China: Beyond the Global Production Line

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Introduction

In this chapter, we will study the role of China in stimulating global change in two distinct ways. The first, which appears in main section two, refers to aspects of China's engagement in the highly globalised ICT industry. This account briefly explores the manner in which China, or rather leading Chinese or Chinese-based non-western firms like *Huawei*, not only penetrate western markets but also base themselves in western R&D locations as these are vacated through competitiveness failures. There follows a section based on an account of a large industrial platform which embodies ICT and other applications (e.g. batteries) in 'green' technologies like solar energy, light emitting diode (LED) lighting, electric vehicles, renewable energy, construction and the design of eco-cities. This signifies recognition in China that critiques from the west about excessive fossil fuel emissions in China and the contribution these make to global warming has some practical purchase. As China seeks to evolve rapidly away from its 'world factory' reputation, its success in innovating a significant 'green technology' platform will decide whether it is willing and able to make a global contribution to the environment's 'long emergency' domestically and if by so doing it creates new, more affordable, means whereby the world may follow suit in the years to come.

In the first section of the chapter following this introduction attention is devoted to three complementary theoretical perspectives that seek to explain transition in the dominant production regime fuelling market-led development from one based on fossil fuels to one based on renewables. The first of these adopts a multi-level perspective regarding the de-stabilisation and resilience to 'shocks' of complex adaptive systems such as socio-technical systems (STS). The second focuses on the manner complex adaptive systems resolve de-stabilisation shocks by means of innovations associated with recovery from, creative destruction, events. And the third, the evolutionary economic geography (EEG) perspective which by its emphasis on path dependence, path-interdependence, relatedness and proximity helps synthesise a theoretical framework connecting regional development to these three change-drivers, namely transition, resilience and innovation. It will be argued that China's global engagement has stimulated and been stimulated by all three.

Path dependence has had an overly equilibrium perspective (David, 1985), tending to emphasise negative 'lock-in' issues in favour of a more open and innovation-friendly perspective (Martin & Sunley, 2006; 2010). Moreover, in tune with this more positive view, a prevailing reliance on 'chance' explanations for innovative events (Arthur, 1994) is questioned. In its place a more socially constructive approach reflective of Garud & Karnøe's (2001) notion of 'mindful deviation' by social agency to effect change is introduced. This aligns to an important EEG concept, namely 'proximity' where path interdependence may occur. Under conditions of proximate path interdependence, innovation is able to occur in line with the key complexity theory concepts of 'preadaptation' and the 'adjacent possible'. Accordingly, as we shall see, despite geographically dispersed 'relational' proximities within, for example, multinational corporate structures innovative acts generally occur in specific localised spaces even if knowledge from many global locations is recombined to achieve them. The exception is the phenomenon of 'the multiple' where the same innovation occurs simultaneously in different global locations (Johnson, 2010).

Three Perspectives on Co-evolutionary Transition

The Multi-Level Perspective (MLP)

Starting at the simplest level, MLP is a one-dimensional dynamic representation of the progress of innovation from an initial, competitive, niche-market situation through a trajectory that leads to it becoming a 'dominant design' or a small circle of diverse dominant designs within the socio-technical system (STS). The STS comprises the main sub-systems of modern society, including: industry, markets, science, technology, culture and policy sub-systems. For a dominant deign from a previous technological paradigm to be challenged by an innovative dominant design and eventually displaced, there has to be a high degree of 'buy-in' by each sub-system within the STS. This is the essence of 'co-evolution' in the sense that STS sub-systems evolve at their own pace in relation to evolutionary movement by the accompanying sub-systems. During this process interactive loops from the array of sub-systems give stimulus or feedback to the 'emergent' eco-innovation paradigm and its 'dominant designs'. Over lengthy time periods from innovation initiation (in some well-known cases like wind turbine energy this can take at least thirty years), the preceding dominant design has been de-stabilised and the eco-innovation (e.g. renewable energy) design combination (e.g. wind, solar, marine, biogas, biomass) triumphs as the main source of energy supply at 'landscape' (i.e. nationally and globally pervasive) level. The process is

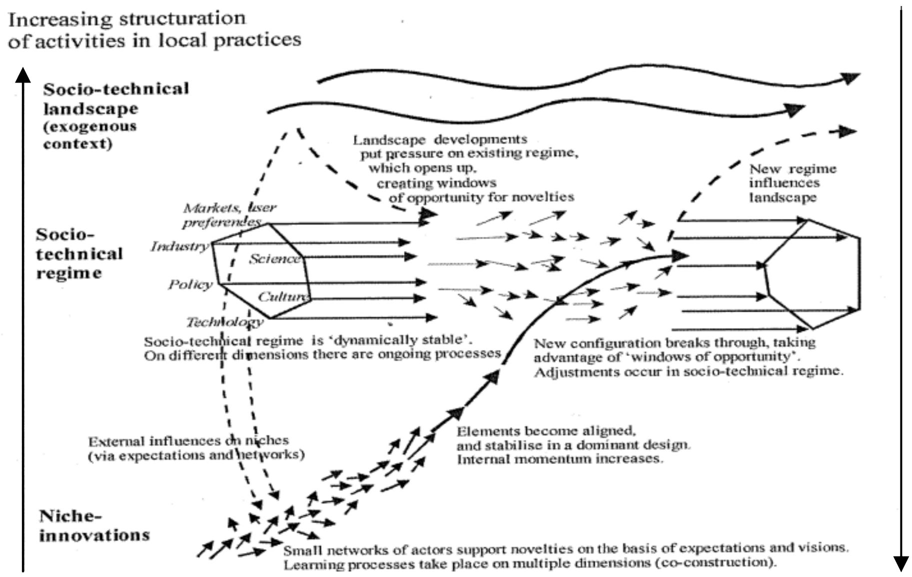

Fig. 1. Multi-level Perspective on Evolution of Eco-innovations

Source: Geels (2006)

represented in Fig. 1. At the niche level are candidate innovations of the kind listed in Fig.1 including also innovations in systems, components, parts and services. These compete robustly either as single firms or firm networks. Such competition is likely to receive stimulus from a process called 'strategic niche management' comparable to 'infant industry' protection, whereby national and/or regional regulation, subsidy and incentive structures protect emergent technologies according to politically set priorities. Different parts of the STS may be influential at different times. In some cases 'culture' can be important in the articulation of a discourse of critique and renewal of political priorities. At other times 'science' or 'technology' may be to the forefront as discoveries or innovations evolve solutions to hitherto intractable problems. If these enable innovations to be competitive in 'markets', they will begin to articulate consumer preferences which 'industry' should gear up to fulfil. If not, but niche eco-innovations provide desirable public goods, 'policy' may be to the fore with an appropriate subsidy regime. This approach is designed to address the lengthy processes attending the transition of the global economy from non-renewable energy to renewable energy. In that event, at the level of the socio-technical regime, de-stabilisation will not begin until dominant designs enter the market, attract customers and begin to displace, for example, fossil fuel energy in favour of leading renewable energies or conventional cars with renewably-fuelled ones of various kinds.

