Greening China's 'Cars': Could the Last be First?

David Tyfield & John Urry

CeMoRe, Lancaster University

CeMoRe Working Paper

September 2012

1) Introduction

Climate change is a grave global and social problem. Transportation, which accounts for at least one quarter of global greenhouse gas emissions (GHGs), is key to efforts to mitigate 'climate change'. Perhaps the most significant single development for the 'global environment' is the recent transformation of mobility within contemporary China. This society, now central to the world economy, has in twenty years gone from one predominantly based upon slow means of travel, especially walking, carts and cycling, to one based upon fast modes and especially car and truck transport (as well as slow moving oil tankers and container ships (French and Chambers, 2010)). Although its GHG emissions remain small on a per person basis (e.g 0.75 MtC/capita vs. 5.5MtC/capita in the US in 2005 (Winebrake et al., 2008: 218)), it is now the world's largest emitter (Climate Group, 2008).

Cars in China have increased from 9.2 million (2004) to 40.3 million (2010), the total number of vehicles from 27.4 million to 90.9 million (NBS, 2005; 2011). Growth is expected to continue at 7/8% p.a. in the medium term (Sperling & Gordon, 2009: 209). Forecasts vary but range from 60m cars by 2020 and 300m by 2050 (Feng et al., 2004) to 100m as early as 2015 (Chen et al., 2004, quoted in Winebrake et al., 2008: 217). Another estimate sees cars growing tenfold 2005-2030 (Watts, 2009), with oil consumption rising from 110Mt to 500Mt per year. Furthermore, the number of private cars is growing even faster at 22% *p.a*. so that individually owned cars are a growing proportion. Surveys suggest that most of the Chinese population would buy a car if they could afford one. The size of its population and the increasing income of Chinese households have already made China the world's largest car market.

This shift involves rapid and extensive urbanisation. It is thought that by 2030, one billion people, or nearly 70%, will live in cities, adding a further 350m urbanites (MGI, 2009). Such cities are organised around fast transport and extensive movement for work, family life and leisure. Yet car intensity in China remains relatively low, especially compared with the US. This suggests further dramatic growth, but also enormous problems. American car intensity would seem impossible within China. It would mean some 970m cars, 50% more than the entire worldwide car fleet in 2003 (Girardet, 2004), and the consumption of 102% of current world oil output (calculation using IEA, 2011 and Winebrake et al., 2008: 216).

The question is whether China, the latest and most significant society to undergo automobilisation, could be the first to decarbonize personal vehicle transport. This possibility has triggered a growing literature from think-tanks, consultancies and global governance institutions. Is it possible that China could ‘leapfrog’ into the lead here? Could the last turn out to be first?

We treat automobility as a matter of socio-technical systems and of their possible transitions. However, we also argue for examining various elements often downplayed even in ‘systemic’ analysis, especially regarding power or politics. Our relational analysis raises questions regarding the parallel co-construction of institutions (including forms of ‘state’ or governance), collectives and subjectivities by way of technologies of knowledge and measurement. The prospects for low-carbon mobility system transition is not only crucial regarding sociotechnical transitions in response to climate change and energy issues, but also provides a window into inter-related issues of political economy, innovation from below, adventurous consumption and novel mobilities.

In section 2 we review the challenges of automobility in China before turning, in section 3, to the socio-technical systems perspective and the need for a more concerted attention to power. This leads to discussion of the inter-relations between regimes of accumulation, socio-technical systems and associated innovations. In sections 4 to 6, we turn to various elements of the automobility system in China. In section 4, we review the current state of the Chinese car industry, its comparatively low innovation capacities and the continuing dominance by joint ventures (JVs) with major overseas partners. This yields a picture of poor prospects for Chinese low-carbon leadership, but this is transformed by examining disruptive, or ‘game-changing’, low-carbon innovation of electric vehicles (EVs) and especially electric bikes (section 5). In section 6, we turn to the possible deprivatisation of mobility as well as the transformation of cars from primarily mechanical to digital machines. This allows us to discuss cultural and political challenges to low-carbon post-car mobility in China and a possible future scenario. We conclude by considering whether China will lead in innovating low-carbon mobility systems.[1]

2) The multiple challenges of Chinese automobility

Urban automobility is central to contemporary social and economic life in the ‘west’ in the twentieth century. But until the Reform of 1978 very few cars were produced in China (Gallagher, 2006: 1); it was rather uniquely a ‘bike society’. In the late 1970s there were 56 small car plants producing 150,000 cars a year mainly for Party and State officials (Thun, 2006: 54). But since 1978 and the launching of ‘Reform and Opening Up’, China has been pulled into this vortex of accelerating personal mobility (Nyiri, 2010). A very significant car system developed, with production capacity for 31m cars by 2013 (New York Times 2011). This represents the fastest automobilising of any major society, dwarfing growth elsewhere.

This growth has consequences for urban areas being redesigned, often with celebrity-architects, around the car-system and its smooth 'passages'; for enhanced atmospheric pollution, making some cities intolerably unhealthy for walkers and cyclists (and drivers!); for health and safety, with car death and injury rates amongst the highest in the world (Shanghai Star 2004); for rapidly rising oil consumption, with China recently experiencing the 'peaking' of its oil supplies as it increasingly scours the world for new sources (with likely geopolitical conflicts); and for the global climate, where automobility growth is one of the fastest growing sources of GHG emissions and is the main sector with an absolute emission growth trend, thus undermining modest reductions of emissions elsewhere (Paterson 2007: 37).

This is also at a time when some parts of the world are reducing their dependence upon automobility partly because of the (inter-related) economic and financial collapse from 2008 onwards and rising oil prices resulting from the ending of 'easy oil' (Heinberg, 2005; Homer-Dixon, 2006; Hopkins, 2008) so that the "world is about to get a lot smaller" (Rubin, 2010). What remains is mainly 'tough oil', geologically (deep water, shale, tar sands) and/or politically (Russia, Libya, Nigeria). Oil prices are now at least ten times higher than they were in 2000, some iconic car firms are in freefall, and there is a cultural turn against 'gas-guzzlers'. These trends are stimulating a search to replace the 'steel-and-petroleum' car system. Such a system shift would not just be to engender reduced GHG emissions through improved engine efficiency, with the risk of a rebound effect of increased use leading to overall emissions that are just as high. Rather there is significant interest in socio-technical re-engineering that would involve a step change from high- to locked-in low-carbon systems.

So China's dash for huge increases in oil-based personal vehicles is occurring as innovations are developing that would replace the current car system with an alternative *After the Car* (Dennis & Urry, 2009) or which involves *Reinventing the Automobile* (Mitchell et al., 2010). This would be a singular moment. In socio-technical change, systems do not develop in a smooth and predictable fashion, often involving false starts, niches, reversals, disruptions and so on. Elsewhere we examined disruptive innovation, arising unexpectedly and from organisations or social groups not part of the mainstream (Tyfield et al., 2010, Tyfield and Jin, 2010). Current disruptive changers with regard to global vehicle systems include Better Place, MIT MediaLab, ULTra, Rocky Mountain Institute and so on. There is much innovative activity but this has not yet come together to engender a sociotechnical system that could become globalised in time to slow down rising GHG emissions and temperatures (Urry, 2011).

