



**LUND UNIVERSITY**  
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# Can China successfully Leapfrog into Electric Vehicle dominance?

*An assessment of China's Electric Vehicle development from an  
institutional perspective.*

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**Abstract:** The concept of the leapfrog, whereby developing economies ‘jump’ directly to adopting the advanced economy technologies without having to follow the development paths of their predecessors, is a very appealing theory. A leapfrog attempt is visible in the Chinese governments ambitions to react to the recent change of focus of the global auto industry to developing more sustainable vehicles to address the growing global environmental challenges. From having a very small automotive industry at the end of 1970 producing vehicles of poor quality for the domestic market, to being the largest producer of vehicles in the world from 2009, China’s track record is phenomenal, but such a ‘leap’ could be overly ambitious and unfeasible. This essay addresses the question of whether China can achieve a technological leapfrog into electric vehicle dominance. By reviewing the leapfrog concept and using empirical studies and data to assess whether the necessary conditions of a technological leapfrog are present in China, I can assess the likelihood that they will be able to achieve the national policy. It is concluded that the probability that China can achieve a technological leapfrog to electric vehicle dominance is very small.

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## **1.0 Purpose of my thesis.**

This paper looks at the progress of the Electrical Vehicle (EV) development in China, and assesses whether the leapfrog strategy is feasible. The analytical framework that is used to assess the likely success of the leapfrog is based on five categories put forward by Sauter & Watson (2008) when they looked into empirical data from various technological case studies. The reader should try to keep in mind an institutional view when reading through the paper, i.e. how the five categories either incentivise or constrain the EV leapfrog strategy. An area which has not been looked into before when addressing the prospects of China's EV strategy is the effect of the decentralised structure of government. Nevertheless, given the limited data in this particular field that one can use to make empirical recommendations, this paper should be seen as a paper that highlights weaknesses of the strategy and offers suggestions to help the development, as well as ideas for future research.

## **2.0 Introduction**

China clinched the number one position in the world for automotive sales in 2009 and is predicted to equal the United States in its total number of vehicles registered on the road soon after 2020 (Wan, Sperling, & Wang, 2014). This is a remarkable feat for an economy that only 40 years ago was economically backward and where vehicles were either for industrial purposes or for the privileged government officials. For most economies, their domestic auto industry is one that is looked favourably upon seeing the economic benefits that it brings in terms of tax revenue and, possibly more importantly, in providing jobs. Furthermore, more than just these economic benefits, the auto industry often stimulates technological innovation that can be transferred throughout the economy. However, alongside these economic benefits of a booming auto industry, there are several negative aspects that should not be overlooked. Such aspects include the increased reliance on oil imports, the worsening of urban air pollution caused from vehicle exhaust emissions and the increased production of greenhouse gases that disrupt the environment. These are just a few of the negative externalities of the auto industry's success in China, highlighting the important role of electric vehicles in overcoming these challenges. These could perhaps be some of the reasons behind why one of the least likely economies to take part in the global race to produce electric vehicles, is attempting to compete with some of the leading automotive producing nations to secure its place in the future of vehicle engineering.

Given its short 30 year history in producing cars that of a similar quality to Western cars, one could easily argue that the Chinese central government's ambitious statement to "leapfrog the auto industries of other countries and seize the emerging EV market" (Howell, Lee, & Heal,

2014) is more than over-reaching itself. Nevertheless, it could also be stated that the strong hand of the central government in economic affairs, the huge economic resources at their disposal and given China's less mature economic development in comparison to other well established industrialised economies, provides greater possibility to implement the new required infrastructure for electric vehicles. Therefore this paper treats the case that China could in fact be in an advantageous position when compared to economies like the U.S. and Japan in 'the race' for electric vehicle development.

### **3.0 Background to China's leapfrog in electric vehicles**

Though in recent years the promotion of electric vehicles in China has been more apparent, discussion and initial phases of development began in 1991 under the 8th Five-Year Plan where research and development into electric vehicles was first promoted (Li & Sun, 2011). Since then, in all following Five-Year Plans the Chinese government has taken further steps to encourage the growth of the electric vehicle industry. For example, in the 10th five-year plan the Ministry of Science & Technology (MOST) initiated the 863 Electric Drive Fuel Cell Project that received RMB800 million in funding, or the 11<sup>th</sup> five-year plan where MOST gave a further RMB1.1 billion towards the New Electric Vehicle Project. In the following essay, the term Electric Vehicles (EVs) incorporates vehicles with new powertrain mechanisms such as Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Fuel Cell Electric Vehicles (FEVs). Possibly the most well-known and grandest project implemented by the Chinese government in order to bring about the technological leapfrog is the "Ten Cities, Thousand Vehicles" (TCTV) program in 2009 (Earley, Kang, An, & Green-Weiskel, 2011). From 2011 the number of cities included increased to twenty-five. Under the TCTV program, ten cities were chosen to pilot the launch of electric vehicles with the target of having total EV sales of 10% of all nationwide automotive sales by 2012 (Wan, Sperling, & Wang, 2014). Further, the central government's goal was to have a total of 500,000 EVs on the road by 2015, and to reach 5million by 2020. In order to reach this goal the Central and Local governments offered huge subsidy programs to stimulate consumer demand, alongside many other incentives such as free vehicle registration plates which represents a large monetary burden to non-EV consumers.

Despite such encouragement from central and local government in aiding China's leapfrog in electric vehicles, the electric vehicle industry stands in stark contrast to the auto industry as a whole. Figures indicate that numbers of EV sales fall far below what was hoped for by 2015. Less than 0.1% of total civilian vehicle sales was made up of EVs in 2013 (Wan, Sperling, &

Wang, 2014). Another source indicates that as at the end of 2014 the number of sales is around 70,000, of which the majority are from sales to taxi and local government vehicle fleets (CKGSB Knowledge, 2014). It is therefore the intention of this essay to analyse the leapfrog from an institutional perspective, looking into particular features in order to shed light on what is influencing the decisions and economic behaviour of both consumers and producers and to demonstrate why China is failing to accomplish its national policy. Though this essay does not explicitly look into the demand from consumers of electric vehicles, it will present a comprehensive assessment of the possibility of a successful technological leapfrog which includes addressing factors that affect consumer demand. Moreover this essay places particular focus on the role of the decentralised government and the consequential limitations that it provides in the National Electric Vehicle Strategy. Using the ‘market-preserving theory’ by Montinola et al. (1995) to discuss the leapfrog potential, this essay will indicate the basis for the fragmentation in EV development.

#### **4.0 Previous research into EV leapfrog**

The most recent publication that looks into the China’s leapfrog into Electric Vehicles is Howell, Lee & Heal’s 2014 article, “Leapfrogging or Stalling Out?”. Their paper follows a similar structure to this essay in terms of painting a picture that addresses the technological leapfrog from various standpoints. Although included in the title, their paper does not attempt to investigate China’s EV development strategy using the leapfrog concept. Instead they assess the success of the development by measuring the results of the government initiatives, therefore observing whether the targets are met. Moreover, they offer suggestions as to whether certain initiatives, such as the infrastructure rollout, are the most effective ways of doing so by contrasting them to the developments of other economies that are also engaged in electrical vehicle development. The major contribution from their publication is in their investigation into the comparative costs of Battery Electric vehicles versus the internal combustion engine vehicles. They essentially present a damning report that indicates current weak competitiveness in EVs. This report, like others such as by Wan et al. (2014), Zheng et al. (2011) and McKinsey & CO. (2015), simply presents results based on analysis of China’s electric vehicle development, without using the leapfrog concept as a conceptual framework.