It is clear that MLP contains useful theoretical and practical guidance in relation to envisaging and envisioning a process by which eco-innovation can be stimulated. The notions of 'eco-innovation niche' and 'strategic niche management' are interesting and important. At the STS level, it is also important to recognise the co-evolutionary nature of the distinctive sub-systems that need to be in some degree of stable alignment to bring about regime-level change at least in a potentially 'lighthouse' region, city or preferably country. Finally, it is important also to recognise the strong element of feedback or stimulus given by national legislation that creates conditions whereby eco-innovation may become 'emergent' through incentives, regulatory instruments and subsidies. The weaknesses of this approach are threefold; first, despite its origins in the policy-world it does not give much guidance on eco-innovation stimulus *governance*. Rather it tends to rely rather heavily on a possibly naive belief that eco-innovation only comes from small firms operating in highly competitive niche markets. Secondly, it lacks a notion of de-stabilisation or crisis as a motivator for speeding-up eco-innovation processes, tending to take a benign perspective on system innovation (compared to, for example, Schumpeter's 'creative destruction' concept of innovation). Finally, it lacks dynamism in general and specifically in regard to issues of space (e.g. 'lighthouse' or 'transition regions') and time (i.e. slow versus fast changes in conditions for eco-innovation). These questions are treated in a more sophisticated but also quite complex manner in the 'Panarchy' perspective.

The MLP Resilience Model

Resilience is a related but more dynamic theoretical approach that facilitates understanding of the source and role of paradigm and regime change in adaptive systems. This seeks to understand transition in terms of both gradual and episodic change, on the one hand, and local and global change, on the other. It thus shares with MLP the interest in STS, multi-level interactions and co-evolution but it promises to overcome MLP deficiencies in space, time and dynamism. It seeks to recognise but not be theoretically dominated by Simon's (1962; 1973) seminal thinking on the *hierarchical* nature of complex adaptive systems by taking into account the cross-scale, interdisciplinary and dynamic nature of change theory. Of key importance to understand resilient responses to a major endogenous or exogenous shock to the system are two key variables

- *System potential* sets the limits to what is possible - the number and kinds of future options available (e.g. high variety of industry provides more future options than low variety)
- *System connectedness* determines the degree to which a system can control its own destiny through internal controls, as distinct from being influenced by external variables (e.g. a region with high legislative and taxation control in its multi-level system demonstrates high connectedness)

Together, these determine *System Resilience* or how vulnerable a system is to unexpected disturbances and surprises that can exceed or break that control. System resilience also emphasises the interconnectedness of levels between the smallest and the fastest and the largest and the slowest (Folke 2006). The large, slow cycles set the conditions for the smaller, faster cycles to operate. But the small, fast cycles can also have an impact on the larger, slower cycles. Thus, in respect of innovation, a national and/or supranational regime may set favourable conditions for innovation. A case in point would be the 'shock' to China's command economy system by Deng Xiao Ping's internal reforms that paved the way to regional economic experimentation with marketization at provincial or city-regional levels. In principle, though, a region may anticipate its slow-moving institutions and begin swiftly innovating independently, expressing local collective demand or proto-market building by technologically advanced or interested firms. Either way, resilience can be seen to be a precondition for restoring adaptive system stability.

Complexity Theory

Complex systems display: dispersed interaction (e.g. regionally specialised knowledge domains); absence of a global controller; cross-cutting hierarchical organisation (e.g. multiple economic governance jurisdictions, including MLP); continual adaptation; permanent innovation; and 'far-from-equilibrium' (prone to crises) system dynamics (Arthur, Durlauf & Lane, 1997). In Kauffman (2008) it is demonstrated that key features of complex systems are scientifically 'lawless' in that they cannot be reduced to the level of understanding provided by physics. This is due to two features that are of especial interest to the understanding of ecological and economic development namely 'Preadaptation' and the 'Adjacent Possible'. The 'autopoeisis' (self-organization) and 'autocatalysis' (self-energising) characteristics of complex ecological and economic systems can be understood in terms of their key characteristics of 'preadaptation,' on the one hand, and pursuit of the 'adjacent possible' on the other.

In the economic sphere, Kauffman (2008) describes a case of preadaptation in the economy. It concerns the invention of the tractor, the massive engine of which continually broke its chassis when mounted. An engineer, noting the scale and rigidity of the engine block, suggested it could form the chassis too; 'And indeed that is how tractors are made' (Kauffman, 2008, p. 152). Well, not all tractors: probably the reference is to Henry Ford's *Fordson* Model F which was completed in 1916 and was the first lightweight, mass produced tractor in the world. Ford engineer Eugene Farkas successfully designed the engine block, transmission, and axle housings bolted together to form the basic structure of the tractor. By eliminating the need for a heavy separate chassis, costs were reduced and manufacturing was simplified. With the small size and innovative frame of the first Fordson, the tractor was well-suited for mass production and mass agricultural markets (Klancher et al., 2003). Hence the Ford philosophy of satisfying affordable mass market demand drove the innovation, which nevertheless advanced the industry standard.

The 'adjacent possible' refers to the fulcrum of evolution, connecting the restless character of economic (or ecological) life to progress beyond the current *status quo ante*. It is a cumulative capacity in which the more variety the system displays, 'the easier is the creation of still further novelty' (Kauffman, 2008, p. 151). However, because the further out from the present human capability for prediction dramatically decays, such novel moves are generally fairly short-range but adjacent. Adjacency means 'close at hand' but it implies no particular directionality. Thus it can be straightforward, or an angle forwards, sideways or, interestingly, backwards. This captures the Schumpeterian notion of innovation being intimately bound up with new combinations of knowledge, including re-combinations of old knowledge as well as of combinations of new and old and even, conceivably, new and new knowledge.

Evolutionary Economic Geography

Earlier it was possible see more clearly the element of 'path inter-dependence' introduced by Martin & Sunley (2010) that defines key spatial forces underlying and influencing inter-organisational relations. They mean it largely in terms of the economic geography dimension, including inter-dependent technological paradigm interaction. This can be explored further in terms of 'relatedness' conjoined to 'transversality'. This moves the discourse closer to that of regional regime/paradigm interaction because 'transversality' is the policy correlate of relatedness. Policy – whether by government, public-private governance, or private governance by intermediary or lead-firm initiative – may be active where market failure means that potentially complementary firms or industries in geographical proximity never meet to discuss possible innovations. If policy is not active, then innovative 'structural holes' (Burt, 1992) will remain unidentified unless and until firm 'search' of the selection environment eventuates, possibly due to the rise or entry of new incumbents. High market uncertainty in a context that values 'innovation' as the highest virtue of the accomplished firm (and region) owing to its overwhelming contribution to productivity and growth, means regional regimes increasingly assist such search for structural holes by inducing speed-up in the process, as we shall see.

The parallel concept to path dependence of importance to EEG is related variety or, more generally, 'relatedness'. The advocates of 'relatedness' indicate the pivotal position occupied by the idea of 'related variety' in evolutionary economic geography. Research effort is expended in relation to path dependence and relatedness in seeking to assess the relative importance of each in understanding the evolution of agglomerations or clusters, the core problematic of economic geography. In doing this, light is cast on the role of numerous other of the key process elements of interest to evolutionary economic geography, such as: innovation, technology, knowledge spillovers, learning and the creation of new regional developmental pathways. Foremost, authors apply these perspectives to issues of externalities and regional growth, on the one hand, and technological change in new path creation, on the other.