A further issue is whether existing carbon interests in the rich North, the 'carbon military-industrial complex', would 'permit' a low-carbon transport system which could undermine the enormously powerful carbon complex, of vehicle manufacturing companies, oil exploration, refining and distribution corporations, and state and semi-state oil interests. Former Shell executive Leggett calls this complex of corporations and states the world's most important single "interest" (2005: 12, 15). It lobbies against regulation and intervention in energy markets and energy prospecting; it funds foundations to engender climate change scepticism; it denies the finite nature of carbon resources and undermines mass transit alternatives; it bends foreign policies and military interventions to its interests; and it undermines some post-oil innovation, with GM killing off its own prototype electric car (see the DVD 'Who killed the electric car?'; Urry, 2011: chap 6).

It is often argued in economic development, drawing on the biblical doctrine from St Matthew, that "the last will be first, and the first last" (Matthew 20.16), or the 'advantages of backwardness' (Gerschenkron, 1962).[2] So it is wrong to presume that low-carbon transport systems will originate from the heartlands of existing vehicle and oil industries in the US, Western Europe or Japan. And the widespread adoption of mobile phones in societies where there are few landlines is now a famous example of how there can be 'leapfrogging'. Could China, the last, come first; could it be where a still-being-formed personal vehicle system takes root and takes over the world? Could China 'leapfrog' towards a post-car low-carbon mobility system, or will this transformation be a long 'hard slog' (Rock et al., 2009)? The stakes for global energy and climate futures could not be higher.

3) Sociotechnical systems and power

We begin by noting that car and truck production is still the most important global industrial sector (Mikler, 2009), the "industry of industries" (Dicken, 2007: 278), responsible for vast employment and resource consumption worldwide. It was the site of "the development of the assembly line, the intensified division of labour, the mechanisation of increasing numbers of task and then later flexibilized production, just-in-time (JIT) delivery, robotisation", and hence mass consumption via "radically reduced" prices (Paterson, 2007: 95). It is also characterised by intensive R&D and intellectual property (Dicken, 2007**)** increasingly organized into global innovation networks due to rising costs (especially for low-carbon measures). The automotive sector is also a global oligopoly dominated by a handful of OECD-based TNCs. It is the "paradigm case of globalized industry" (Paterson 2007: 98), but with a strong national basis, not least regarding continued state support. The industry is also paradigmatic regarding global political economic crisis, with huge overcapacity (including in China) and dependence upon financialized profits (Blackburn, 2006), stagnating demand in home markets and a shift towards growth in the 'BRIC' countries, altogether generating once-in-a-generation opportunities for breakthrough by new players.

But automobility is more than just a car industry. It is "automobile use and everything that makes it possible" (Rajan, 1996). Given its problems, China's opportunity is not to become the best in this defunct system, but to develop a new model. And this demands attention to simultaneously social, organisational and technological aspects (Dennis and Urry, 2009; Geels, 2005). Technological developments occur in mutual and parallel interactions with economic, social and political change (Levy and Rothenberg, 2003). Moreover, while evolutionary economics stresses the importance of consumption (Bhidé, 2008) and the absorptive capacities of a system to make use of innovations from elsewhere (Cohen and Levinthal, 1990), these analyses overlook power and politics in socio-technical 'regimes'. The central importance of power in understanding socio-technical change is illuminated when conceptualized as relational, dispersed and productive (Paterson, 2007: 126). For (socio-technical) order and common-sense – the very institutions of 'normal', ongoing socio-technical change – must themselves be constructed, together with 'technologies' that make such ordering materially and conceptually possible with new orders of governance that enact such 'conduct of conduct' (Dean, 2010).

Furthermore, as it incorporates capitalist industry, a sociotechnical automobility regime must also construct a mode of regularisation of accumulation (Paterson, 2007) that depends upon political contestation and new political constituencies, coalitions and 'imagined communities' (Anderson, 1983), forms of state and subjectivities (Lemke, 2011). Finally, innovation capacities must themselves be analyzed in these terms. In particular, with innovation increasingly distributed around the world in various regional and global innovation networks (GINs), a Chinese-led automobility transition would involve a new 'international division of labour of innovation' (IDLI), with all this would entail for the global distribution of innovation super-profits in a global knowledge-based economy. Thus low-carbon automobility transition in China would involve profound social, institutional and political economy change on a global scale going far beyond the mere introduction of 'low-carbon' vehicle technologies by the automotive industry.

We turn now to examine, given these operations of power and property, whether system change might be possible and with how some of that might happen in and through innovations within China.

4) 'Production': new fuel systems

There are several options for reducing GHG emissions: increased efficiency of combustion of conventional internal combustion engines (ICE), biofuel-based synthesis of fossil fuel substitutes, and alternative fuel vehicles (AFVs) (batteries, hydrogen fuel cells or various hybrid engines). Currently Japanese companies are taking the lead with hybrid electric cars, German companies primarily focus on improved diesel engines while continuing work on future hydrogen cars, and American companies are improving petrol engines, with battery electric and hydrogen cars as future technologies (Mikler, 2009).

Overall the 'best solution' at present for decarbonising travel is electric vehicles of some sort (Sperling and Gordon, 2009:7). They have several technical advantages over ICEs, including: 90% vs. 37% energy efficiency respectively; no energy use when at rest or free-wheeling; and the possibility of regenerative braking offering a further 20% energy efficiency (Sperling and Gordon, 2009: 23). In China almost all car companies, state-owned and 'private', large and small, have significant investment in electric vehicles (EVs) (BCG, 2011; Gao et al., 2008; World Bank, 2011; see Section 5).[3] The Chinese car industry is not targeting incremental improvement of ICEs since this technology is wrapped up with the existing global auto industry which largely excludes Chinese firms.

Since its rebirth the Chinese car industry has been divided into state-owned enterprises and JVs with foreign car companies. The latter have dominated while national efforts to rationalize the former from a plethora of small, regional 'champions' had limited success (Gallagher, 2007). A third element is 'private' companies, usually with growing local state support, such as Chery or Geely. But this is a fragmented industry that lacks economies of scale and suffers from overcapacity (Thun, 2006). There are also fairly weak exports. Nevertheless, there has been spectacular growth. And there is "little doubt that auto firms located in China will rise to the challenge of global integration" (Thun, 2006: 245). The question remains, however, "whether there will be much that is *Chinese* about these firms and their broader supply networks" (ibid., emphasis added). What are the prospects for new fuels and materials being innovated not only *in* China but *by* China?

Innovation and absorptive capabilities are limited, especially by comparison with dominant firms elsewhere, with key technologies still largely imported. This augurs ill for even 'catching up' with the moving target of developing innovation capacities, let alone any 'leapfrog' in Chinese vehicle innovation to global dominance. And there is no guarantee of Chinese techno-economic catch-up (e.g. Hung, 2009; Steinfeld, 2004). Interviews with automotive executives in 2009 revealed little confidence in the ability of Chinese companies to bridge the gap between R&D and successful deployment.[4] These findings have been corroborated by further UK-China research which found significant gaps in Chinese low-carbon innovation capacities, particularly regarding key technologies, systems engineering capabilities and management of electric batteries, despite the existing expertise of some Chinese firms in lithium battery technologies for other uses such as mobile phones (Watson et al., 2011).