Wang & Kimble (2011), however, in their article “Leapfrog to electric vehicles: patterns and scenarios for China’s automobile industry” use the idea of leapfrogging in their investigation. The authors’ first step, and what can be considered as their major contribution to this field of research, is to discuss in detail the leapfrog concept. They extend existing research into the

leapfrog model in order to make the concept less ambiguous and more defined. From this they then review the research once more to highlight the various types of technological leapfrogs that are possible, presenting examples along the way. Only after this, they can effectively introduce the topic of EV's in China where they address various aspects of the development process, both looking at the challenge of the large upfront cost to consumers that reduces demand. Then they address the technological capacity aspect related to the high level of battery technology production required for EVs. Certain qualities of this article lie in the final conclusion where the authors debate the strengths and weaknesses of China's leapfrog attempt by drawing on empirical findings, which make them put forward suggestions of possible scenarios of what type of leapfrog will result. Despite this, as is the case with all other literature I have read, the authors discuss the high degree of fragmentation in production of EVs, leading to reduced volumes in production and hence higher costs as the producer cannot take advantage of the lower cost point with increased output (i.e. economies of scale), yet they fail to thoroughly analyse and pinpoint why this might be the case. Instead they offer solutions over how the producers and the government can attempt to correct the separation of standards and reduced volume outputs. This is an area where the present essay will try to further the investigation and offer suggestions as to what the root cause of the fragmentation is.

In this essay, a theory will be introduced to add to the debate on the likelihood of China successfully achieving its EV leapfrog strategy. It is the theory of Market Preserving Federalism put forward by Montinola, Qian and Weingast in their paper on "Federalism, Chinese Style: The Political Basis for Economic Success in China"(1995). Though not attempting to address any form of technological leapfrog strategy, their work presents the case in which the decentralisation of government helped bring about competition and economic success for the nation. Montinola et al. clearly outline their theory and highlight the effects that the decentralised structure has on governmental official economic incentives. As will be discussed in further detail below, it is this incentive for more local governmental competition that is argued to undermine the central governments ambition of leapfrogging to electric vehicle leadership.

As somewhat of a side note, previous research, Gallagher (2006), has discussed how the concept of the technological leapfrog can at the same time be an environmental leapfrog. i.e. introduce a new advanced technology that has better energy efficiency and is less polluting, rather than using the old more harmful technology as the development path might dictate. This is not the case for all newly introduced technology or production methods, however, the environmental leapfrog can be seen in the case of EVs - so long as the method of electricity

production has less negative environmental impact than that of standard gasoline cars. Though not crucial to this study, the idea of the environmental leapfrog is worth bearing in mind as it helps to understand some of the reasons why EVs are so heavily promoted by the Chinese government. These reasons are, as aforementioned, the desire to reduce urban tailpipe emissions, reduce green house gases and to decrease the reliance on oil.

### **5.0 Does China's goal really represent a leapfrog?**

Some commentators would argue that the Chinese leapfrog into Electric Vehicles is not so much a leapfrog, but more of the Chinese industry simply following the development paths of its forerunners, the Western industries. They could suggest that China is catching-up with the likes of the West, under the auspices of Gerschenkron's advantage of backwardness, i.e. the possibility to achieve faster development by starting from a lesser technologically advanced position (Gerschenkron, 1962). The following section attempts to highlight Chinese inferiority in automotive production at the global level in comparison with its Western competitors in order to show that the ambitions of the Chinese government and auto producers are not short of a leapfrog ahead of its current capabilities and industry development stage.

Since Jeep first entered the Chinese market in a joint venture with Beijing Automotive Works in 1983, and soon after in 1985 with VW becoming the first Western Original Equipment Manufacturer (OEM) to build a plant in China with its joint venture partner Shanghai Automotive Co. (SAIC), the road was mapped out for the way by which foreign automotive manufacturers could enter the Chinese market. This form of collaboration was promoted in the Chinese automotive industry as political leaders were under the impression that it would provide the foundations from which Chinese domestic brands could successfully grow, by fostering a large degree of technological transfer and industry know-how from the OEMs to the domestic counterpart. Similarly, in exchange for their longstanding global knowledge of the auto industry, the OEMs were inclined to accept the collaboration since gaining access to such a gigantic market was an opportunity they could not turn their backs on.

Despite the joint ventures that have brought the western country OEM's into the country since China 'opened-up', and although China is the number one producer of cars worldwide, Chinese domestic brands are unable to compete in terms of quality and safety with the well-established Western brands. Disregarding the brand consciousness of the average Chinese consumer, they prefer to purchase cars that have are produced by a manufacturer with a

foreign connection due to their better build quality, outselling domestic vehicles 3:1 (Tham, 2013). That is not to say that quality improvements have not occurred, a recent J.D. Power survey (2014) indicated that the number of mechanical faults had decreased in recent years. Nevertheless the quality of the Chinese vehicle overall is just not of the same quality or on the same competing field as the Western OEMs (Mitchell, 2014). This problem is demonstrated in Europe and North America where the Chinese domestic brands are still unable to make much headway against the market shares of the Western brands. Unable to make much of an impact in the Western markets, Chinese vehicle manufacturers typically sell their cars to poorer economies whose mass market consumers cannot afford the higher standards of Western OEM cars, both in terms of drive quality and safety standards. It is not in the scope of this thesis to go into detail as to why this may be so, but commentators have pointed to the large fragmentation and the heavy handed presence of the state in the auto industry that has prevented domestic brands from making the best of its market opportunities. Without taking away the efficacy of China's current progress, as the fact that building an auto industry from scratch is an incredibly difficult and long-term project that requires the successful forming of an economy in itself, there are many aspects of this sector which require attention. The essential point that should be taken from this is that the Chinese domestic producers are well and truly positioned behind that of some of the Western economies OEMs, such as Germany's VW, Mercedes or BMW, the USA's GM or Ford and Japan's Honda or Toyota. Therefore, as will be demonstrated in the following section which presents the various types of leapfrogging that can occur in new technologies, and taking into account that Chinese domestic automakers have yet to *master* or produce a conventional ICE vehicle to the same standard as Western OEMs, the decision to start developing Electric Vehicles can be seen as a leap ahead of itself. If China were to first attempt to create a successful car industry, with Internal Combustion Engine (ICE) vehicles that could compete on the international market with the West's, they could be seen to be following the development path of the industry's forerunners. However, the leapfrog is a national ambition that has been pushed for in order to put the Chinese on the global map for automobiles.