With respect to externalities and regional growth Boschma (2005) and Frenken et al., (2007) note that a key research question has been the extent to which firms in agglomerations benefit most, if at all, from ‘Romer externalities’ of *localisation* (Romer, 1991) or ‘Jacobs externalities’ of *urbanisation* (Jacobs, 1969). Specialisation and diversification are the key differentiating dynamics respectively of these two perspectives on growth and agglomeration. However, while under perfect market conditions specialisation would logically require less inter-industry knowledge transfer effort because similar specialist technologies were being utilised and lateral absorptive capacity among incumbents would be accordingly high, such is seldom the case. Therefore, the gains from efforts, not least by intermediary agencies, to assist knowledge transfers among different industries might yield a greater regional reward than awaiting intermittent market signals for firms to react to. Beyond sectoral relatedness, evolutionists also place strong emphasis on *technological* relatedness, even among diverse industries, as being a necessary but not sufficient condition for cognitive proximity, meaning clarity of understanding the other’s business model, processes and potential, possibly leading to innovation-led profitability (Kaplan, 2008). Their empirical research shows advantage accrues from the absorption of knowledge spillovers from regional (and extra-regional) industry that is cognitively relatively proximate in some way (technological, inputs, skills) whereas gains from Romer externalities are less so.

We are now in a position to summarise the key elements of the foregoing review that are of value in guiding the following analysis of regional-national interactions on eco-innovation. Table 1 lists the important elements from the

Theoretical Approach	Key Innovation Characteristics
Co-evolutionary, Multi-level Perspective	Multi-level Interactions (Cyclical) Interactive Socio-technical Systems (STS) Potential (High Variety) Connectedness (Robust Endogenous Institutions) Resilience (Resistance to De-stabilisation; Renewal)
Complexity Theory	Preadaptation/Exaptation - Cognitive Reversal - Borrowing - Searching Adjacent Possible
Evolutionary Economic Geography	Path Dependence/Path Inter-dependence Relatedness/Transversality Proximity

Table 1. Theoretical Perspectives on Multi-level Innovation System Interactions

foregoing review before these are marshalled into a conceptual model of the processes whereby eco-regions may be stimulated or blocked by the dominant (national) socio-technical systems of consequence to the sustainable energy and mobility fields. Equally, there will be interest in the extent enlightened national institutional frameworks have stimulated regional innovation, including eco-innovation. As is evident, while the theoretical perspectives are distinctive, they all adhere to broadly evolutionary ecological and economic principles, so there is a degree of overlap and associated redundancy. (high variety), connectedness (institutional or regime robustness) and resilience (capability to resist shocks and exercise renewal /innovation) are central to the analysis. Nevertheless, the concepts of STS, potential and connectedness as explicanda of resilience and strategic niche management are directly appropriate for 'creative destruction' followed by innovation analysis. Similarly, the complexity theory identification of preadaptation and the adjacent possible explain processes by which innovation proceeds through knowledge recombinations related to proximate and non-proximate path-interdependence and relatedness. These are otherwise also known as 'strange attractors' in complexity theory (Urry, 2003) Hence Table 1 assembles highly complementary concepts of significance and value to the explanation of innovation, including eco-innovation. Accordingly, these largely complementary concepts may be arranged in the form of a conceptual model of innovation which is subsequently

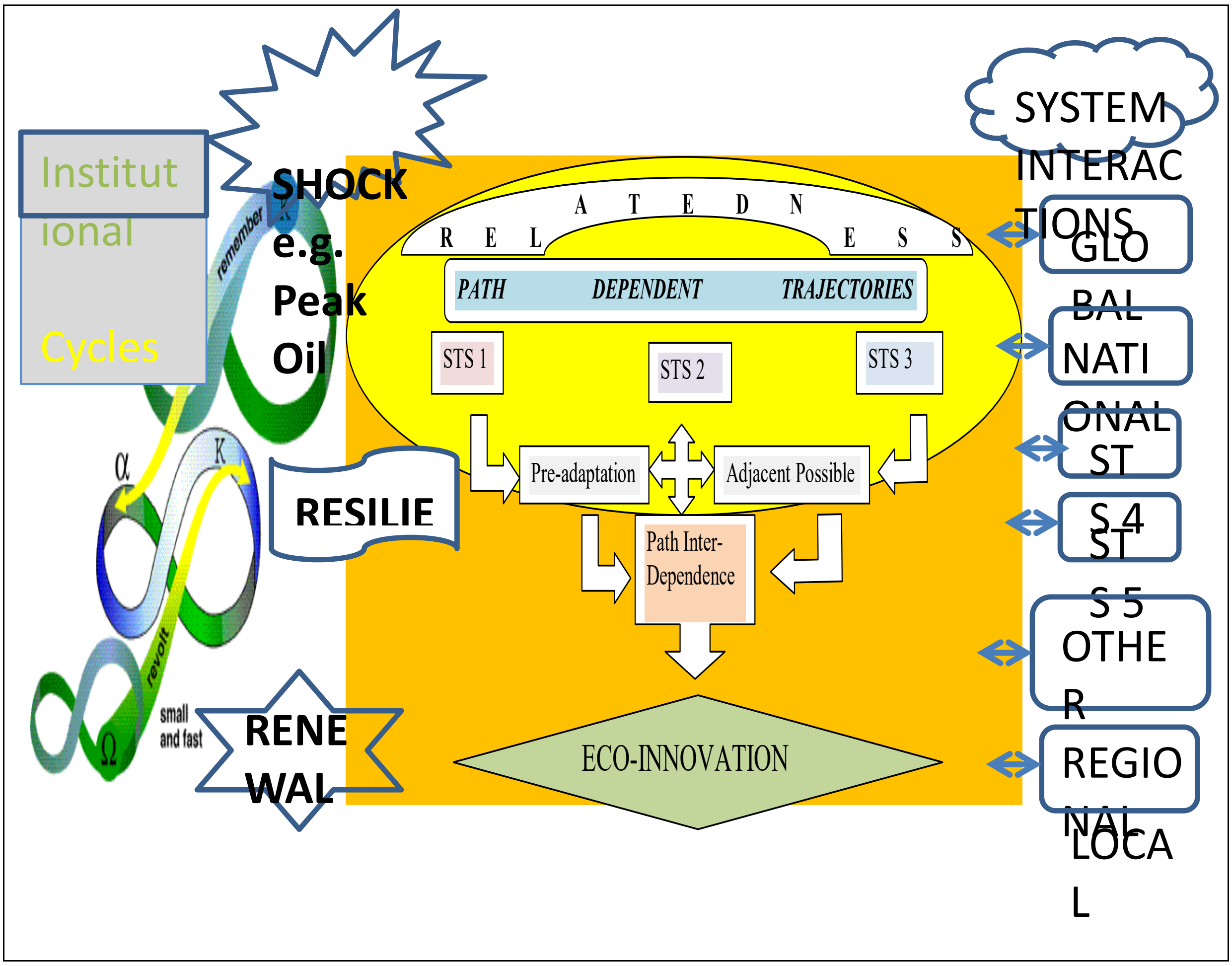

Fig. 1. Multi-level Co-evolutionary System Adaptation, Resilience & Innovation

tailored to the analysis of selected cases of relevance to the twin transitions involving China moving, first, from locked-in command economy to global market competitor and, second, from fossil fuels industrial age polluter to post- hydrocarbons eco-innovator.

