production (CEP, 2016), and there are no cost effective and environmentally friendly ways to deal with used batteries in China. Should China reach its target of total annual production and sales of 5 million NEVs by 2025 (16 times that of 2016), there could be 250,000 metric tons of redundant batteries in 2020, as the average effective lifespan of electric vehicle batteries is five to eight years (*China Daily*, 27 November 2017).

provides a *prima facie* evidence of the way in which a pro-active state can alter the development trajectories of an industry, from the establishment of a domestic production network to the evolution of a GPN, and is a counter-example to Yeung's (2016:193) argument concerning the importance of inter-firm competition for regional development.

The empirical example presented in this paper has to be interpreted within a context of capabilities and capacities, policy aims and cost effectiveness. First, no single global lead firm has the capability and capacity to reach the targeted NEV output set by the Chinese state within the allotted timeframe, and this creates a golden opportunity for the rise of potential lead firms in China. Importantly, the financial subsidies are payable to automakers and this supply push policy increases the competitive advantages of Chinese firms and the subsequent establishment of domestic NEV production networks without coupling with global lead firms.

Second, the relevant section of the original document 28 concerning *Made in China 2025* is about 'energy saving vehicles and NEVs'. In other words, the industrial policies are not restricted to NEVs. The document specifically points out that development includes policy support for BEVs, fuel cell vehicles, the environmental efficiency of internal combustion powertrains, advanced transmissions, the use of light-weight materials, advanced information technologies and artificial intelligence in manufacturing (State Council, 2015:section 6.6). The NEV policy becomes *de facto* a BEV policy. What this paper suggests is that there is, so far, limited indigenous upgrading of the indigenous technologies. There is a high level of localization in the BEV supply networks but a highly fragmented market dominated by a vertically integrated BEV-maker (BYD) and a few large battery-makers, although a number of small firms have entered the industry to secure subsidies. Key battery and battery management system technology companies in China are still not global leaders (including in software to recapture the kinetic energy from motion), and some battery-makers may not be able to scale up their production capacities. The projected excess production capacity points to unavoidable industrial consolidation in the near future, possibly putting the long-term cost effectiveness of state subsidies in doubt and raising questions about opportunities for rent-seeking. If it is indeed the case, it may mirror well-publicized cases of excess production capacity, subsequent industrial consolidation and inefficiency in the utilization of public capital for local development in the iron and steel, cement and solar panel industries. Massive increases in industrial production within a short period can produce industrial volatility and reduce the incentive for long-term investment in innovative activities.

Figure 1: Global and domestic production networks and their intersections with the local state



Source: Author

Table 1: Government subsidies for different types of NEV in China, 2010-2020 (in *yuan*)

NEVs type	Driving range	2010-13	2014	2015	2016	2017	2018	2019	2020
BEVs	80-149 km	35,000	33,250	31,500	25,000 *	20,000 *	Nil	Nil	Nil
	150-250 km	50,000	47,500	45,000	45,000	36,000	20,000$	?	?
	250+ km	60,000	57,000	54,000	55,000	44,000	45,000#	33,000 ?	33,000 ?
	400+ km	-	-	-	-	-	50,000	?	?
HPEVs	50 km or above	35,000	33,250	31,500	30,000	24,000	22,000	18,000	18,000
Fuel-cell vehicles		20,000 (from 2013)	19,000	18,000	20,000	20,000	20,000	20,000	20,000

Notes:
*: driving range of 100-149 km
$: driving range of 150-299 km
#: driving range of 300-350 km
Sources: Compiled from EVdays, 2015; *China Daily*, 27 November & 20 December 2017 & 26 February 2018; *South China Morning Post*, 5 December 2017.

Table 2: The Top 10 NEV-makers by sales volume (in units) in China, 2014-2017

	2014	2015	2016	2017
BYD	16,081	63,144	102,910	113,035
	32.09%	35.80%	31.88%	20.64%
BAIC	5,528	16,670	46,416	100,631
	11.03%	9.45%	14.38%	18.38%
SAIC	2,736	11,123	20,073	44,209
	5.46%	6.31%	6.22%	8.07%
Zotye	8,697	24,376	37,060	35,755
	17.35%	13.82%	11.48%	6.53%
Know Beans	-	-	-	35,202
	-	-	-	6.43%
Chery	9,043	13,577	20,963	33,591
	18.04%	7.70%	6.49%	6.13%
Geely	4,978	26,554	49,168	32,241
	9.93%	15.06%	15.23%	5.89%
JMC	-	4,793	14,232	30,015
	-	2.72%	4.41%	5.48%
JAC	2,398	10,606	18,193	28,055
	5.12%	4.78%	6.01%	5.64%
Changan	-	1,413	4,917	27,707
	-	0.80%	1.52%	5.06%
Top 5	65.93%	63.58%	63.95%	60.05%
Top 10	98.70%	97.66%	97.24%	87.74%
TOTAL sales	50,115	176,378	322,833	547,564

Note: Know Beans (ZD) is a JV shared between Geely and another four companies, so Geely's market share could be 12.32% in 2017.
Source: compiled from CPCA (2018).

Table 3: The top 10 NEV models in the world, 2015-2017 (in units)

Models:	2015	2016	Jan-Oct 2017
BAIC EC180	N/A	4,128	49,191
Nissan Leaf	44,826	48,246	40,064
Toyota Prius Prime PHEV	N/A	N/A	38,002
Know Beans D2 EV	N/A	1,938	37,093
Tesla Model S	47,815	51,528	36,402
Tesla Model X	N/A	16,932	30,074
BYD Song PHEV	N/A	N/A	20,624
BYD e5	N/A	13,767	20,239
BMW i3	25,137	22,748	20,067
JAC iEV6s	N/A	N/A	18,382

Notes:
Chinese NEVs have launched new models almost every year, e.g., the top selling BYD models were the Qin and Tang in 2015 and 2016 (ranked third and fourth), respectively.
The above figures are compiled from the monthly top 10 models by sales so the summation of this data may not equate to the top 10 models per annum, i.e., they are rough estimates to show the trajectory of Chinese brands vis-à-vis other brands of NEVs. Moreover, not all cars delivered to dealers are actually registered and sold (see Schmitt, 2017 for Tesla).
Source: compiled from D1EV (2017a).

Table 4: Emission standards for passenger vehicles with petrol engines in China

Stage / Standard	Reference	Region	Implementation dates
CN4	Euro 4	Nationwide	1 July 2011
		Beijing 4	1 March 2008
		Shanghai 4	1 November 2009
CN5	Euro 5	Nationwide	1 Jan 2018
		Beijing 5	1 Feb 2013
		Shanghai 5	1 May 2014
CN6a	Euro 6	Nationwide	1 July 2020
CN6b		Nationwide	1 July 2023

Note: The implementation date is based on the vehicle's first registration date.
Source: Delphi, 2017:35.

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