Similarly, as will be discussed in much more detail in the remaining challenges to EV development in China, further evidence that suggests that a leapfrog strategy is being attempted can be seen from the limited technological transfer that occurs between the more advanced Western OEMs to the domestic Chinese. Though it was one of the main reasons for the forming of the joint-venture collaborations, technology transfer of Electric Vehicle knowledge has occurred to an even lesser extent than with conventional ICE expertise. In order to create a better forthcoming environment for technology transfer, more Intellectual Property Laws (IPL) have been put in place. However, it is still often the case that the



upholding of these laws and also the feasibility of litigation within China makes OEMs less willing to hand over their latest research, technology and techniques for their vehicles. There is the fear that their product will be ‘reverse engineered’ (Howell, Lee, & Heal, 2014) and then the know-how will be distributed across the industry at the detriment to their sales. Taking advantage of the fact that Chinese authorities do not precisely know what the latest technology is in EV development, Western OEMs manage to circumvent the transfer of their new technology to their joint-venture counterpart, as contractually agreed, by providing Intellectual Property (IP) which is perhaps up to 2 years old. The implications of this helps to indicate that what China attempts to do is indeed a technological leapfrog, rather than merely to catch-up and follow in the path of the West. The technology that they first receive through technology transfer is absorbed and imitated, but then to achieve their target as a lead player in the EV industry, there is acknowledgement that they must develop this technology further by being creative and producing real innovation. (Gallagher, 2006)

## **6.0 What is a Technological Leapfrog? Theoretical foundations.**

Although discussing the concept of technological leapfrogging in relation to the possibility of developing country progress in the ICT industry, Steinmueller (2001) offers a clear definition of a technological leapfrog that can be easily adapted to China’s electrical vehicle development:

“...bypassing stages in capability building or investment through which countries were previously required to pass during the process of economic development.”  
(Steinmueller W. , 2001, p. 2)

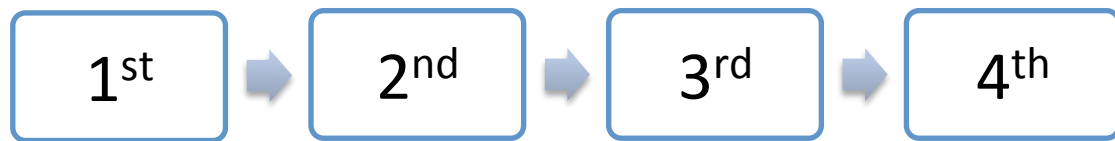
The essence of the technological leapfrog therefore is that it is not necessary for a developing nation to follow in the exact footsteps of the developed nations that were “previously required to” develop in an evolutionary manor. In certain technologies that meet particular broad criteria, newly industrialising economies can miss certain stages of development by skipping to the most modern technology in use. An example of this bypassing of older technologies can be demonstrated by the development of a train infrastructure in newly industrialising economies. Given present day modern and highly efficient electric or fuel train engines, it would be unreasonable for a newly industrialising economy to formulate an industrial development plan using steam trains based on the reasoning that advanced economies have historically followed this path. Instead, it can be presumed that the newly industrialising

economy would decide to build a system based on modern technology, saving them time and resources in long-term development.

However, this description of the leapfrog could be considered too simplistic; it is not sufficient to merely describe leapfrogging as the simple idea of “skipping a stage in an existing development path” (Wang & Kimble, 2011). Certain types of technology, such as trains and mobile phones have been demonstrated to be easily transferred and adopted into developing societies given the straight forwardness of their functioning. Where technologies have a greater degree of complexity in terms of building the requisite infrastructure and require a higher social capacity level (Abramovitz, 1986), attempting a leap-frog might not be the best way forward. The general concept of technological leapfrogging has been used in many research papers, chiefly those investigating the ability of newly industrialising economies to catch-up with the advanced economies in sectors such as telecommunications and ICT (Lee et al. 2005, Fan 2006). Despite this, the literature on leapfrogging is not extensive, nor unanimously defined. This section looks to better explain the concept in order to further understand the possibility of China to leapfrog to the forefront of the global electrical vehicle market.

Irrespective of the intended national goal of the technological leapfrog in China’s electrical vehicle industry, this paper presents the interpretation of leapfrogging as that of a strategy used by the government in order to achieve national objectives. Before discussing the various leapfrog paths, it is important to understand that the principle behind the concept of leapfrogging is that “particular technologies have particular trajectories or paths that define their development” (Wang & Kimble, 2011). Though no development path is the same, the broad level development process is. The way that a technology has resulted is a direct function of its development process; characterised by the theoretical knowledge and accumulated external influences that the development encounters on the way. It is therefore firstly necessary to demonstrate the structure in which technologies ‘normally’ develop. Characterised by Lee and Lim as ‘the normal path of development’ (Lee & Lim, 2001), the illustration below demonstrates the pragmatic process of technological development; moving from the 1<sup>st</sup> stage to the 2<sup>nd</sup> and so on until the present day technology is reached. Using illustrations from Wang & Kimble (2011) I will discuss the various types of leapfrogging strategy.

**Figure 1: Normal path of development**



Following on from this illustration and on what has been discussed already with the ‘skipping over the steam train stage’ in its railway development example, the first type of leapfrogging that is most apparent is that of the ‘stage skipping leapfrog.’

**Figure 2: Stage skipping leapfrog**



As illustrated in figure 2, rather than following the ‘normal path of development’ as in figure 1, the industry instead ‘leapfrogs’ over the 3<sup>rd</sup> stage of development (or generation of technologies) to the more advanced 4<sup>th</sup> stage. Again, relating to the previous example of skipping over the steam train, or in the development of a telecommunications network based on mobile phones in China (example below), it would not be considered particularly sensible or logical to follow the ‘normal path of development’ Therefore, the stage skipping leapfrog often is regarded as somewhat of the normal process for industry development.

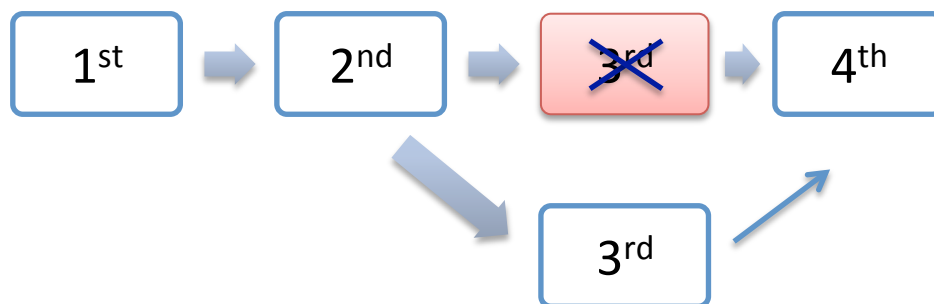
China was able to successfully leapfrog into technologies such as the mobile phone (Gallagher, 2006). Rather than spending huge sums of money on physical infrastructure, in terms of roads and phone wires, to accommodate for a wired telecommunications network, the very nature of mobile phones in their use of radio signal and the fact that to use a mobile does not require substantial education by any means, makes the mobile an ideal example of leapfrog technologies. As such, China was able to skip the fixed wire telecommunications network stage that many developed economies went through in their development.

Rather than relying on market demand to bring about the desired leapfrog, as exemplified in the previous example, another way in which a leapfrog can occur is through the implementation of government policy. In relation to the Chinese electric vehicle industry development, this aspect is incredibly relevant and specific policies will be discussed in a

later section. Though not in the automobile sector, an example of where Chinese government policy has led to a successful stage skipping leapfrog strategy is seen in the city of Rizhao and its new Solar Power capabilities. Located in the northern part of China and with a population of approximately 3 million people, 99% of Rizhao’s households use solar water heaters. Traffic signals, street and park lights are similarly powered by solar panels. In combination with a subsidy programme that reduced the cost of solar water heaters, the municipal government was able to carry out such an impressive feat through legislating that all buildings in the district must install solar water heaters. As a result, 99% of households purchased new solar water heaters, reducing not only the amount of gases they emit per household, but also their running costs over the long-term (C40 Cities, 2011).

The next type of leapfrog that has been determined is the ‘path creating leapfrog’ and this demonstrates a break-away from the normal development path of industrial development. Figure 3, below, illustrates that in the industrial development phase, rather than taking the 3<sup>rd</sup> stage that the preceding economies have taken, an alternative route is explored, before progressing to the 4<sup>th</sup> stage that may form a *new* ‘normal path’ altogether.