China and Asia Pacific: Rapid Emergence of Innovative Regional Industries

ICT: Global Platforms for Desktops, Laptops & Smartphones

The economic geography of the interaction between the West and Asia Pacific around IT (i.e. personal computers, laptops, Netbooks, etc.) is only different in certain specifics from the one that will be presented for ICT (mobile telephony, smartphones, tablets etc.) because it is even more asymmetrically evolved towards Asia Pacific (e.g. rise to dominance of *Lenovo, Acer, Asus, Samsung, Toshiba* and Asian-assembled Western badges like *Dell, Apple* or *Hewlett Packard*). In the west, leading competitors have experienced debilitating shocks. Thus in 2010 *Dell* closed its desktop computer manufacturing plants in Winston-Salem, North Carolina costing 905 jobs and Lebanon, Tennessee. *Dell*'s remaining U.S. manufacturing plants are in Miami (*Alienware*), and Austin (servers; Round Rock). It bought *Perot Systems* for some $3.9 billion in cash, to make the company its global services delivery division. *Dell* moved production of computers for customers in Europe, the Middle East and Africa from Limerick in Ireland to Lodz as its Polish operation. *Dell* also owns production facilities in Asia at Penang, Malaysia and Xiamen, China. Besides owning plants, *Dell* also gets its products made by third-party manufacturers, like *Quanta* and *Compal* in Taiwan for note books or its standard SmartStep PC by Taiwan's *Mitac*, which is manufactured in China. For some specific components and peripherals, the locations are as follows:

1. Monitors Europe and Asia (Phillips, Nokia, Samsung, Sony, Acer)
2. PCBs Asia and Eastern Europe (Sanmina- Singapore/Malaysia, Celestica-Dongguan, China)
3. Drives Asia, mainly Singapore (Seagate/Maxtor-Suzhou, Western Digital-Shenzen)
4. Box builds Asia and Eastern Europe (Hon Hai/Foxteq-Foxconn; Taiwan/China)
5. Chassis Asia and Eastern Europe (Hon Hai/Foxteq-Foxconn; Taiwan/China)

Taiwan-based *Foxconn Technology Group*, which includes *Hon Hai Precision Industry*, supplies a constellation of global ICT brands including *Nokia, HP, Apple* and *Dell*. Most of that production comes from its plants in Shenzhen, in the Pearl River Delta area, one of the three major Chinese coastal manufacturing hubs, along with the Yangtze River area around Shanghai and near Beijing. It has

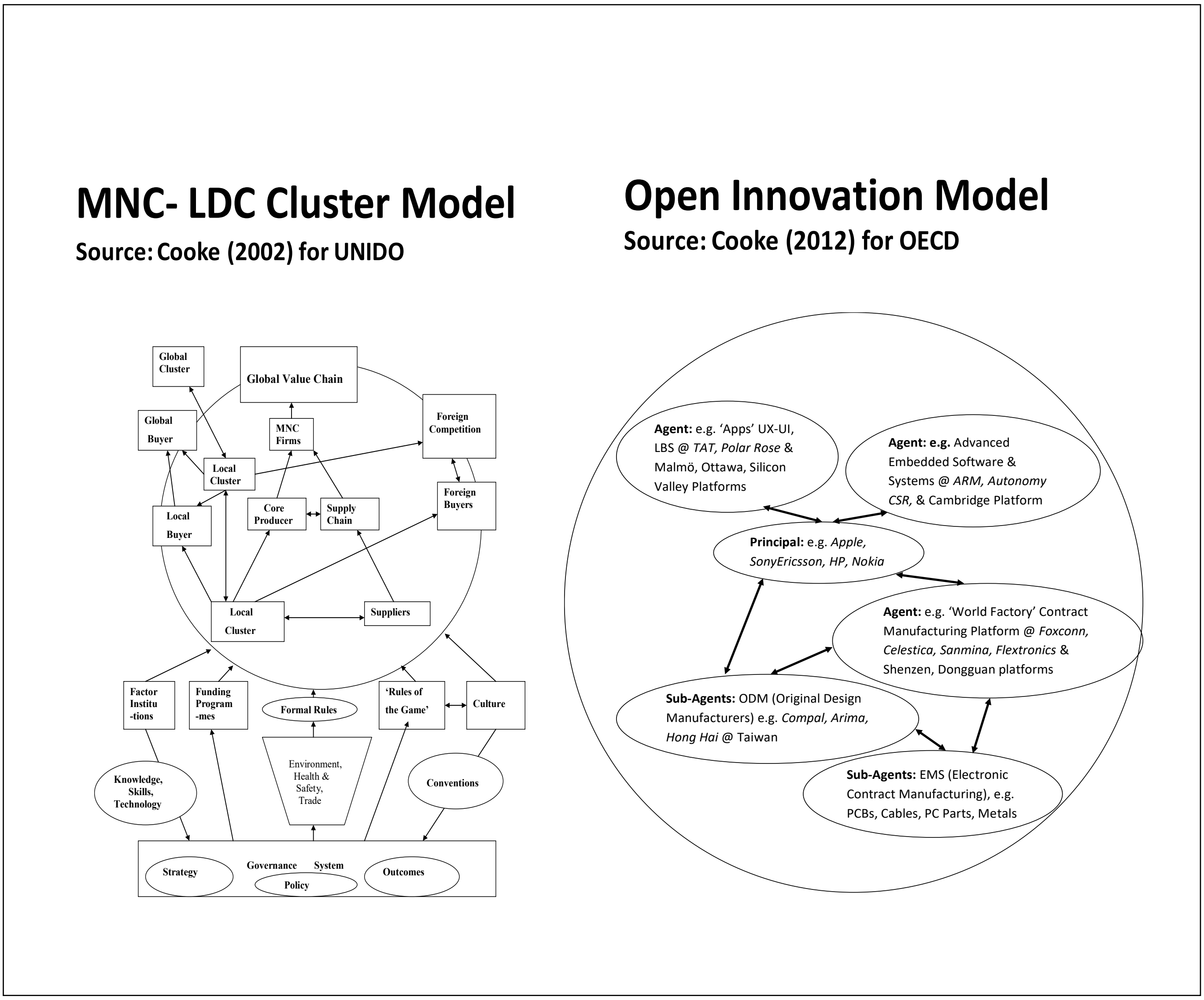

Fig. 2. From Global Production Networks to Global Production Platforms
Source: Centre for Advanced Studies, Cardiff University

now moved inland to Henan province, 1,600 km (1,000 miles) from Shenzhen, where wages are lower and workers more plentiful, keeping mostly higher-value, engineering and R&D work in China's coastal areas. *Foxconn* will have as many as 1.3 million workers in China by the end of 2011, up from 920,000 in 2010. This kind of tough global competition involving significant shocks to traditional hardware manufacturers as Asian competitors rise, to inland populations soon to be recruited to the world's largest factories, and to managements charged with charting new ways forward into knowledge-intensive services, occurs far more swiftly than it did when the new international division of labour was first being mapped out. It demands a new ‘complexity geography’ of ‘complex adaptive systems’ that can capture the destabilisation and re-stabilisation effects of such massive and significant moves. In only some ten years the ‘world factory’ model of massively scaled production platforms in locations like Shenzen, on the one hand, and monopolistic embedded software and systems platforms like Cambridge (UK) for chip design or Malmö, Sweden, Ontario and Silicon Valley for smartphone ‘apps’ have reconfigured the global production framework from a ‘diffused network/cluster’ model to a more focused ‘distributed platforms’ one (Fig. 1). Europeans and North Americans are seeking blue oceans of less severe competition by continuing to emphasise their evolving advantages in knowledge-intensive services, particularly in the ‘closed’ versus ‘open’ worlds of smartphone and other digital software, systems design and services. They also, of course, continue to embed their reliance upon Asian, especially Chinese ‘world factory’ capabilities for the production of hardware. South Korea, notably *Samsung*, is innovative in handset design and software, systems and services. However, China’s giant *Huawei* known in the early 2000s as a low-cost, telecommunications-equipment maker that has been increasingly competing with larger Western rivals is challenging global markets and positions itself in western technology and innovation strongholds like Sweden, also selling GSM services to Finland. By 2009 it was third largest mobile infrastructure seller in the world after *Ericsson* and *Nokia Siemens Networks* having displaced *Alcatel-Lucent*.