Innovation does occur but there is a focus upon cost-cutting rather than new 'cleantech'. Sperling and Gordon (2009) note that this may explained by the high barriers to entry for such hi-tech innovation associated with global oligopoly and relatively weak R&D, notwithstanding growing government funds since such support is dwarfed by the explicit and implicit government subsidies in the home states of dominant firms.[5] Intellectual property protection in China also remains a key concern, especially for technology-intensive foreign investment.

A key consideration is thus the extent to which Chinese companies can benefit and learn from international collaboration (including technology transfer) and competition with foreign firms that currently dominate low-carbon innovation. This is especially the case from the perspective of decarbonising automobility given unprecedented time limits that render slow, 'organic' development inadequate. The Chinese supply chain has been improving for some time as the greatest beneficiary of JVs, while the increasing importance of modular innovation and electronics creates openings for Chinese firms where they have growing global competitiveness (Ernst, 2008; Altenberg et al., 2009). Similarly, regarding 'basic' R&D, both the quantity and quality of Chinese science continues its meteoric rise (Leydesdorff and Wagner, 2009). And even while comparative weaknesses remain, there are notable exceptions that are also of major significance for AFVs, such as nanotechnology for battery technology (Nanochina, 2007).

The JVs themselves, however, tell a less positive story. Although JVs were set up from the mid-1980s, the pioneer being Beijing Jeep, China's joining of the WTO in 2002 lead to a huge growth in FDI. This, in turn, cemented the dominance of the part-foreign-owned JVs, with over 80% total sales (Winebrake et al., 2008: 225) but also more innovation, dominating several important measures, including value production per employee and ratio of new model production (ibid.: 227). Similarly, analysis of Chinese patents granted between 1985 and 2005 to automotive TNCs in the Fortune Global 500 and Chinese companies in the country's top 500 industrial enterprises reveals the utter dominance of the former, both absolutely and relatively (Chen, 2008). Moreover, this discrepancy is apparent in comparison between JVs and the TNCs that are party to them, indicating how little technology transfer has taken place (Chen, 2008). As one senior car executive from a major auto SOE we interviewed put it in 2009, they "hardly get any core technologies and key parts through" their JV and are "enslaved" by this dependency.

There is some evidence of the changing role and scale of the 'state' here. For instance, just as Sperling and Gordon (2009) note the growing importance of sub-nation-state governance, so too in China cities such as Shenzhen and provinces are increasingly important in developing policies for AFV innovation. For instance, in order to limit overall growth of car numbers while also stimulating AFV demand, major cities have introduced licence plate auctions (Shanghai) or quotas (Beijing) with possible exemptions for AFVs. Several cities have also used procurement, in particular electric buses, to support EV development and 25 cities support AFV demand in some way, such as purchase subsidies or tax exemptions. For instance, Changchun (home of FAW, one of the 'Big 3' automotive SOEs), runs electric buses and plans to provide 500 EVs, together with after-sales servicing (Xinhua 2011).

Furthermore, although national policy has until recently done little to stimulate innovation in low-carbon automobility, things have begun to change. First, in 2009, subsidies of RMB3000 were introduced to stimulate sales of small cars. EVs emerged as the focus of a growing national support as one of seven 'key strategic emerging industries over next 5 years', with RMB100 billion (£10 billion) of support over the next 10 years. The government aims to have 500,000 EVs on Chinese roads by 2015, and 5 million by 2020. EVs are subject to 0% sales tax and receive consumer subsidies of up to RMB 60k from central government, which is supplemented by the city-based programs. Moreover, there are moves to tighten the regulations on the size of engine of ICEs that qualifies for sales subsidies. Finally, regarding technology transfer, press reports of new, tighter national rules on IP and brand sharing to stimulate technology transfer are receiving increasing concern from Western businesses.

Tthe national 12th Five Year Plan makes relatively little explicit mention of EVs but does include significant targets of a 45% reduction in GDP energy intensity by 2020 compared with 2010. Regarding energy generation more broadly, targets for 2020, which look likely to be met, will make China a world leader in absolute generation of renewable energy (wind, hydro, nuclear and solar thermal, with a large but export-oriented solar PV industry as well) (Watts, 2011). This is very important for the low-carbon credentials of plug-in EVs, given the continuing dominance of coal-fired electricity generation.

Furthermore, in autumn 2011 there are growing reports of a possible carbon tax being discussed by the State Council, with 'fierce debate' even pushing towards a carbon cap. No less important are moves towards redefining the assessment criteria for cadres posted around the country in order to rebalance emphasis on implementation of policy away from GDP growth at all costs and towards environmental concerns. Thus while there can be no presumption regarding a 'natural' reduction in GDP importance (vs. Pan, quoted in Watts, 2011), there is growing contestation at all levels of Chinese governance regarding environmental issues that should translate into tightening standards of car emissions.

The continuing failure of JVs as a source of spillover thus suggests other models of international collaboration may be more promising. One major SOE uses technology consultancy agreements with Western-based firms for all major parts (Interview 2009). Chinese auto companies have also stepped up their acquisition of foreign companies. Geely purchased Volvo from Ford in 2010, while BAIC was an early bidder for Opel from GM and ended up buying a platform (with associated IP) from Saab. Carefully chosen acquisition may assist Chinese low-carbon innovation. For instance, BAIC has established a spin-off company (Beijing Electric Vehicle) that uses the revamped Saab design and platform and attracted collaboration with both Daimler and Hyundai. Another example is SAIC, which purchased Rover (apart from the actual brand name) in 2005 and then also acquired the related MG brand. SAIC's strategy is to use the 'Roewe' brand (a Sinified variation on the Rover mark) and the upstream R&D and commercialization capacities of the Rover team at the Longbridge site in Birmingham. This includes access to automotive engineering expertise at Warwick University and hence to UK government funding for EV research. Roewe has had considerable success, with a mass-produced pure electric mini (EP11), a hybrid plug-in mid-range Roewe 550 due to be launched in 2012 and a Roewe fuel cell car to follow in 2015.

Chinese car companies are thus developing commercially viable EVs. Yet whether it is 'organic', domestic development in the automotive sector or the harnessing of learning from overseas companies, the 'upgrade' of Chinese innovation is likely to be a 'hard slog' (Rock et al., 2009). Furthermore, oil and car firms are hugely powerful within China, presenting a structural obstacle to low-carbon mobility technologies.[6] But the combined impact of the crisis of neoliberal globalisation, the emergence of disruptive innovation and new kinds of consumption may temper this conclusion.

5) Disruptive low-carbon innovation

Disruptive innovation cuts across and significantly reframes the importance of developments in China regarding other elements of a possible shift to a low-carbon mobility system (as specified in Dennis and Urry, 2009: chaps 4, 5). Such innovation has the potential to be not merely disruptive of particular technologies, firms and industries, nor even of broader sociotechnical systems (e.g. digital vs. film photography), but also of larger political economic regimes and the international division of labour of innovation.

Disruptive innovation involves the social redefinition of existing technologies by developing “cheaper, easier-to-use alternatives to existing products or services often produced by non-traditional players that target previously ignored customers” (Willis et al., 2007: 1) and/or their use in novel contexts and combinations. The concept was first introduced by Christensen (1997) in management studies, building on the work examining technological change at the level of the firm (e.g. Tushman & Anderson, 1986; Abernathy & Clark, 1985).