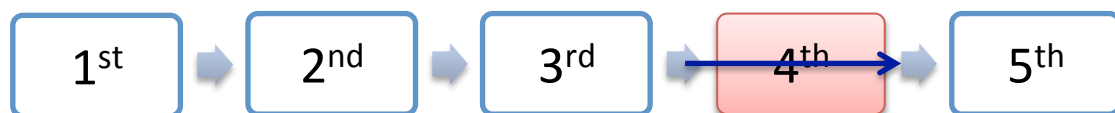
**Figure 3: Path creating leapfrog**



Wang & Kimble (2011) highlight that this type of leapfrog requires a significantly higher level of technological capability than in the previous two models. The economy must be advanced enough to acknowledge potential opportunities for their industry’s development and question why the forerunners did not take this path. There is a much higher degree of risk involved in this model. If they fail in their attempt, this venture could be costly in both time and resources, thus delaying their development overall. However, if they are successful in taking an alternate path from the norm, by “seizing the initiative ... [they can] become the leader in that particular field of technology” (Wang & Kimble, 2011).

The final model of leapfrogging that can be envisaged is one that has been put forward by Gallagher in her paper on the ‘*Limits to leapfrogging in energy technologies?*’ (2006). She suggests that leapfrogging can be: (1) the “skipping over generations of technology” and essentially catching-up with the competition, as already illustrated by figure 2 and is similar to Abramovitz’s (1986) catching-up theory; and (2) where skipping over generations actually results in the industry/economic player “leaping ahead” of the other players and becoming a leader in the technological field (Gallagher, 2006). Wang & Kimble (2011) classify this type of leapfrog as a ‘paradigm changing leapfrog,’ as if successful with the leapfrog, the economy will create a new technological arrangement where they are able to “re-write the rules altogether” (Wang & Kimble, 2011).

**Figure 4: Paradigm changing leapfrog**



It could be logically assumed that this type of leapfrog is an ideal strategy for any type of industry, as it would give the inventor an advantage over their competitors for a period of time and potentially allow for surplus profits to be made. Gallagher (2006) offers an example of this type of leapfrog being successfully carried out by the development path of the Korean steel industry. This industry came from behind, leapfrogging up to, and ultimately outperforming “the former top producers of steel to become one of the technological leaders of the industry” (Gallagher, 2006). Nevertheless, this form of leapfrogging necessitates a great deal of technological and innovative capability for the given industry, and so is a strategy that cannot be easily adopted.

What should be taken from this section is that the different models of leapfrog require some form of national technological capacity. For particular technologies to be successfully adopted and diffused around an economy, a “solid foundation of intermediate technology” is required (The Economist, 2008). Technologies that could be presumed to be a simple mimicking and catch-up process in newly industrialising development plans, are often only a success in the developed world as they are “underpinned by infrastructure that dates back to the 20<sup>th</sup> or even the 19<sup>th</sup> century” (ibid.) Newly industrialising economies, without such strong foundations or longevity of existence in a particular area, could attempt leapfrog strategies

that will inevitably fail, wasting precious resources. As such, even though the hope of gaining a competitive advantage can be incredibly appealing for an economy, ‘path creating’ and ‘paradigm changing leapfrogs’ should be undertaken with caution. Where the economy does not possess the technological capacity, it could be suggested that they follow a ‘catch-up’ development path or ‘stage-skipping leapfrog’ that sticks to the status quo but brings them up to a level where they can be present on the global market.

Especially with regards to Electric Vehicles, it has been suggested that the taking of “technical and financial risks are best left to industrial countries, which have the resources to manage them” (Kojima, 2003). This allows for the initial flaws and faults of the first generation products to be resolved by economies that can afford minor setbacks. Nevertheless, given what has been mentioned already, in terms of China’s commitment to their national policy for the promotion of domestically produced electric vehicles, this advice has likely been ignored. The types of leapfrog that can be conceived with China’s EV ambitions are both the ‘stage skipping leapfrog’ and the ‘path creating leapfrog’. Seeing as China’s ICE capabilities are not at the same level as the Western OEMs, and given that the Western OEMs have been engaged in electric vehicle development for longer than China has, ‘stage skipping’ can be seen by the leap over the mastering of the ICE to where the Western OEMs are now. Similarly, as will be discussed below, as there is limited ‘top quality’ IP transfer from the Western OEMs to Chinese electric producers, the ‘path creating leapfrog’ can be envisaged as Chinese producers could be forced to innovate and build their own technology, which may set a new precedent.

## **7.0 An analysis of Electric Vehicle Development in China:**

After discussing the various kinds of leapfrogging and highlighting some of their particular characteristics, the following section looks to examine the theoretical and empirical evidence of China’s technological leapfrog into Electrical Vehicles. The theoretical foundations for the concept of the leapfrog have been amalgamated by Sauter and Watson (2008) from the studies of various other technological leapfrogs in developing countries; such as Korea’s steel industry, China and India’s Wind industry and the rollout of mobile phone networks in many newly industrialised economies. The section uses these foundations to identify the obstacles, uncertainties and opportunities in relation to the Chinese national policy of EV development.

In accordance with Sauter and Watson’s report (2008) on technological leapfrogging, this section will analyse the efficacy of the EV leapfrog from five categorical perspectives. These

perspectives attempt to provide a whole-rounded assessment of their EV strategy, whilst also demonstrating that the goal is more difficult due to the inter-connectedness between the barriers and challenges. The varying perspectives are not exclusive of one another, but are in fact linked and many cross-overs can be observed.

## **7.1 Absorptive Capacity**

The perspective that shall be discussed first is the Absorptive Capacity. Defined by & Wesley (1990) as “the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends” (Wesley, Cohen, & Levinthal, 1990), this somewhat vague concept can also be applied at a national level. Essentially the concept refers to the ability of the latecomer, in this case China’s domestic automotive industry, to understand and be able to readily adopt new technologies and techniques into their production model to successfully leapfrog. Undoubtedly “this ability builds inextricably upon prior related knowledge” (Sauter & Watson, 2008). It is self-evident therefore that the absorptive capacity of both firms and nations in their ability to take on and install developed economy technologies is a direct result of prior investments into that particular sector, in to areas such as R&D and general industry structure. For example, whether it be at the company or national level, if they are at a stage of their development path for the particular product, which is so far below that of the developed economies and the capabilities of the economic actors involved are not on the same page as the developed, any attempt to adopt the advanced technology could be envisaged as somewhat of a ‘leap of faith’. Considerable difficulties are bound to be incurred as the developing country simply doesn’t have the capability to assimilate the technology, and the project could fail without substantial help.

In the case of China’s EV national policy, it could be argued that they have an industrial base in the automotive industry that is much better placed than many other developing economies to take on the EV challenge. Although EV’s represent a completely different form of powertrain system (engine propulsion) than conventional ICEs, and though the auto industry is not as well-established as those in Western countries, as mentioned in the industry briefing above, China does have a history (albeit short) of producing vehicles. Reiterating what has been said above, the auto industry has been focussed on for many years as a core feature of the economy, and its ability to succeed is and has been recognised to stem from a focus on product assimilation and R&D. As such, whether it was learnt from the joint-venture collaborations or by trial and error, the Chinese auto industry has the fundamental capabilities in vehicle manufacturing and adopting new Western techniques.