As indicators of this industry’s global dynamics, earlier and in an easterly direction, for example, *Nokia* has R&D sites in seven countries: Finland, in Asia China and India, as well as Kenya, Switzerland, the United Kingdom and the United States. Nokia operates a total of 12 manufacturing facilities outside Finland: Manaus, Brazil; Beijing, Dongguan and Suzhou, China; Farnborough, UK; Komárom, Hungary; Chennai, India; Reynosa, Mexico; Jucu, Romania and Masan, South Korea. Litigation among these global suppliers is not uncommon. In early 2011, *Huawei* asked its former partner *Motorola* to stop the sale of its wireless network unit to *Nokia Siemens*. The company claimed that it had provided the phone maker with $878m worth of equipment and technology for wireless networks that it had developed. *Nokia Siemens'* $1.2bn purchase of *Motorola*'s wireless network business, therefore, amounts to an illegal transfer of *Huawei*'s intellectual property, alleged the company. *Huawei* also said that the deal would cause harm to its business interests as *Nokia* is its competitor. *Nokia* first filed suit alleging that *Apple* had infringed *Nokia* products regarding technologies used on the iPhone, iPad and iPod Touch. *Apple* has filed a lawsuit, challenging one of the seven patents *Nokia* filed against it at the end of 2010. *Apple* is already involved in disputes with other Android device makers *HTC* and *Motorola*, so *Nokia* would have continued to be in the firing line had it partnered with *Google* rather than *Microsoft* in 2011 for its future smartphone operating system. *Motorola*, once a global innovator and market leader now also uses the *Google* Android software platform for its handsets. Other ormer top competitors that succumbed to faster-moving rivals include *Ericsson*, *Palm*, *Siemens* and *Alcatel*. *Ericsson*, which competed with *Motorola* and *Nokia* in the top three throughout the 1990s, combined its phone unit with that of *Sony* in 2001 to help regain lost market share; *SonyEricsson* now ranks sixth. *Siemens* and *Alcatel*, both in the top five a decade ago, never recovered from market-share losses and ended up selling or giving their mobile-phone businesses to Asian rivals. *Motorola*'s handset business, which occupied second spot globally as recently as 2007, has fallen to seventh, and was spun off in early 2011 from the rest of the company in a bid to recover. *Motorola Mobility* offers tablet devices with seven- and ten-inch screens. In the increasingly crowded tablet market, the larger device would compete with the iPad and a smaller device would compete with *RIM*'s planned PlayBook tablet and *Samsung*'s Galaxy Tab, which also uses Android.

As can clearly be seen the ICT inside these convergent communication devices is now a cheaply produced, commodified technological input (chips, PCBs etc.) assembled in locations such as Shenzen, China by giant overseas contract manufacturers such *Foxconn* of Taiwan. The value of the products shipped lies almost entirely in the software, system and services supplied on smartphones and the innovative applications ('apps') increasingly produced by start-up businesses in the West. In the paper, an account is given of the main innovative elements of this rapidly evolving industry, demonstrating how the division of labour among tasks has been divided up over the globe. In this, the West retains the leading edge in software, systems, services to some extent, and 'apps' but Asia Pacific dominates hardware and in South Korea hardware engineering and design where there remain innovative applications to be exploited. Thereafter, a different account is given of the utilisation of commoditised IT and ICT componentry in new applications that frequently utilise

ICT technologies as derived part of a new demand for ICT enabled devices in new markets; the one concentrated upon in the second half of the paper is eco-innovation, including renewable energy, electric and other mobility (vehicles) and related areas experiencing growing demand in the West, China and South Korea especially; the other, mentioned briefly where linked to eco-innovation, concerns personalised healthcare for which there is growing demand in the West and Japan. These accounts are preceded by a theoretical section which frames the evolutionary economic geography-influenced analysis of global ICT in relation to innovation interactions between the West and Asia Pacific.

The global power of the smartphone 'apps' platforms is testified to in the following narrative. Thus in addition to the smartphone litigiousness discussed above, *Apple* and *Google* have recently ended a 'phoney war' to engage in an all-out contest, the victor in which will be the one who can attract the most desirable apps for the smartphone and tablet platforms that use their proprietary operating systems. Industry experts expect *Google* to prevail because of its open source and open innovation model, which means the quantity (if not the quality) available on its Android system overtakes *Apple* 'apps' in mid-2012 (LMS, 2011). A counter-argument favouring *Apple* is that 'apps' entrepreneurs who want to make profits rather than experience the glory of publication on *Google* will prefer *Apple*'s closed innovation model (iOS system) because of its superior IPR regime which allows for contractual appropriation by suppliers of income streams (e.g. digital newsprint).

Apple's newsprint 'app' scheme charges 30% of subscription fees and disallows data sharing (e.g. subscriber addresses). *Google*'s model charges publishers only 10% of subscription fees and subscriber information will be passed along. It is basically a scope versus scale contest in which *Apple*'s App Store runs on tight control, high vetting and censoring of apps, while inducing high customer loyalty. *Google*'s approach is more liberal but also less quality-minded since Android has been an open source project from the start. Thus customers buy Android through buying an *HTC*, *Huawei*, *Motorola* or *SonyEricsson* smartphone rather than from *Google* itself.

Thus China, Taiwan and South Korea have delivered successive shocks to the recent Nordic hegemony in mobile telephony. During the decade after 2000, first markets, then production home base, were invaded by rapidly expanding Asian producers from South Korea (*Samsung*) and China (*Huawei*). This resilience 'shock' (Gunderson & Holling, 2002; Folke, 2006) led to three major shifts in a key innovator economy in mobile telephony, namely Sweden (as described in Chapter XXX). First, globally influential hardware producers like *SonyEricsson* abandoned in-house hardware production, going instead for the Android platform, and re-focused upon managing global network and network management services for telcos. Vacating research and production markets released talent pools in Swedish regions that were rapidly occupied by vertically integrated behemoth *Huawei*.

Second as well as moving heavily into services, *SonyEricsson* and others evolved 'open innovation' relationships with innovative start-ups moving to partner or acquire them. Other globally leading 'smartphone' firms like RIM (BlackBerry) and *Apple* for $29 million were also swiftly in the same acquisition market in 2010. Elsewhere, new open innovation 'apps' markets evolved for start-ups presaging a new tech-boom' based on inflated stock-market value estimations. In the North American 'apps' heartlands of Silicon Valley and Ontario (Ottawa, Waterloo, Toronto) most new 'apps' start-ups contract with the Apple Apps Store and to a lesser extent RIM. However Nordic ingenuity in this burgeoning field means some niches have global precedence, interesting the likes of these large incumbents. Use of social networking, 'positioning' and 'visualisation' expertise sites are increasingly user-interactive with novel space and flows valuation methodologies like 'Crowdsourcing' (Page, 2006; Howe, 2009; Shirkey, 2010).

Accordingly, third, it can clearly be seen that the external 'shock' to the mobile telephony system in Sweden has provoked 'endogeneity' in the mobilisation of resilience 'potential'. Recall, this is the concept that addresses the capacity of complex adaptive systems to respond to shocks by drawing upon internal related variety or 'relatedness' of industries through the interaction of which innovation may be forthcoming. Such 'potential' has been swiftly mobilised at the lower level in the multi-governance hierarchy of systems support policy – in a medium-sized reconverting city - rather than by decree of multinational capital or central government. The key mediating role is performed by alert regional development agencies, by a platform-building policy of pursuing innovative 'strange attractor' cross-cluster knowledge recombinations, assisting firms to find innovative 'white spaces' (Johnson, 2010), (or ‘structural holes’; Burt, 1992) among the cluster-platform elements. China’s initiation of market shock processes began in 1992 with economic reforms, thereafter firms have been enabled to grow rapidly by serving the large internal market and then attacking selected western markets with more advanced products, utilising talent released from advanced technology research by the onset of Chinese (Huawei) and other Asian (*HTC, Samsung*) competition in ICT.