Christensen noted that successful innovations in numerous industries initially emerged not from advances at the high-technology frontier but of lower-cost and/or lower-technology alternatives. Such innovations targeted users and markets that were previously excluded while offering ‘good enough’, rather than cutting-edge, levels of functionality in the first instance. But they also effected a social redefinition of the technology, setting it on a novel developmental trajectory. Hence a ‘disruptive’ innovation could be contrasted with a ‘sustaining’ innovation, which simply improves technological performance according to established definitions.

Moreover, such innovation poses a ‘dilemma’ for large, successful firms. The very source of their current competitive strength, most notably in having refined systems for managing innovation along established trajectories for which there is known demand from existing customers, is likely to be a weakness regarding disruptive innovation (Christensen, 1997). As institutionalist sociology also shows, large mature industries tend to be institutionally “resistant to major innovation”, since their continuing success depends upon and entrenches particular routines, practices etc… that “constrain […] consideration of the full range of options” (Levy & Rothenburg, 2003: 185; DiMaggio and Powell, 1983).

Furthermore, by targeting lower-cost and/or lower-functionality of technology in the first instance, such disruptive innovations may well be unprofitable for large established companies, which are seeking the super-rents of hi-tech innovation, charging premium rates for the latest, cutting-edge technologies. Such innovation, therefore, can disrupt not only established firms, markets and sector boundaries but also entire corporate hierarchies.

Such innovation is very significant for low-carbon development; it is a particular strength of Chinese firms; and it is highly relevant to future personal vehicle systems. First, given the time constraints, existing technologies will have to effect most decarbonisation rather than waiting for new ‘magic bullet’ technologies. By focusing on low-cost and a wider consumer appeal, therefore, disruptive low-carbon innovation could rapidly transform socio-technical practices within the global North and a rapidly growing global South.

Secondly, the innovation focus of many Chinese firms is low cost. This need not be a matter of low-cost reproductions at lower quality of existing commodities. Rather, Chinese entrepreneurs increasingly offer a combination of low-cost combined with high-quality and diverse products that redefine market sectors and business models (Zeng and Williamson, 2007).[7] That China’s strength is in disruptive rather than low-cost and low-tech innovation thus suggests a way of squaring the seeming opposition between low-cost innovation and decarbonisation.[8] This is even attracting the attention of major TNCs such as GE as enabling ‘reverse innovation’, in which innovations pass from the global South to North (Immelt et al., 2010). Moreover, such innovation is also relevant to automobility where small, private disrupters are the ‘principal source of entrepreneurialism in the Chinese automotive industry’ (Sperling and Gordon 2009: 212/3).

The strength of Chinese firms in disruptive innovation stems, first, from considerable institutional constraints upon the familiar proprietary, hi-tech model of innovation, notably the dominance of the Chinese economy by TNC-based FDI (with associated IP dominance). Moreover, China benefits from: a strong culture of entrepreneurial tinkering together with an increasingly materialistic culture and a zeitgeist of commercial opportunity in a rapidly changing and growing socio-economy; a large number of scientifically/engineering-trained young people; growing consumer demand for high quality products but at low-cost; the reduced barriers to entry into many industries (including cars) through modularized and disaggregated innovation networks; cheap, global access to hi-tech electronics; and a changing value chain and low-cost manufacturing options.

Thirdly, then, can we expect EVs to emerge as a disruptive innovation and will China be at the forefront? The Chinese car industry is being transformed by some young but ambitious, private companies that started off as low-cost producers but are increasingly moving into more expensive and technologically sophisticated products, such as Chery or Geely. These companies are devoting considerable resources to EVs. The company attracting most attention (including from Warren Buffett), however, is BYD (‘Build Your Dreams’), which recently shifted into cars from high quality but low-cost mobile phone batteries. From its inception as a car company BYD has targeted battery-powered EVs. Its E6 comes with an impressive, if not yet independently tested, range of 300km on one charge.

BYD is also aggressive in its expansion plans, rather than seeing EVs simply as a niche product. It aims to be China's largest car company by 2015 and the world's largest by 2025, built on the EV market. In these vaulting ambitions it enjoys significant support from the city government of Shenzhen where it is based, a local state that not only lacks an established, ICE-based automotive SOE and is thus free of this power bloc, but is also known for its free-market entrepreneurialism and China's most innovative regional economy. BYD has also recently announced a 50/50 JV with Daimler (Mercedes), evidence of the interest of established car firms in its unorthodox business model while potentially expediting the improvement of BYD's innovation and technological capacities.

But not surprisingly there are significant problems facing BYD, and the Chinese EV industry. Technologically, the main bottleneck is improving the cost, life, charging time and weight of batteries. BYD has significant strengths in battery technology, reducing costs while improving functionality, but still lacks some key technologies and innovation capabilities, such as reliable, safe integration of packs of batteries into the complex electronics of a car. It has struggled to get the E6 to market and is now nearly two years behind its original schedule. In terms of EVs low-carbon credentials, another key consideration is the continuing intensity of coal combustion in generating electricity, at approximately 70% (iCET 2011). The major socio-organisational barriers are the charging infrastructure and appropriate consumer demand. These issues challenge the classification of EVs as disruptive innovation at all, in that the EV is not redefining markets by servicing the demand of previously excluded groups of customers through low-cost but good-enough and innovative products or services. Rather the EV is being constructed, including by BYD, as a vehicle "that people can use like a normal car" (BYD executive quoted in the Watts 2009; see RAE, 2010, which strongly distinguishes between complementarity and system substitution).

Moreover, EVs are much more expensive than conventional ICE cars and depend upon government support. Indeed, even considerable government support is not enough to stimulate demand for EVs in China. Consumer demand remains almost entirely absent. This is even so for hybrid cars that need no recharging; apparently one Prius was sold in 2010! (Waldmeir, 2011). Overall, then, EVs are a product innovation that Chinese entrants like BYD are attempting to fit within an old model of individual car ownership. They may be something of a red herring for the transition to low-carbon mobility, indicative of over-emphasis on new high-technologies and neglect of socio-organisational considerations.

This can be seen by comparing the EV to the electric bicycle ('E2W', electric two-wheelers). China is the undoubted leader, with approximately 120m by 2009/10, sales rising from 40,000 in 1998 to 13m in 2006 (Weinert et al., 2008). The appeal of this transport is as a low-cost, speedy (maximum speeds can reach 40-50 km/h) and 'nimble' form of transport able to weave through congested streets and onto and off pavements. Moreover, the market is dominated by small start-up Chinese companies, some of which have grown to large enterprises, using their own technology. The E2W is thus a significant Chinese disruptive low-carbon innovation, built on the recombination of technologies by small players offering low-cost but attractive alternatives and of increasingly high quality that may come to redefine both the market for vehicles (by including new groups of consumers) and the broader system of urban automobility. Moreover, the E2W is smaller, lighter and more mobile, making it much more energy efficient.