More specifically for Electrical Vehicle development, as previously outlined in the five-year plans, the level of R&D expenditure has increased exponentially since policy makers deemed it a national strategy. However, unlike technologies such as wind power or mobile phones, EV development relies on the rollout of a complementary service in order for them to be embraced and adopted by the market to a much greater degree. This complementary service is the charging network that allows consumers to recharge their vehicles, in much the same as conventional vehicles do, at service stations or at on street parking sites. Disregarding the reduced range competence and lengthy charge time of these vehicles, for the EV strategy to succeed, EVs require a network of charging stations that allow for them to be equally as convenient as ICE vehicles when travelling in order for them to compete on the most basic level. If the network is not present, consumers could rule out EVs as an option instantly and so taking away the 'wind' from the national strategy's 'sail'.

## **7.2 Technological Capabilities**

Linked to this, and the second aspect that shall be discussed, is that a nation's adaptive capability is related to and to a certain extent dependent on its technological capabilities; "i.e. the stock of resources for generating and managing technical change" (Pavitt & Bell, 1993). In the context of the EV technology leapfrog, technological capabilities refer to the ability of the nation to have the right skills, experience and knowledge, and the institutional framework to allow for their development. The institutional framework will be discussed later, but with regards to the nation's technological capabilities, it takes into consideration the linkages between the different institutions in the vehicle's development. i.e. between the research centres, the universities, the charging network suppliers, the ministry for technology etc. These resources must be centred on the making of "intangible capital" (Sauter & Watson, 2008) so that the advanced technology can not only be assimilated successfully, but refined and improved upon. It goes without saying that the greater the technological capabilities of the nation, the higher the likelihood that they will be successful in the development of the advanced technology.

Taking a different perspective of this idea of technological capabilities, it can also be applied away from simply production and development of the vehicles and related services. There must also be a level of technological capabilities on the side of the consumer. "Developing countries [consumers] need to be able to adapt, operate and maintain technologies originally developed in industrialised countries" (Sauter & Watson, 2008), otherwise any attempts to



adopt new technologies would be futile. In terms of EVs, as their functionality is essentially the same as that of conventional vehicles, it could be said that the average consumer (driver) could easily adapt to driving an EV. With this said, on deeper investigation the consumers adaptability to EVs depends also on the charging infrastructure, as discussed above, and whether they would have to alter their travel plans based on whether the battery in the vehicle could take them the whole way to their destination. These aspects of EVs that impact consumers are not unique to China, but affect consumers in all markets that have electric vehicle penetration to a similar degree. Given the current stage of EV and battery life being in a relatively immature phase of development (in comparison to ICE development), the typical distance that an electric vehicle can travel averages between 140 and 200 km. Therefore, those consumers who travel long-distances regularly in China, and with the limited charging infrastructure available, might find a battery electric vehicle (BEV) not sufficient. Despite this analysis of the average distance travelled of Chinese drivers in the National Statistics (2014), can give indication of whether EV's would be easily adopted, from a consumer technological capability perspective. The average distance travelled per journey on highways is 61km in 2013 (National Bureau of Statistics of China, 2014) which would suggest that an EV would provide sufficient power for the average passenger journey. Though this does not give any indication about how often this journey is taken and so whether there is enough charge time between journeys.

### **7.3 Knowledge**

The third aspect of assessing the success of a technological leapfrog is knowledge. In order for successful absorption to take place both at industry and consumer levels, a significant degree of understanding is necessary. Lee & Lim (2001) have demonstrated that knowledge build up is critical for a leapfrog; both in terms of gathering an internal knowledge bank and also gaining access to external knowledge to keep up-to-date with global changes. In terms of building up internal knowledge of EVs, as discussed above, China has made positive steps as it has funnelled huge sums into R&D for various institutions to promote a broad intellectual base. Despite this, because of China's comparatively limited experience in the automotive industry, in order to allow a greater intellectual network to develop, the Chinese government should do more to expand its access to external knowledge and expertise. The 'Titans' of the automotive industry have been looking into the electric vehicle market for considerably longer than any Chinese domestic producer, gaining the valuable expertise that is acquired over time (Tillemann, 2015). This know-how is an extremely valuable commodity, saving time and money in terms of R&D expenditure.

To repeat briefly what has been mentioned before when attempting to demonstrate that the national policy of Electric Vehicle development is in fact a leapfrog strategy, one can recall the effect of lax Intellectual Property Laws. “Frontrunner firms are generally reluctant [in any case] to share knowledge with catching-up firms who might become their direct competitors” (Sauter & Watson, 2008) Moreover, without such a legal structure in place, Western OEMs have been even less than forthcoming in handing over IP to their Chinese joint-venture counterpart for fear that it will be copied and shared widely among other domestic producers. Though the Chinese government recognised this and attempted to resurrect the lack of technology transfer by mandating it in formal contracts, Western OEMs use loopholes by handing over ‘yesterday’s’ technology. Therefore, it is clear to see that the Chinese domestic industries access to external knowledge, that is superior to their own, is quite significantly limited by the lack of IP protection. This has proven to put the EV development on the back foot in the race to EV market dominance, presenting a major constraint to the development until IP laws are tightened up.

#### **7.4 Institutions**

To analyse any form of development would not be complete without looking at it through an institutional lens. According to North, institutions are the incentives and constraints that shape economic decisions and actions, enveloping a broad variety of aspects that influence economic activity, both formal and informal. Fundamentally they are laws and legislations, established practices, social norms, cultural traditions, common habits and routines. Looking at the institutions that are present in a society allows for a thorough assessment and provides a gauge of whether the efforts to bring about a technological leapfrog will be successful.

This section will mainly focus on the formal institutions in place as they are better able to be observed and their effects measured. Especially in the case of China’s EV strategy, “any leapfrogging strategy cannot only envision the latest technology to be ‘absorbed’ in a given national context, but also needs to focus on the policies by which this is to be achieved” (Sauter & Watson, 2008). The specific attention on Chinese policies is because this strategy is a government led national aim, and therefore the formal structures are key indicators of whether the government is doing enough to support the project. It could be argued that without the government desire to promote EVs in China there would not be much presence at all of them in the market, not only given their relative inconvenience to the consumer at this early stage of development when comparing them to conventional ICE vehicles, but also given the fact that China is a middle-income economy. When looking at global EV

development plans, the majority are found in the high-income economies, and thus China's ambition is somewhat of an anomaly where one might presume other goals to naturally take precedence. As such, "public interventions in support of leapfrogging are required" (Sauter & Watson, 2008) in various areas to push the project forward. Moreover, the Chinese government can look to the other leading economies in this field to adopt their successful policies, somewhat skipping over the policies which were not as promising. This section will specifically focus on formal institutions such as the emission targets set by the state, the import protection in place and most importantly for this study, the structure of the government.

Though not within the main scope of this thesis, an interesting point to raise given what was just said is whether the Chinese government should attempt this technological leapfrog at all. Although China is an economical powerhouse with the second largest economy in the world, their GDP per capita in 2013 is \$6,807.4, ranking them 84<sup>th</sup> in the world (Worldbank 2015). Furthermore, despite year on year increases, China's Human Development Index measurement is 0.719, giving them a global ranking of 91 (ibid.). These figures indicate that there is a lot of room for improvement in other sectors of the country which perhaps should be prioritised and focused on before large amounts of resources, both monetary and policy attention, are diverted away to flagship technology projects.