Eco-innovation

China has experienced rapid economic growth in the past thirty years, but the same fast economic growth means China is now facing major challenges regarding resource and environmental issues associated with rapid development. Learning from early experimentation with ‘industrial symbiosis’ (more commonly known nowadays as ‘industrial ecology’) evolved in Nordic cities like Kalundborg, Denmark and Örnsköldsvik, Sweden (Cooke 2010), China has been one of the more assiduous global practitioners of this approach. It is a system of productively recycling industrial waste according to a ‘closed loop’ input-output waste-to-new product methodology. Interest in industrial ecology began in China in the 1980s and early experimentation began in that decade in Tianjin (see below), China’s State Environmental Protection Administration (SEPA) promoted the EIP concept and initiated a pilot programme for eco-industrial parks in 1999. Guigang Eco-industrial Park was one of the earlier of these new demonstration sites in China. It is located in Guanxi Zhang Autonomous Region in coastal southern China adjacent to Vietnam. The park was initially managed by the *Guitang Group*, a state-owned enterprise with over 50 years of agro-food history. The economy of Guigang was traditionally dependent upon sugar refining and processing which declined rapidly during the 1990s. The EIP initiative was to transform the declining *Guitang Group* from a conventional sugar-producing industrial system to an eco-industrial system. The *Guitang Group* set up the eco-industrial complex based on sugar production at what became the largest sugar refinery in China. The complex includes sugarcane farms, sugar-making plant (it produces 120,000 tonnes of sugar annually), an alcohol plant (10,000 tonnes), a pulp and paper mill (85,000 tonnes), a calcium carbonate plant (8000 tonnes), a cement plant (330,000 tonnes), and a fertilizer plant (30,000 tonnes). The paper-mill uses sugar slag generated from sugar production while the cement mill uses another by-product, sugar sludge, as a raw material input for the production of cement (Fang et al., 2007). *Guitang Group* is responsible for managing the whole eco-industrial system at the EIP. The material and by-product exchange occur primarily within the same complex, significantly improving the efficiency of its many processing plants (Fang & Lifset, 2008). Subsequently the group was privatised and has extended its exchange network to receive by-products from other sugar producers allowing increased production. This *Guitang Group* success inspired the city of Guigang to adopt a five year plan to become an Eco-industrial City. By 2007, there were 24 national EIPs established in China. Most of them are organised and managed by the administrative commissions of the development zones and the governments at city and county level, while others are under management by private enterprise. Now, the concept of eco-industrial development has expanded from park, community-level, and city-level, to provincial level such as Liaoning Province, a demonstration province for the circular ('closed loop') economy (Fang et al., 2007).

As noted, China's State Environmental Protection Agency (SEPA) was one of the few worldwide seriously to promote the concept of the closed loop economy with a specific programme to assist model eco-industrial parks across the country, another of which, Tianjin, is located on China's north-east coast 150 km. from Beijing. It is China's sixth largest city and one of four administered directly by central government. Following development of its EIP, Tianjin also became a forerunner and demonstrator in the development of the eco-city concept. The Tianjin Economic-Technological Development Area (TEDA) exemplifies an existing industrial region with developed industrial symbiosis linkages among key facilities. TEDA was formed in 1984, and provides a utility sharing infrastructure including electricity, gas, steam, water and wastewater treatment, for all regional facilities including reuses of rubber, ash, metals, and organic materials. Unlike some Chinese eco-cities, notably Dongtan, which has suffered from the expense of its design and difficulties over land assembly among municipal and private owners, Tianjin has a working eco-city neighbourhood built by the Sino-Singapore Tianjin Eco-city partnership, a strategic cooperation project between China and Singapore to improve the living environment and build an 'eco-culture', as stated in the official announcement. Located in Tianjin's 'Binhai New Area' a Special Economic Zone, home to global businesses like *Rockefeller*, *Tishman-Speyer*, *Motorola* and *EADS Airbus*, the eco-city has a planned population for 2020 of 350,000. As an official eco-city and home to *Tianjin Qingyan Electric Vehicle Co.*, Tianjin hosted 2010's *New Energy Vehicle Technology & Investment Congress* that assembled over 120 industry executives and experts from the new energy vehicle value chain to discuss best practice, global market trends and industry outlook. In line with its green credentials Tianjin is also home to *Tianjin Lishen Battery*, one of the world's largest manufacturers of lithium-ion batteries. These are the energy source for Coda Automotive's US-badged, Chinese-built *Hafei Saibo* electric saloon car, which in 2010 began selling in California where its price of $45,000 can be offset by $10,000 from a federal tax credit and state incentives.

Two other city-regions that display less central state governance structures than Tianjin but where city prefectural initiative has stimulated the rapid evolution of Chinese Eco-Industrial Clusters are Yangzhou on China's east coast and Shenzen, near Hong Kong in the south. Yangzhou is home to China's official, Ministry of Science & Technology affirmed (2007) leading semiconductor lighting cluster, otherwise light emitting diode (LED) lighting. In 2009 it was designated the national LED pilot city by the same ministry. The industry began in 2003 with the founding of *Darewin Opto*, which was joined by six other companies, one manufacturing semiconductors, two specialising in assembly and four producing lighting applications. On this basis, the city prefecture of Yangzhou determined to be the key local driver of the industry, committing $5 million for research, applications and testing in three new industries; new light sources, new energy and new materials. By 2009 a full supply-chain involving base material-epitaxial-wafer-chip-assembly-application interconnections had evolved, reaching $1 billion output value. In 2009 the city announced an enhanced LED technology fund of $3 million to buy foreign Metal-Organic Chemical Vapour Deposition (MOCVD) equipment for advanced LED epitaxial wafer production. This unprecedented city-level investment attracted leading firms *Canyuan* and *Rainbow* from elsewhere in China to augment the cluster to over 30 firms with a $2 billion output value. Table 2 gives a detailed breakdown of the Yangzhou LED cluster as of 2010. This successful city-regional strategy has

Enterprise Category	Percentage	Employment	Number of Enterprises
Upstream (substrate; epitaxial wafer)	20%	80-100	6
Midstream (chip)	20%	80-100	5
Downstream 'Packaging' (assembly)	20%	260-300	7
Downstream (lighting application)		300	15+

Table 2.Leading Enterprises in the Yangzhou LED Lighting Value Chain
Source: Jingan (2010)

been to gain advantage in the wafer fabrication phase of the value chain to control the LED and a burgeoning photovoltaics value chain in proximity. The solar energy competence has developed as an 'adjacent possible' from the epitaxial wafer base since silicon is the key material in both technologies. To that end the prefecture has also funded a 2km² Silicon Industrial Park in the Yangzhou Development Zone, a Semiconductor Lighting R&D Centre as part of the branding strategy of *'Yangzhou LED City'*.