E2Ws could redefine the very concept of the 'car'. Several of China's E2W disrupters, such Lüyuan or Pearl Hydrogen, were explicitly founded as a route towards the future construction of other EVs and are already experimenting with further forms of vehicle (such as 3-wheelers) based on existing battery or fuel cell technologies (Tyfield et al., 2010). The form of these larger vehicles is open to considerable experimentation and radical redesign, since an electric drive train removes the engine and transmission of an ICE around which the rest of the car is built. Developing EVs from E2Ws enables innovating companies and hobbyists to explore disruptive possibilities. This is particularly clear when set against the growing practice of *shanzhai* or 'knock-off brands': the tinkering of small garages with existing cars to convert them to electric vehicles (Wang 2011). This practice is already widespread in many smaller Chinese cities and focuses on small vehicles, often 3-wheelers.

The competitive threat of this 'game-changing' innovation is now attracting the attention of established car companies. At the Shanghai Expo in 2010, GM-SAIC displayed its EN-V bubble car (Economist, 2010), which cannot be easily classified as either an EV or an E2W since it sits two people side-by-side but has only two parallel wheels, which gyroscopically raise the vehicle up into a balanced position when the engine is on. Furthermore, this electric bubble car enhances the possibilities for redesign, with a front entrance rather than side doors and a carbon-fibre rather than steel shell, giving it a futuristic and 'wow' appearance likely to appeal to the technology-hungry Chinese consumer. This futurism is also bolstered by using digitisation and ICTs, such as being able to summon it by phone, automatic parking, peer communication and sensors to prevent collisions. Production involves considerably less heavy industry with costs down 20% by comparison with a conventional car, hence reducing both the retail price and barriers to entry for competition, and hence pushing prices down further.

Such disruptive innovation and the increasingly credible ‘wild card’ threat of redefining mobility means that this Chinese innovation may be ‘game-changing’, including for the role of foreign innovation and investment in China. This may recontextualize and transform the problems of international collaboration and technology transfer in the conventional car industry. For instance, whereas GM responded to government demands to set up an innovation centre by establishing PATAC, an engineering centre for localization of products at the cost of only $25m and with commercial benefits for GM in this capacity, the growing competitive threat of disruptive innovators will mean such incumbents will be commercially compelled to bring new technologies and to seek out innovative collaboration in China, redirecting innovation some super-rents to China. There is also the growing possibility of smaller firms (e.g. Formula 1 Mclaren) from the global North seeking collaboration in China.

In either case, through localised modularisation and the associated local economic development, including of novel ‘clusters’, this will also stimulate further building of innovation capacities for a competitive lead. And given that innovation is not static, this could dramatically accelerate improvement of innovation in China, against the slow and uncertain catch-up, low technology transfer and continuing OECD dominance of IP under the proprietary, hi-tech model of recent decades. Furthermore, as disrupters establish new industries – founded on low barriers to entry, more relational and less proprietary models of knowledge and innovation management (including different forms, fora and foci of R&D), and new production models – this will also directly challenge, and thus deepen the crisis of, the over-propertised neoliberal accumulation regime of financialized globalisation; a change in the ‘knowledge economy’ towards more ‘open’ forms now widely observed across various industries (Chesbrough, 2005; Heller, 2008; von Hippel, 2006).

Disrupters might thus change the relation even of overseas companies (both TNCs and SMEs) to IP in that they will have to pursue business in China despite or regardless of the risk of IP loss/theft rather than choosing to withhold it on the assumption that catch-up is unlikely (e.g. Hurley, 2011). Indeed, since such innovation is the competitive advantage of firms but their formal IP and technologies are increasingly insecure, there will be a commensurate shift to the advantages of tacit and embodied knowledge that will spur further innovation in the West in order to maintain the competitiveness of these tacit capacities.

All these advantages of disruptive innovators, however, must also be understood in terms of their world-making potential, i.e. as sources of power with significant political implications. In particular, such Chinese disruptive, low-carbon innovation could forge a Gramscian historic bloc that will be construct a new regime of accumulation against carbon capitalism, both in China and globally. The advantages of E2Ws are not simply the technological advantages of their lightness and better energy efficiency, but their potential for transforming the model of urban mobility, including the associated political economy, both national and global. And this despite the fact that Chinese government support of electric mobility is almost entirely for EVs, with e-bikes penalized in many major cities (e.g. Pucher et al. 2007: 389) and *shanzhai* EVs languishing in a legal 'grey area' (Wang 2011), despite these promising more for the environment, urban mobility and Chinese 'world-leading' firms. A key difference between these two routes in China is consumer demand.

6) Consumption: deprivatisation, digitisation and smart vehicles

As Bhidé (2008) stresses, a vibrant and 'venturesome' culture of consumption of new, innovative products is often crucial in incubating localized innovation capacity and is a strength of the American innovation system. Three elements of a post-car system are relevant: deprivatising ownership, digitising cars and 'smart'-ing vehicles by introducing real-time and two-way information flows (Dennis and Urry, 2009). These enable "smart paratransit, smart carsharing, dynamic ridesharing and telecommuting" and "neighbourhood cars" (Sperling and Gordon 2009: 8). These would enable the management of congestion and energy inefficiency that vehicle technology cannot resolve.

First, there is some experimentation in deprivatisation and smart cars in China. Beijing is exploring moves to higher charges and administrative measures to reduce private car use alongside the ongoing expansion of public transport, especially the metro (New York Times 2011). Similarly, the singular power to mobilize resources and orchestrate social life of the Chinese political system would be amenable to constructing digitally coordinated traffic systems. But the low demand for EVs is matched by the relative absence of deprivatised car clubs and digitised cars. Nor is this simply a matter of the expense of these more hi-tech vehicles or the lack of innovation capacity amongst Chinese firms for such technologies. Rather, there are significant social barriers to these innovations.

China is an increasingly consumerist society reflected in the widespread ambition to own a car, and the bigger the car the better. This manifests a deeper transformation based on the current political economic regime of the CCP-led national project of rapid economic growth, combined with little socio-political emancipation. There is the gradual retreat of the party-state from coordinating economic life and its replacement with the market economy, hence freeing up private enterprise and destroying the support mechanisms of state provision. The result is what Chang (2010) neatly calls 'individualization without individualism', increasing personal responsibility for one's economic well-being and experience of personal autonomy in economic choices but without the socially-effective ideology of the individual as locus of value, political autonomy and open expression. For those Chinese who have become adults since 1989 – the primary beneficiaries of this change – there is increasing and jealously guarded personal autonomy but expressed through material and status competition.

The private ownership of a car is arguably the primary manifestation of this as the top economic priority of most Chinese. Young people especially often prefer to own a car (which displays success even while stationary), taking longer, slower journeys and/or working longer hours in order to avoid 'rush hour', and to live with their parents (whose flat no one will see). Moreover, against both deprivatisation and 'efficient' social coordination afforded by digitisation, the very appeal of the car is the promise of the expansion of a (consumerist) personal autonomy and even rebellion, just as the car was marketed in the West in the post-war period (Paterson, 2007). In short, the Chinese dream is American-style automobility. China is thus creating a problem that the West is trying to solve, rather than capitalizing on the relative absence of this obstacle to a different post-car system (Zhao, 2006).

The trend is thus towards further personal car ownership, increased pollution, gridlock, car deaths and GHG emissions. Moreover, these problems are potentially more severe in China due to the challenges of a 'compressed modernity' (Jacques, 2010; Chang, 2010), which exacerbates the potential for mismanagement of socio-technical risks; a trend exacerbated further by the national priority of 'rush-to' GDP growth which encourages the cutting of corners to meet overwhelming political-economic imperatives (Han and Shim, 2010).