#### **7.4.1 Emission Targets**

When addressing the current emission targets and legislation in China, the equivalent level of EURO 5 that is one stage behind EURO 6 implemented in the EU in 2014, there are two aspects at work that indicate a flaw in the leapfrogging strategy (Transport Policy, 2015). Firstly, referred to by Gallagher (2006) as the 'Vicious Circle', the Chinese government is reluctant to implement stricter emission standards on its automotive companies in line with those of the EU as they fear this would be handing over the competitive advantage to the foreign-Chinese joint ventures. Since Chinese environmental laws treat all different entities the same, the government recognises that the foreign-Chinese joint venture automotive companies would be able to comply with the increased emission standards relatively easily (Gallagher, 2006). With their more advanced and cleaner technology developed in their home markets they could transfer this to the Chinese market. However, the Chinese domestic auto companies, with their less advanced clean vehicles could find themselves constrained by the new standards, potentially forcing them to sacrifice market share and business to the foreign-Chinese joint venture companies whilst they implement changes to comply. On multiple

levels this lack of a formal, stringent incentive slows down the roll out of EVs. For the domestic automotive companies, it allows them to sit back and not constantly push for developments to be made in their EV development as they won't be penalised. Whilst for the foreign-Chinese joint ventures, the foreign counterpart is not incentivised to transfer their more technologically advanced electric engines to the Chinese market, a factor which worsens the transfer of knowledge problem that domestic companies face. Furthermore, the foreign auto producer is also able to make use of the gap left open in the market for their 'less green' vehicles that do not comply with the home market emission regulations. Thus, allowing them to continue production lines and reduce long-run production costs.

It is understandable that the government does not want to penalise their own companies, though one speculator has noted that "if the government put policies in place to require advanced technologies, the Chinese companies/engineers would somehow do it" (Gallagher, 2006). Alternatively, another way to escape from this 'vicious circle' is to push for the government to assist in the development of domestic technologies in EVs so that when regulations are tightened, the domestic companies will not be left behind. As discussed in the above sections on R&D expenditure, the Chinese government is funding a great deal into EV research in order for them to be able to compete on the same level. This funding falls under the 863 programme (Earley, Kang, An, & Green-Weiskel, 2011) and is one of many efforts to advance domestic knowledge. This indicates that rather than working with 'sticks and carrots' as economic institutionalists might recommend, the government is potentially only addressing the capabilities for the short-term.

#### **7.4.2 Import Protection**

As has been the case in many of the Asian 'Tiger' economies as they developed from developing to developed economies in the latter half of the 20<sup>th</sup> century, successful development and progression often relied on various far-reaching policy interventions. Though not apparent across all the 'Tiger' economies, governmental industrial policies helped the lesser established economies in their catch-up. Policy interventions such as import-substitution were one aspect that some argue to be crucial to their successful development. If import substitution is well thought through and protects the right industry for no longer than the sufficient amount of time required for the industry to become competitive on the international market, in accordance with the infant industry argument the government intervention can be justified.

The same could be said for a technological leapfrog whereby the industry, electric vehicles in this case, receives sufficient protection from the international better established ‘players’ to allow for its own industry to progress. Whilst it could be said that the Chinese domestic EV producers are not far behind the frontrunners in this market, in terms of general knowledge, experience and reputation in the automotive market they are behind, and so a form of protection can be justified temporarily. This being said, a degree of international exposure is required to ensure that the protected industries do not become complacent, ensuring that they are incentivised to invest in R&D and make improvements to their technologies. The current state of affairs in China shows that they are indeed protecting their domestic EV producers in the form of an import tariff on all foreign produced EVs. Though decreased slightly when China entered the WTO, the rate of the tax levied on foreign cars is 25% and is paid by the consumer. Moreover, imported vehicles are hit doubly as they are not eligible for the national and provincial subsidies that are offered to consumers at point of purchase, and also the consumer has to queue for a license registration, paying the full price, which domestic EV consumers do not. This then leads to a much greater upfront cost to the consumer and could possibly lead some to prefer domestic EVs. Nevertheless, based on quality alone domestic produced EVs are not a like-for-like substitute for certain foreign branded EVs. Therefore it could even be assumed that those consumers who looked to buy a foreign branded, more advanced, electric vehicle might not then buy a domestic EV, preferring to buy a conventional ICE foreign vehicle instead; undermining the environmental aspect of China’s EV development ambition. For the leapfrog strategy this government intervention takes away some of the incentive for domestic producers to push for more R&D investment. Though the average quality of their EVs may be less than that of the Western models, they can be competitive on price, especially with the import protectionist measure. If there were no import duty on foreign EVs, nor any discrimination in terms of access to subsidies or licenses, the market for EVs in China would be much more competitive. These added competitive pressures could be presumed to incentivise the domestic producers to increase efforts to be able to compete alongside the Western OEMs. It has been suggested by a recent McKinsey report (2015) that China should remove its foreign EV import tariff to increase aggregate market demand for EVs. This is because foreign EV’s can potentially “stimulate the market development and demand through additional competitive offerings” (McKinsey & Company, 2015). According to them, given the early stage of EV development in China, the Chinese governments prioritising domestic production should give way to boosting consumer interest and industry innovation by allowing foreign EVs in tax free.

### **7.4.3 Decentralised government impact**

In a similar light, when considering the effect of competition on the Electric Vehicle development, the structure of the Chinese government is very applicable to this topic, with some commentators having expressed concern over too much provincial competition and fragmentation resulting from governmental decentralization undermining national targets. The core theme of the decentralized federalist system in China, which evolved during the transition period, is providing the incentive for sub-national governments to increase competition in decision making, in order to foster greater economic growth. It has become apparent since its implementation that there is considerable contradiction in the creation of provincial competitive incentives for economic growth and attempting particular national ambitions, such as electric vehicle development.

At the core of the argument for greater decentralisation is the increased allocative efficiency that will result in the economy. This is due to the sub-national governments having a better understanding and knowledge of where resources would be most beneficial to the local economy, based on preference and need. Increased allocative efficiency would, as economic theory dictates, transpire into increased economic growth. Fiscal decentralisation is a key component in China's transition from a centrally state-planned economy towards a market-orientated economy through lowering the transaction costs of doing business there, and therefore can account for much of their phenomenal economic growth and development since 1978 (Shen, Jin, & Zou, 2012). The Chinese federalist model is different from the standard Western form of federalism as in place of electoral accountability and having a free press to act as restraint on government, the Chinese system divided authority amongst all levels of government. Montinola et al. (1995) describes this system as a form of "market-preserving federalism", whereby the division of authority limits the extent that the all levels of government "encroach upon its market" (Montinola, Qian, & Weingast, 1995, p. 55), increasing responsibility, accountability and confidence in the Chinese market, hence incentivising business formation.

Through the Fiscal reforms of 1980, 1985 and 1988 and the later Tax Sharing Reforms of 1994 (Shen, Jin, & Zou, 2012), the old centrally planned system was overhauled, and a system which encompassed the conditions of a 'market-preserving federalist' system was formed. The increased responsibility in "generating and retaining some of their own revenues" (Tang, Lo, Cheung, & Lo, 1997, p. 864) was the most important feature of the reforms as it created the local official incentive to favour economic development in their jurisdiction. The importance of this in relation to the national policy of electric vehicle development is that, although decentralisation allowed for the principle-agent problem to be overcome, by aligning all parties' interests in bringing about overall economic growth, the

desire for provincial officials to increase their revenue by promoting electric vehicle production has caused overcapacity and too much competition.