Shenzen's eco-city is Pingdi, located to the east of the main city and one of the three large cities of the Pearl River Delta alongside Guangdong and Hong Kong. It is in 2011 planned and approved ready for development to begin. In the city-region a key industry set is ICT, electronic equipment and automotives. A key firm is *BYD* China's (and the world's) largest producer of lithium ion batteries. This firm made strategic use of 'relatedness' and the 'adjacent possible' to innovate in electric vehicles from its origins in (laptop) batteries. Founded in 1999 the company has developed its own iron-phosphate-based lithium-ion (LFP) battery following over ten years R&D. The core battery technology can be applied in all the main types of electric vehicles and has a lifetime of over 10 years with a charge time to 50% of its capability in 10 minutes. The company started by supplying batteries to mobile telephony companies such as *Nokia* and *Motorola*. In 2003 *BYD* made the acquisition of *Qinchuan Motors* of Xian which gave it the opportunity for the company move from part and battery supplier to car marker (Fig. 3). In 2008, *BYD* purchased *SinoMOS Semiconductor* of Ningbo to facilitate its upstream value chain and accelerate its development of electric vehicles. It attracted $230 million from global billionaire investor Warren Buffett through his *MidAmerican Energy Holding Co*. for a 10% investment stake. This investment strategically helped BYD extend its markets for electric vehicles from China to global. In its corporate strategy, *BYD* plans to sell some 9 million electric

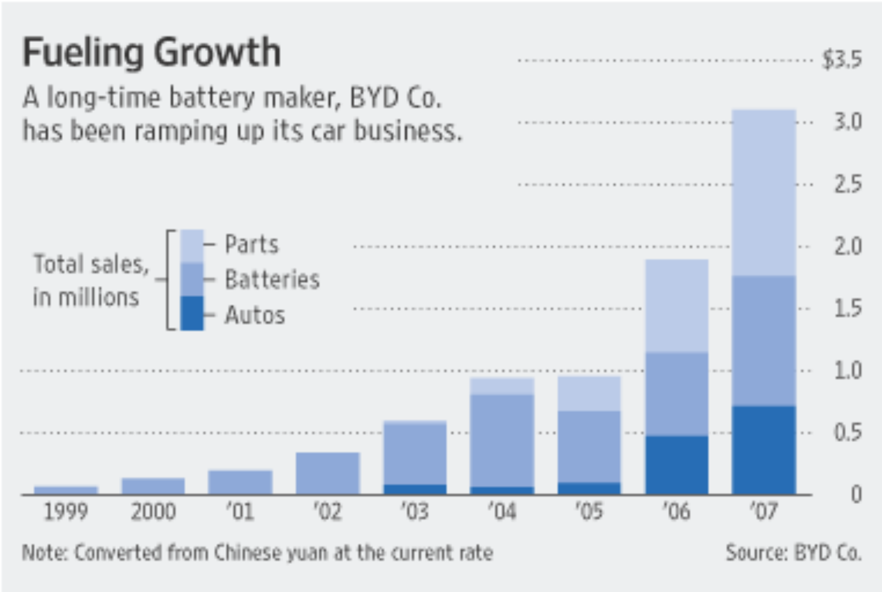

Fig. 3. Business transition of BYD Co.1999-2007
(Source: BYD, Co.)

vehicles by 2025 to surpass the leading global automakers in electric vehicle (EV) technology. Pingdi is located in proximity to the *BYD* value chain and is part of the wider, related variety electrical and electronics industry platform. The design of two large, open campuses and high valuation of local ecological areas, with fully protected rare flora and fauna, make Pingdi highly attractive for eco-innovation.

One open campus, close to the existing Gaoquiao Industrial Park is dedicated to eco-innovation. Key innovative platforms at Gaoquiao include digital applications to energy (smart grids), transport (information systems), water, waste, green buildings and eco-cities. Shenzen region, with *BYD* batteries and electric vehicles, also has the Chinese State Grid's EPRI and other R&D institutes specialising in vehicle charging (V2G) requirements and standards alongside development of EV charging stations. Related to the evolution of the eco-city concept is the construction industry, which is China's fourth largest industry, contributing some 9% of GDP. The Chinese government has set the detailed goal to reduce energy consumption. In the 11th five-year plan (2005-2010) the target was also set to reduce building energy consumption by 50%; to improve energy efficiency of government institutions by saving 10% energy per unit construction area and per capita; and to reduce electricity consumption of appliances by 29 billion kWh

(Osterkorn, 2008). The Ministry of Housing and Urban-Rural Development, the Ministry of Finance, and the National Development and Reform Commission have passed numerous laws and regulations on building standards in recent years (Table 3). To promote energy efficiency six key areas are focused upon. State and local government supply financial support for a range of demonstration projects in some major cities (The Climate Group, 2008). EMC, shown as a financial mechanism in Table 3 is an active private company in China which has been involved in developing energy-efficient green buildings.

With the rapid rise of a Chinese middle class, energy consumption by residential building is expected to grow by 5% annually, more than doubling by 2020 (McKinsey & Company, 2007). There are several barriers to improve energy efficiency in buildings in China, including lack of rigorous enforcement of building energy codes; lack of incentives to save energy due to a fixed rate price of

<table>
<tr><td rowspan="4">Legal environment</td><td>Plan:</td><td>China medium and long term energy conservation plan</td></tr>
<tr><td>Laws:</td><td>• Renewable energy law;
• Energy conservation Law</td></tr>
<tr><td>Regulations:</td><td>• Energy conservation regulation for civil buildings;
• Energy conservation for state-funded institutions</td></tr>
<tr><td>Support Measures:</td><td>• Special funds;
• Standards;
• Labelling;
• Assessment;
• Quality control</td></tr>
<tr><td>Six key areas</td><td colspan="2">• 50% energy conservation design standard for new buildings;
• Heating system metering and retrofitting in North China;
• Energy conservation in government and public buildings
• Solar and geothermal renewable;
• New building materials;
• Building energy auditing and assessment</td></tr>
<tr><td>Demonstration projects</td><td colspan="2">• Energy conservation and retrofit demonstrations for government and public building in 24 provinces and municipalities;
• Heating system metering and retrofit demonstration for existing building in 15 provinces and municipalities in North China;
• 212 demonstrations and promotion projects for renewable energy applications in building in 25 million m^2;
• 100 demonstration projects for green building and 100 demonstration project for low-energy-consuming buildings;
• Energy efficiency auditing and labelling for civil buildings in 18 provinces and municipalities;
• Solar roof plan.</td></tr>
</table>

Financial mechanism	Government support special funds:	• Renewable application in buildings; • Energy conservation for government and public buildings • Heating system metering and retrofit for existing buildings in North China; • Renewable energy-saving building materials
	Private sector:	• such as EMC

Table 3. Government policies on green building and energy efficiency in China
(Source: The Climate Group, 2008).

heating energy and out-dated heating system design with coal-fired, heat-only boilers (WBCSD, 2009). As shown in Figure 3, building insulation comparisons indicate that there is a significant gap in insulation efficiency between Chinese and comparator countries and cities. At least one third of buildings in China need an energy performance upgrade.