This intensifies social pressure, evidenced in the growing influence of the internet and social media. China is a society 'online', with the latest smartphones ubiquitous and an estimated 500m internet users by 2010. Their primary use is relatively anonymous social interaction (via message boards, chatrooms or social media such as Sina Weibo, China's Twitter, the original being banned), gaming and e-commerce (e.g. Ali Baba, Baidu). But interactive social media are increasingly used to express dissent, whether as alternative accounts or as outrage, including socio-technical mismanagement such as the High Speed Rail crash outside Wenzhou in June 2011 (Yang, 2009).

These trends, however, may be directly significant for low-carbon mobility, with Chinese disruptive innovators capitalizing upon this high level of digitisation. Because of their consumer appeal it might be possible that services and products develop that offer Chinese consumers *both* the experience of enhanced personal autonomy with the affirmation of superior material status *and* more efficiently coordinated mobility. Sperling and Gordon (2009: 222) describe the emergence of "dynamic ridesharing" services "using Web sites and other forms of wireless communication", with a web survey finding more than 30 Chinese websites for such services and reports of over one million matches using such "online ridesharing bulletin boards". Moreover, "approximately 90 percent of posts requested money" on the largest such website showing that if this succeeds then it will not be based on philanthropy, public spiritedness or government subsidy. As these services and vehicles become successful, their distinctive 'Chineseness' could also mobilize considerable techno-nationalist pride. Were that to happen, the 'American Dream' of a large car would face a compelling opponent of a post-car system.

Such disruptive innovation would thus transform consumers themselves. In particular, these disruptive low-carbon innovations (at least those that succeed) could act as technologies that transform and collectively redefine and responsibilize consumers, making them the subjectivities of an advanced liberal form of governance of a low-carbon and deprivatised sociotechnical mobility. And it will achieve this via consumption itself, rather than by political fiat or emancipation.

Chinese disruptive innovation may thus here be a key *political* force – for better or worse – in forging a new historic bloc of an emergent middle class that is simultaneously: the most important (global!) source of new consumer demand; online and enabled by 2.0 social media; and responsibilized, especially regarding such global risks as GHG emissions and embodying a new moral economy of 'necessary' versus 'profligate' mobility. In this world of new subjectivities the deprivatisation of vehicles would be transformed from an unthinkable infringement on personal autonomy. Instead, personal car ownership itself would be viewed as a decadent 'Western' extravagance. Status would be associated with the fashionable membership of car sharing clubs with the best services and latest vehicles on the fastest toll-roads. Similarly, regarding digitisation and smart cars, instead of being the admission of Big Brother into a cherished space of individual 'freedom', old mechanical vehicles would become the preserve of selfish, off-line, unmanageable, wayward and dangerous drivers. Social status would derive from using the most sophisticated in-vehicle ICTs, the most efficient journey planning and real-time coordination software, and achieving the greatest level of software-managed energy efficiency. Steel-and-petroleum cars would seem so twentieth century!

Social enterprises would run fleets of cars, leading to more centralised and manageable credit risks, offering different levels of access and service for different tariffs. This would also transform the financing of automobility, with further significant political economic repercussions. Instead of covering the personal purchase of vehicles, at the limit wages for workers would need to cover only minimum transport fees for workers to get to work on time, the dangers, inconvenience and discomfort of this journey being their business alone. As such, and against the relative empowerment of an emergent Chinese middle class just discussed, this would break the direct link between expanded production/ accumulation and wages, further disempowering (industrial) labour and enabling a further redefinition of labour/capital relations towards relatively uncontested accumulation of productive capital.

Yet such a development would be particularly significant, especially in conjunction with a transformed production model and shifting IDLI that creates increasing opportunities for lucrative ‘knowledge’ work in China associated with automobility. The main source of global demand of an increasingly affluent Chinese middle class (including such knowledge workers) will be progressively enabled in a positive feedback loop of greater opportunities for rewarding well-paid work through increasing membership of car clubs, increasing demand for such services, the latest low-carbon vehicles from responsibilized, online, cosmopolitized, ‘green’ consumers, and greater localized development of the economy and innovation.

Conversely, a larger section of the Chinese population, again on which continued accumulation on a global scale will increasingly depend – an industrial workforce of some 533m by 2020, or over 100m more than the entire aggregated equivalent workforce in the global North (Jacques, 2010: 186) – may well be exposed to ever-more cut-throat, insecure and socially undervalued manufacturing work, their contribution to production, consumption (including of mobility) and innovation effectively irrelevant from the perspective of capital accumulation except insofar as their potential for its interruption is minimized. Evidently, this model of accumulation will drastically *increase* the already high levels of inequality in China.

7) Conclusion

We have examined the prospects of a post-car system developing in China. We showed that low-carbon disruptive innovation is important in analysing the prospects of a new system of production, consumption and innovation, so transforming relationships between Chinese and ‘Western’ partners and markets. We also demonstrated that this kind of innovation is important in constructing new imagined communities, subjectivities and associated technologies of control.

Our analysis of contemporary China highlights the exceptional level of state/city commitment to EVs which may be the source of a genuine ‘100 flowers’ movement; the lack of a world-leading automotive industry in China, so that while established SOEs are a strong lobby they are open to challenge; the historically unprecedented and massive urbanization of China, which offers multiple opportunities to business and policy to innovate new urban forms; the overlapping crises undermining the current model of automobility, which is still unfolding and yet to hit China in its full severity; and China’s particular strength for low-cost, good quality but not high-tech, proprietary innovation such as E2Ws or *shanzhai* as agent of ‘positive’ change that may capitalize upon structural destabilisation.

And there are plenty of possible destabilisations. We would expect transitions here to involve multiple overlapping crises rather than smooth movement from ‘here’ to ‘there’. Such deepening crises could involve: urban congestion and/or pollution set against a growing environmental movement and 2.0-enabled proto-civil society; a global oil shock or other huge resource price spike with inflationary consequences; a renewed slump in the global economy with state measures exhausted and spreading to the BRICs; falling car sales and concomitant GDP slump below the sacrosanct ‘8%’ p.a.; finance/property bubbles bursting; growing tension with Western TNCs over technology transfer and IP sharing; a panic triggered by a seeming EV breakthrough elsewhere in the world; or some global security emergency or war (whether starting in North Korea, Taiwan, Iran, Pakistan etc…).

‘China’ could be the first society in which there emerges successful experiments in post-car low(er)-carbon mobilities *especially* as these varied crises could hit home; this is, after all, how 20th century automobility emerged in the US. But this will be take 15-20 years with EVs unlikely to make profits in the next 5-10 years without government support (Feng 2011), so that it seems unlikely that China will ‘leapfrog’ (Gallagher, 2006) to be a standalone, global leader of a new EV automobility. Leadership will emerge slowly because it will be inseparable from socio-political changes on a global scale.

We have explored scenarios of how a range of elements could come together to construct possible post-car systems, but our tentative analysis leads primarily to questions not answers. Could the world’s greatest ever ‘bike society’ make a dramatic return and lead the world, or at least much of the world, in a post-car low energy system of electric bikes and related tiny electric vehicles? Could the love of the technologically new reflect itself in China in a system of fashionable digitally coordinated bikes and small mobile machines that are so 'twenty first century', 'such fun'? And for whom in China and then elsewhere as the four-person privately-owned car comes to be seen as so 'last century'!