Given the importance that has been put on the EV national policy by the central government, through the various directives and also financial provision made available, there is recognition amongst many provinces that promoting domestic producers of EVs could potentially bring in huge sums of revenue for them, as well as providing employment opportunities for their citizens. Therefore, local governments want to ensure that when demand for electric vehicles expands greatly, their auto industry is at the forefront and is able to supply the market, therefore bringing in tax revenues. As such, it cannot be considered irrational for local governments to aid their EV auto industries. They do this by providing large amounts of subsidies, both directly and indirectly to keep the businesses artificially afloat. Direct subsidies include preferential financing, tax breaks, cash grants, R&D grants and local subsidies to the consumer. Whilst indirect subsidies include governmentally controlled raw material prices as well as the governmental purchasing of their provinces produced EVs (Haley, 2012). This type of local governmental support has been termed ‘local protectionism’ (Marquis, Zhang, & Zhou, 2013) and represents another challenge to Chinese EV development as it can prevent companies achieving their long-run average cost and scale economies. The Shanghai local government, for example, openly discriminates against non-local manufactured electric vehicles by making them ineligible for the financial subsidy offered to consumers, giving instead to its own three locally produced electric vehicles (Wan, Sperling, & Wang, 2014). Local protectionism is even worse in the governmental purchasing of public fleets as the non-locally produced new electric vehicles are excluded from the outset. Nevertheless, attempting to resurrect this issue, in 2013 the central government mandated that 30% of the provincial electric vehicle public fleet has to be bought from outside their own province (Wan, Sperling, & Wang, 2014).

Neoclassical economic theory states that competition is good as it results in the production of many different varieties of good to appease diverse consumer preferences. It is, however, questionable, whether this is the case in China. Under the Ten Cities, Thousand Vehicles Programme, over 25 cities in nearly as many provinces have been included, resulting in a lot of competition for and strain on central government resources and support. Seeing as this is a central government led plan, rather than market led, central government has to provide the strong foundations and support to ensure its success. This is more difficult when there are many companies to support. As a consequence local governments, according to Marquis et al. (2013), have become far more “self-serving.” They have placed greater attention on developing electric vehicles and standards that are more specific to their local requirements

than to a national or international design. Therefore, despite the central government legislation on EV purchasing for local governments, further difficulties arise from the fact that certain EVs made in Shenzhen are not compatible with the charging infrastructure in Shanghai, for example. Hence acting as a considerable disincentive for a consumer to purchase an EV as driving it in particular areas of China would prove difficult.

To conclude this section, the decentralised structure of the Chinese government can be seen to be a constraint on EV development as it has created “too much local competition [that] complicates rather than facilitates the development of a national formula” (Marquis, Zhang, & Zhou, 2013). In order to try combat this consequential fragmented development, there needs to be a re-alignment of central and local government interest, ensuring that the local officials are not simply focusing on short-term gains. This could potentially be resolved by adding certain indicators to local officials performance assessments, i.e. number of locally produced EV models that fit to a national and/or international standard - the higher number the better for national targets. This would, however, first require the central government to take a greater role in terms of specifying the national standards that all domestic producers need to adopt.

### **7.5 Accumulative Processes**

The fifth perspective that a technological leapfrog should be looked at builds further on the absorptive capacity discussed previously. What is meant by accumulative processes is the knowledge that is built up and gained over time from being involved in a particular industry. Having the “know-how” based on prior experience. “National technological capabilities in production, operation and maintenance often build upon knowledge related to previous technologies” (Sauter & Watson, 2008), thus presenting the significance and potential challenge of this symbiotic relationship. Whether the country needs to have reached a specific level of necessary technical knowledge and experience in the given sector prior to attempt a leapfrog poses interesting questions about China’s EV ambitions.

With regard to China’s leapfrog in electrical vehicles, the accumulative process refers to their previous experience in producing electric vehicles or technology that is input into EVs, though it could be stretched to include China’s experience in the automotive industry as a whole. As has been discussed in the above and would follow basic logic, the longer the time and hence the more experience that they have in the auto industry, the better placed China would be in taking on this next challenge. They would have stronger foundations to start and



develop from than without such history. Though China does not hold vast amounts of experience in the auto industry as a whole, an area that China does have particular knowledge and experience in is battery technology. As batteries are one of, if not the, most crucial parts of the vehicle, it could be argued that they hold some expertise that will help development. Several top global players in battery production are found in China, such as Lishen, Bak, Wanxiang Group and most notably BYD (Tillemann, 2015). They all have established themselves as suppliers for the consumer electronics market lithium-ion batteries, the same type of battery that is used and is backed as currently the best technology for electric vehicles (Howell, Lee, & Heal, 2014). This is not to mention the huge advantage that China has in terms of supply of rare earths that are a crucial component in batteries. As of 2008 China controlled 96.8% of global output (Wang & Kimble, 2011), placing its battery manufacturing companies at a considerable advantage in terms of access to the rare earth commodities.

Similarly, China has considerable experience in electric scooter vehicles that offers degree of transferable “know-how” for electrical cars. Resulting from a decision in the 1990s to prevent urban air pollution from worsening dramatically as consumers were trading up from bicycles to motorcycles, central government banned gasoline-powered motorcycles in many cities. This provided a gap in the market for electric scooters. There are now well over 140 million electric scooters on the Chinese roads, with this number expected to increase to around 350 million by 2018 (Weinert, ogden, Sperling, & Burke, 2008). These aspects, battery-technology experience, rare earth supply dominance and transferability of electric scooter technology, demonstrate how the electric vehicle industry in China can make use of knowledge from other similar goods within the general ‘block’ of the electric powered vehicles industry. This should positively impact on the national policy for EV’s, though exactly how much is difficult to accurately assess or measure.

A further aspect that is incorporated under the accumulative process aspect is the presence of “technological complementarities” (Sauter & Watson, 2008), i.e. whether the appropriate infrastructure, goods or services are set up in order to allow for the leapfrogging technology to function properly and to its full potential. In the case of Electrical Vehicles, the main technological complementary is the charging network that must be in place for car owners to recharge and continue with their journey. Much in the same way that conventional vehicles refuel at petrol stations, EVs require recharge stations to provide an electrical charge when they are away from their home residence. More than this, given the long charging times that current EV batteries require, even the most advanced Western technology, more than just roadside charging stations are needed. A whole charging infrastructure needs to be in place to allow for the long charging times. For example, in parking garages and on-road parking bays,

charging points should be in place so that the vehicle can be charged whilst the driver is away from the vehicle for extended periods of time. Having this network in place allows for much greater flexibility and convenience for the driver, helping contribute to the practicality of their daily commutes. Without such a network, consumers might be dissuaded from purchasing an EV, instead buying a conventional ICE vehicle. Therefore, this presents a case for how significant the complementary charging network is to the demand of EVs and thus their successful development.

Setting up a charging network is not as easy as one may presume given the large number of stakeholders that need to be included. The current status of China's charging network is a good example of how, despite the one party state that one might presume would be much better placed to dictate the building of the network, it is very difficult to successfully develop. Besides the standardisation issues, mentioned in the above with regards to local protectionism, China faces huge supply shortages of its charging stations. Chinese megacities are far behind its international comparisons in terms of charging poles per unit area, a factor which McKinsey say greatly "constrains EV demand growth" (McKinsey & Company, 2015). Furthermore, consumers in cities that live in high-rise buildings often do not have access to a dedicated parking space, let alone the infrastructure that allows for the ability to install a charging unit. Where it is possible, it is a very lengthy approval process that includes many levels of bureaucracy, which only gives disincentives to consumers from purchasing a new electric vehicle. Essentially, the problem at hand is "what needs to come first: the chicken or the egg?" Government need to take on a greater role to ensure that consumers do not find themselves inconvenienced by the ability to charge their car. By doing so, it would likely increase the consumers demand for electric vehicles and allow for numbers to increase to the level where apartment developers and roadside planners would see a need to install charging poles within their development (McKinsey & Company, 2015).