References

Abernathy W, Clark K, 1985, "Innovation: Mapping the winds of creative destruction" *Research Policy* **14** 3-22

Altenburg T, Schmitz H, Stamm A, 2008, "Breakthrough? China's and India's transition from production to innovation" *World Development* **36**(2) 325-344

Anderson B, 1983 *Imagined Communities: Reflections on the Origin and Spread of Nationalism* (Verso, London)

Dennis K, Urry J, 2009 *After the Car* (Polity, Cambridge)

Bhidé A, 2008 *The Venturesome Economy* (Princeton University Press, Princeton, NJ)

Blackburn S, 2006, "Finance's fourth dimension" *New Left Review* **39** 39-72

Boston Consulting Group 2011, *Powering Autos to 2020: The Era of the Electric Car?* (BCG, Boston)

Chang K-S, 2010, "The Second modern condition? Compressed modernity as internalized reflexive cosmopolitanism" *British Journal of Sociology* **61**(3) 444-464

Chen L, 2008, "International cooperation & governance of low-carbon technologies innovation", Tsinghua University, Beijing, 10 December; copy from L. Chen, School of Public Policy & Management, Tsinghua University, Beijing

Chen Q, Liu S, Feng F, 2004 *The Coming of the Auto Age in China* (China Development Press, Beijing)

Chesbrough H, 2005 *Open Innovation* (Harvard Business School Press, Cambridge, MA)

China Daily 2011, "China to reduce carbon intensity by 17% by 2015", 29 July, http://www.chinadaily.com.cn/usa/china/2011-07/29/content_13006931.htm

Christensen C, 1997 *The Innovator's Dilemma* (Harvard Business School Press, Cambridge, MA)

Climate Group 2008 *China's Clean Revolution* (The Climate Group, Beijing & London)

Cohen W, Levinthal D, 1990, „Absorptive Capacity: a New Perspective on Learning and Innovation" *Administrative Science Quarterly* **35** 128-152

Dean M, 2010 *Governmentality: Power and Rule in Modern Society* 2nd edition (Sage, London)

Dicken P, 2007 *Global Shift: Mapping the Contours of the World Economy* 5th edition (Sage, London)

DiMaggio P, Powell W, 1983, “The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields” *American Sociological Review* **48**(2) 147-160

The Economist 2010, “The bubble car is back: cheap, small and simple – an idea from the 1950s bubbles up again”, 30 September, http://www.economist.com/node/17144853

Ernst D, 2008, “Innovation Offshoring and Asia’s Electronics Industry – The New Dynamics of Global Networks” *International Journal of Technological Learning, Innovation & Development* **1**(4) 551-576

Feng A, 2011, “Electric vehicles require government support: No profits for 5-10 years”, 163.com, 4 September, http://auto.163.com/11/0904/13/7D429L0F00084TV4.html (in Chinese)

Feng W, Wang S, Ni W, Chen C, 2004, “The future of hydrogen infrastructure for fuel cell vehicle in China and a case of application in Beijing” *International Journal of Hydrogen Energy* **29** 355-367

French P, Chambers S, 2010 *Oil on Water: Tankers, Pirates and the Rise of China* (Zed Books, London)

Gallagher K S, 2006, “Limits to leapfrogging in energy technologies? Evidence from the Chinese automobile industry” *Energy Policy* **34** 383-394

Gallagher K S, 2007 *China Shifts Gears* (MIT Press, Cambridge, MA)

Gao P, Wang A, Wu A, 2008 *China Charges Up: The Electric Vehicle Opportunity*, McKinsey Global Institute, New York, http://www.mckinsey.com/locations/greaterchina/mckonchina/pdfs/China_Charges_Up.pdf

Geels F, 2005, “The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930)” *Technology Analysis & Strategic Management* **17**(4) 445-476

Gerschenkron A 1962. *Economic backwardness in historical perspective, a book of essays* (Harvard University Press, Cambridge, Mass)

Girardet H, 2004 *CitiesPeoplePlanet* (Wiley-Academy, Chichester)

Han S-J, Shim Y-H, 2010, “Redefining second modernity for East Asia” *British Journal of Sociology* **61**(3) 465-488

Heinberg R, 2005 *The Party’s Over: Oil, War and the Fate of Industrial Society* (Clearview Books, New York)

Heller M, 2008 *The Gridlock Economy* (Basic Books, New York)

Homer-Dixon T, 2006 *The Upside of Down* (Souvenir, London)

Hopkins R, 2008 *The Transition Handbook* (Green Books, Totnes)

Hung H, 2009 “America’s head servant? The PRC’s dilemma in the global crisis” *New Left Review* **60** 5-25

Hurley J, 2011 “Far East copycats stealing our business”, *The Daily Telegraph* 26 July, page B7

iCET 2011, “Electric vehicles in the context of sustainable development in China”, UN Commission on Sustainable Development, Nineteenth Session, Background Paper 9, 2-13 May, New York

IEA 2011, *Oil Market Report*, International Energy Agency, Paris, 12 October, http://omrpublic.iea.org/currentissues/full.pdf

Immelt J, Govindarajan V, Trimble C, 2009, “How GE is disrupting itself” *Harvard Business Review* October 56-65

Jacques M, 2010, *When China Rules the World* (Allen Lane, London)

Leggett J, 2005, *Half Gone. Oil, Gas, Hot Air and Global Energy Crisis* (Portobello Books, London)

Lemke T, 2011, *Foucault, Governmentality, and Critique* (Paradigm Publishers, Boulder, CO)

Levy D, Rothenberg S, 2003, “Heterogeneity and change in environmental strategy: technological and political responses to climate change in the automobile industry”, in *Organizations, Policy, and the Natural Environment* Eds A Hoffman, M Ventresca (Stanford University Press, Stanford) pp 173-193

Leydesdorff L, Wagner C, 2009, “Is the United States losing ground in science? A global perspective on the world science system” *Scientometrics* **78**(1) 23-36

McKinsey Global Institute, 2009, *Preparing for China’s Urban Billion* (MGI, Shanghai)

Mikler J, 2009, *Greening the Car Industry: Varieties of Capitalism and Climate Change* (Edward Elgar, Cheltenham)

Mitchell W, Borroni-Bird C, Burns L, 2010, *Reinventing the Automobile* (MIT Press, Cambridge, Mass)

Morris I, 2010, *Why the West Rules… For Now* (Profile Books, London)

Nanochina, 2007, “ZAP opened a joint development office in Beijing to expand research in nanotechnology”, 8 August, http://www.nano.org.uk/nanochina/english/index.php?option=com_content&task=view&id=816&Itemid=1

National Bureau of Statistics of China (NBS) 2005 *Statistical Communiqué of the People’s Republic of China on the 2004 National Economic and Social Development* (NBS, Beijing) http://www.stats.gov.cn/was40/gjtjj_en_detail.jsp?channelid=4920&record=37