## **8.0 Final Analysis and Concluding remarks**

Based on the review of the leapfrog concept presented in this essay and having looked at the different aspects that could affect, either positively or negatively, China's ability to successfully leapfrog to a leading position in EV production, this final section attempts to bring all the different aspects together in an analysis of its possibility of doing so. First though, it is important to back up my analysis by comparing the methodology to well regarded research carried out in a similar field of discussion.

According to Moses Abramovitz's 1985 article on "Catching-up, Forging ahead and Falling behind" (1986) he raises the point that the social capabilities are fundamental to a nation's ability to achieve rapid technological growth. When the nation is "technologically backward but socially advanced", huge gains can be made. This can be applied in relation to the EV development in terms of the social capacity to impact the EV national policy success. Though, as Abramovitz points out, the trouble with including social capabilities in assessing a nation's ability to bring about economic or technological gains and catch-up is that they are difficult to accurately measure. He has used proxy measures in previous studies such as years of education to indicate the level of technological competence, however even this could not be argued as a comprehensive enough indicator nor one without problems. Furthermore, with regard to Electric Vehicle development, as has been mentioned above, to drive an electric vehicle is not too dissimilar from driving a conventional internal combustion engine vehicle. Therefore, given that Chinese people are able to drive ICE vehicles, it should be taken as a given that they would be able to easily adapt to driving electric or hybrid vehicles, especially considering the average kilometres per passenger journey to be 61km. Nevertheless, Abramovitz's studies indicate that the "social capability" criteria also brings in wider aspects of a society's capacity and what a nation should have when it attempts a technological catch-up – capacities that are in accordance with the five varying perspectives brought up in this essay when analysing the possibility of a technological leapfrog. Features such as "factors limiting the diffusion of knowledge, the rate of structural change, the accumulation of capital and the expansion of demand" (Abramovitz, 1986) bring clear parallels to the various perspectives discussed from the leap-frog concept. Abramovitz's studies therefore help demonstrate how the analysis undertaken in this essay are similar in scope and are some of the most important factors to include in a technological leapfrog analysis.

Though the picture that has been painted throughout this essay seems to be largely negative and against the possibility that China will successfully accomplish a leapfrog to EV dominance, there are many positive aspects that indicate that Chinese efforts are not completely misguided. Firstly, though not explicitly a core requirement for their leapfrog, the Chinese auto industry has a remarkable record of growth since 1976. Where in the 1980's domestic production stood at around 200,000 vehicles, most of which sold locally, now they are the number one producer in the world, producing a total of 24 million passenger and commercial vehicles in 2014 (OICA, 2014). Alongside this, the Chinese have built an impressive supply value chain with locally produced parts that are included in foreign produced cars. Furthermore, seeing as there is already a high level of supply of batteries in China and given the abundance of rare earths available for the Chinese market, it is not so

farfetched to make the presumption that the EV industry can build from these foundations to make a solid value chain for themselves, and potentially have a breakthrough in battery technology. What's more, based on the governmental emphasis and focus in the five-year plan towards new energy vehicles, there is the political will behind and supporting the EV industry. Though this political support is not unique to China, given the resources and agility of the Chinese state to react and bring about change, this helps considerably in development of new technologies such as electric vehicles.

This being said, the challenges to Chinese EV dominance brought up in this essay are considerable and do present major hurdles to the national goal. This essay looked at the fragmentation and large degree of competition amongst the domestic EV manufacturers and local governments as a result of the decentralised structure of the Chinese government. Though this structure and the theory behind it has been regarded as highly influential in bringing about economic prosperity and development in China, a side effect of it is that competition is prioritised over collaboration and coordination in achieving national goals. Although some attempts have been made by means of creating commercial alliances, these are largely insignificant as the incentive structure for local governments is for them to maximise revenues by protecting local industries. This lack of coordination has knock-on effects not only in the standardisation of technology but also in the building of the required charging infrastructure. As pointed out by the McKinsey (2015) report, the number of parties necessary to construct a comprehensive charging network that includes motorway charging stations, city parking bay charging points and also apartment block charging poles is large. This factor alone is incredibly significant in preventing a technological leapfrog as it has the consequence of increasing the non-monetary cost to the consumer and hence reducing consumer incentive to purchase EVs, which therefore does not allow for producers to reach the lower average cost when producing at an increased volume levels. The overall effect is that fewer EVs will be sold as the upfront costs and non-monetary costs are not low enough for the consumer to justify purchasing an EV in comparison to a conventional ICE vehicle.

Far from being able to achieve a technological leapfrog, these factors demonstrate that an industrial leapfrog will be difficult to carry out. To help solve such a dilemma, significant attention by the state needs to be placed in this area in order to create greater collaboration and coordination between all parties. As discussed above, a way that this could be done is for the central government to include certain indicators in local government performance measurements. Similarly, the central and local governments should make the process for building charging in city parking bays and within apartment blocks much easier to do. Given the short distance travelled per journey by Chinese passengers, for the majority of consumers

having a charging station at their home would provide enough charge for their journeys. As a result it could be envisioned that more electric vehicles will be sold, allowing domestic producers to increase output volumes and so reduce costs.

In terms of the technological leapfrog, either ‘path-creating’ or ‘paradigm-changing’, it is unlikely that either of these will materialise given the inferiority of Chinese technology and the fact that the domestic producers are artificially protected by import tariffs and lower emission standards. These features of protection provides disincentives to domestic producers, constraining research and development, and allows for inferior technology to remain in existence longer than might be expected in a more open market where there is increased transfer of knowledge from external sources and products. Moreover, a technology leapfrog is severely restrained by the lax intellectual property laws that prevent foreign producers from handing over up-to-date technologies and techniques to their Chinese joint-venture partner. Being one stage behind in ‘the race’ is a disadvantage, especially considering when the other competitors are far more well-established titans in the auto motive industry. A potential scenario is that once EV technology has reached a certain degree of maturity, because of Chinese strength in vehicle manufacturing they could still become a market leader in the production of electric vehicles. This is assuming that foreign producers receive greater assurances that their IP will be protected.

To conclude, it is the intention of the author to have presented a case to the reader that allows them to gain some understanding of the concept of the technological leapfrog, in its various forms, in relation to the Chinese prospects of successfully developing a leading EV industry at the global level. Though the ‘race’ to EV leadership is still on-going and largely an open affair, given what has been discussed in this essay, there are multiple reasons that indicate that China will not be the clear leader once the dust settles. This is not to say that a leapfrog will not occur for the Chinese though. Whilst there might not be the ‘path-creating’ or ‘paradigm changing’ leapfrog to leadership as desired, it is much more likely that China will witness a ‘stage-skipping’ leapfrog by means of advancing to the more advanced stage of vehicle engineering before ‘mastering’ conventional ICE vehicles. However, in order to accomplish this feat, a significant amount of effort needs to be made in areas such as infrastructure building, central – local government goal alignment to increase cooperation and collaboration, and bringing up the level of technology present in China via increased exposure to the international competition.

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