NBS 2011 *Statistical Communiqué of the People's Republic of China on the 2010 National Economic and Social Development* (NBS, Beijing) http://www.chinaero.com.cn/english/statistical_data/03/93313_3.shtml
New York Times 2011, "China aims to rein in car sales", 5 September, http://www.nytimes.com/2011/09/05/business/global/china-changes-direction-on-car-sales.html?pagewanted=all
Nolan P, 2004, *Transforming China: Globalization, Transition and Development* (Anthem, London)
Nyiri P, 2010, *Mobility and Cultural Authority in Contemporary China* (University of Washington Press, Seattle)
Paterson M, 2007, *Automobile Politics: Ecology and Cultural Political Economy* (Cambridge University Press, Cambridge)
Pucher J, Peng Z, Mittal N, Zhu Y, Korattyswaroopam N, 2007, "Urban transport trends and policies in China and India: Impacts of Rapid Economic Growth" *Transport Reviews* **27**(4) 379-410
Rajan S, 1996, *The Enigma of Automobility: Democratic Politics and Pollution Control* (University of Pittsburgh Press, Pittsburgh)
Rock M, Murphy J T, Rasiah R, van Seters P, Managi S, 2009, "A hard slog, not a leap frog: Globalization and sustainability transition in developing Asia" *Technological Forecasting and Social Change* **76** 241-254
Royal Academy of Engineering, 2010, *Electric Vehicles: Charged with Potential* (London: RAE)
Rubin J, 2009, *Why your world is about to get a whole lot smaller* (Virgin, London)
Shanghai Star 2004, "Road accidents kill 300 a day in China", 12 April, http://www.chinadaily.com.cn/english/doc/2004-04/12/content_322695.htm
Sperling D, Gordon D, 2009, *Two Billion Cars* (Oxford University Press, Oxford)
Steinfeld E, 2004, "China's shallow integration: networked production and the new challenges for late industrialization" *World Development* **32**(11) 1971-1987
Thun E, 2006, *Changing Lanes in China* (Cambridge University Press, Cambridge)
Tushman M, Anderson P, 1986, "Technological discontinuities and organization environments" *Administrative Science Quarterly* **31** 493-465
Tyfield D, Jin J, 2010, "Low-carbon disruptive innovation in China" *Journal of Knowledge-based Innovation in China*, **2**(3) 269-282
Tyfield D, Jin J, Rooker T, 2010 *Game-Changing China: Lessons from China about Disruptive Low-Carbon Innovation* (NESTA, London)
Urry J, 2011, *Climate Change and Society* (Polity Press, Cambridge)
von Hippel E, 2005, *Democratizing Innovation* (MIT Press, Cambridge, MA)

Waldmeir P, 2011, “Beijing poised to rethink electric car policy”, *Financial Times*, 22 August, http://www.ft.com/cms/s/0/b213d66e-ccaf-11e0-b923-00144feabdc0.html

Wang J, 2011, “The Shanzai Electric Car Revolution in China”, http://blog.p2pfoundation.net/the-shanzai-electric-car-revolution-in-china/2011/06/03

Watson J, Byrne R, Stua M, Ockwell D, Zhang X, Zhang D, Zhang T, Zhang X, et al., 2011 *UK-China Collaborative Study of Low Carbon Technology Transfer: Final Report* (Sussex Energy Group, Falmer)

Watts J, 2009, “China tries to jump-start green car market” *The Guardian*, 3 April, http://www.guardian.co.uk/environment/2009/apr/02/china-e6-electric-car?INTCMP=SRCH

Watts J, 2011, “China plots course for green growth amid a boom built on dirty industry”, *The Guardian*, 4 February, http://www.guardian.co.uk/world/2011/feb/04/china-green-growth-boom-industry?INTCMP=SRCH

Weinert J, Ogden J, Sperling D, Burke A, 2008, “The future of electric two-wheelers and electric vehicles in China” *Energy Policy* **36** 2544-2555

Willis R, Webb M, Wilsdon J, 2007, *The Disrupters* (NESTA, London)

Winebrake J, Rothenberg S, Luo J, Green E, 2008 “Automotive Transportation in China: Technology, Policy, Market Dynamics, and Sustainability” *International Journal of Sustainable Transportation* **2** 213- 238

World Bank, 2011, *The China New Energy Vehicles Program* (World Bank, New York)

Xinhua, 2011, “China's new energy vehicle sector faces growing pains”, 16 July, http://news.xinhuanet.com/english2010/china/2011-07/16/c_13989691.htm

Yan X, Crookes R, 2009, “Reduction potentials of energy demand and GHG emissions in China’s road transport sector” *Energy Policy* **37** 658-668

Yang G, 2009 *The Power of the Internet in China: Citizen Activism Online* (Columbia University Press, New York)

Zeng M, Williamson P, 2007, *Dragons at your Door: How Chinese Cost Innovation is Disrupting Global Competition* (Harvard Business School Press, Cambridge, MA)

Zhao J, 2006, “Whither the Car? China’s Automobile Industry and Cleaner Vehicle Technologies” *Development & Change* **37**(1) 121-144

---

[1] This paper draws upon research funded by the ESRC under their Advanced Institute of Management (AIM) Programme, 2006-10. We are grateful for comments from co-researchers.

[2] See also Morris (2011) for an interesting analysis, specifically regarding the past and future of ‘West’ vs. ‘East’ (i.e. China), in which energy revolutions and climate change play important explanatory roles.

[3] There is also significant effort on development of liquid fuels for vehicles, either by liquefaction or gasification processes, from China’s largest fossil fuel source, namely (low-grade) coal. Unless, however, this leads to gasification (producing hydrogen rather than hydrocarbon fuels) *combined* with

carbon capture and sequestration of the resulting carbon dioxide – an unproven and expensive technology that China has only recently shown any government interest in developing (China Daily, 2011) – such a development would produce a massive *increase* in the intensity of transport-related emissions in China. Biofuels are also gaining increasing government attention, but remain of minor significance not least due to food security concerns (Yan and Crookes, 2009).

[4] The interviews were carried out both in China and the UK in April - July 2009 by one of the authors. For some interviews we worked with a team led by Chen Ling of Tsinghua University, under a grant from Tsinghua University's Low Carbon Research Fund.

[5] For instance, one industry interviewee noted that government support in China, while growing, still represents less than 10% of the funds needed for R&D for a new AFV.

[6] For instance, the car industry is a national pillar industry and the major SOE car firms are both greatly prized and powerful in national and local politics, while China's SOE oil companies are now amongst the largest companies in the world, Sinopec and China Petroleum at numbers 5 and 6 in the 2011 Fortune Global 500.

[7] Companies include here the electrical goods giant Haier, piano maker Pearl River, consumer electronics maker TCL, China International Marine Containers Group (CIMC), computer company Dawning, port equipment manufacturer ZPMC, universal joint manufacturer Wanxiang, solar thermal giant Himin Group, little known biomass company Shengchang Bioenergy, the car company Chery, and battery-turned-car manufacturer BYD.

[8] Or '*poju*', game-changing innovation, in Chinese, in order to reduce the strong negative connotations of the word 'disruptive' (Tyfield et al., 2010). Note also that disruptive innovation is thus *orthogonal* to the issue of hi-tech vs. low-tech. As a *socio*technical form of innovation, the point is not that it uses no or low technology (this is explicitly not the case, for instance, regarding examples such as digital cameras) but that the innovation is not simply an advance along an established technological trajectory.