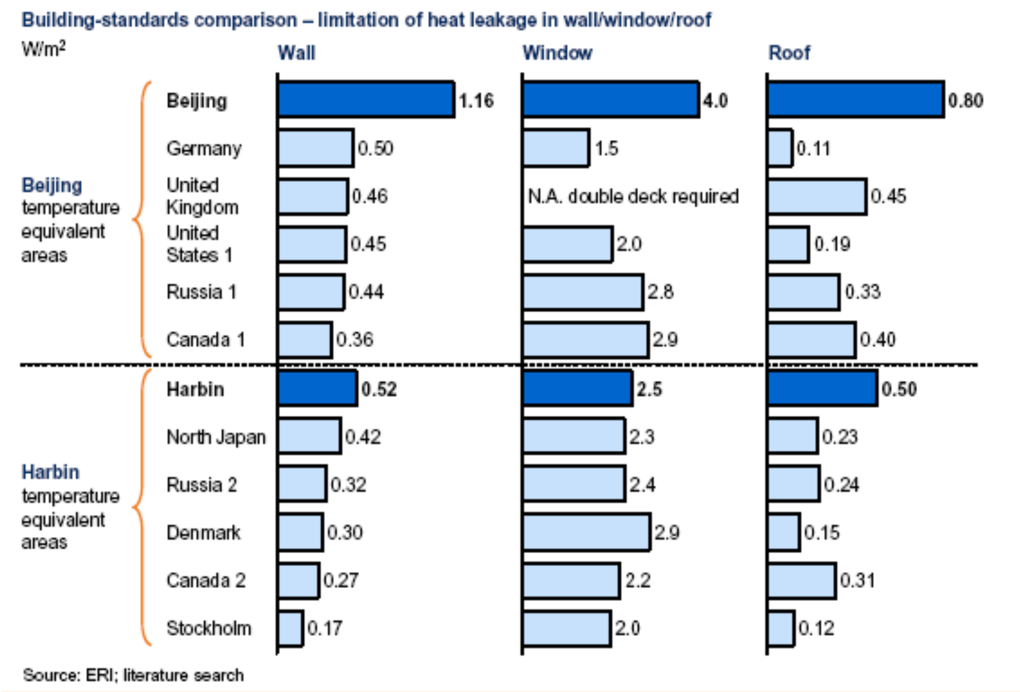

Figure 3. Building standards comparison among several countries and cities
(Source: McKinsey & Co. (2007).

Such energy retrofits in existing buildings could exceed US $380 billion at average cost of 200 Yuan (US$29) per m² (The Climate Group, 2008). Constructing new buildings at world-class insulation standards and installing energy-efficient heating and cooling packages would help capture 8 QBTU of savings, contributing 6 percent of the global energy productivity opportunity (McKinsey & Company, 2007). Total floor space in China is currently 40 billion m2 and is expected to reach 70 billion m2 by 2020. According to the estimation by The Climate Group (2008), the market for new green buildings would be worth between US$220-400 billion, depending on the application scale of green buildings among new buildings. The Chinese government also has been encouraging upgrading of heating systems in China, particularly in the colder north, which would cost about US$30-44 billion (The Climate Group, 2008). In total, market volume for green buildings including both new buildings and retrofits could reach trillions of US dollars (Figure 4).

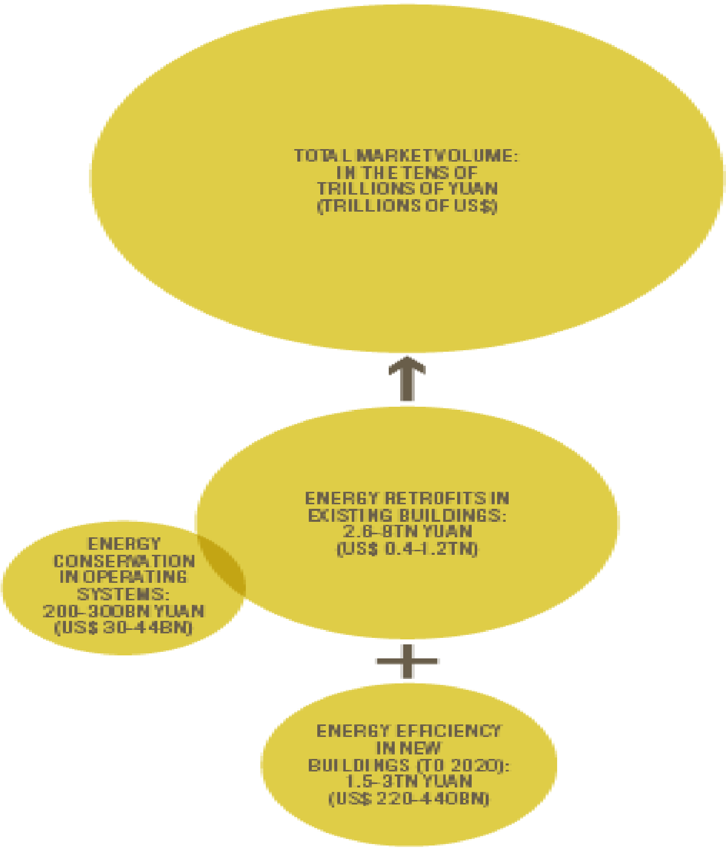

Figure 4.Potential market volume of green buildings in China by 2020
(Source: The Climate Group, 2008)

In parallel with the promotion of green construction in China, renewable energy in the form of wind power has been growing faster than the government had planned in recent years, having more than doubled each year since 2005. In late 2005, the Chinese government increased the official wind energy target for the year 2020 from 20 GW to 30 GW (Lema et al., 2007). The industry reached the original goal of 5 GW for 2010, three years ahead of schedule. Policymakers doubled their wind power prediction for 2010. The government announced an initiative to build a 1000-megawatt wind farm in Hebei, near Beijing, for completion in 2020. *Goldwind* has emerged as the leading Chinese wind turbine manufacturer and has begun to export Chinese turbines and components globally. It currently holds about 3 percent of market share in global wind turbine sales and captured some 30 percent of sales within China in 2006. By 2007, over 40 Chinese firms were manufacturing wind turbines commercially; many of them were engaged in prototype development and testing (REN21, 2008). In some cases these were engineering firms diversifying into this rapid growth market, for example China South Railway Locomotive workshops at Zhuzhou Industrial Park, near Changsha in central China. It was predicted that China would become the world wind power leader by 2010 (Watts, 2008).

National Developments in Eco-innovation

China is both one of the world's largest consumers of non-renewable energy as well as one of its largest producers of non-renewable energy. To put this into perspective, the Chinese government invested $34bn. in clean energy in 2009. The strength of this industry has been augmented by the framework of strategies and incentives provided by the central government. With the dissolution of the Energy & Industry Department in 1993, renewable energy policy has been managed through several organisations such as the Ministry of Commerce and the National Development and Reform Commission. In 2001, the State Economic & Trade Commission had proposed its Tenth Five-Year Plan for Sustainable Development which included a section on New and Renewable Energy Commercialisation Development. The goal of this plan was to curtail carbon emissions through developing renewable energy alternatives such as hydropower, biomass, solar power, wind power and geothermal energy. During this five year plan, the NDRC's Centre for Renewable Energy Development drafted the Renewable Energy Law (2005) which stated the reduction targets as well as the incentives to meet those targets. This law authorised feed-in tariffs for wind power, biomass. The Eleventh Five-Year Plan, from 2006-2010, also stressed greater emphasis on green energy through increasing energy efficiency by 20% by the end of the plan, namely through developing efficient fans, pumps, boilers and lower energy intensity steel and cement. The NDRC established the National Energy Administration (2008), officially judged inefficient, which paved the way for the State Council to establish the National Energy Commission (2010). The commission is responsible for drafting the national energy development plan, reviewing energy security and major energy issues and coordinating domestic energy development and international cooperation.

Detailed incentive policies and programmes included Promoting the Wind Electricity Industry (2006), offering preferential policies for wind power development and the Golden Sun Programme (2009) which provided subsidies, technology support and market incentives to facilitate the development of a solar power industry. The Golden Sun Programme (GSP) focused on solar PV installation through 2011 on a project-by-project basis. Off-grid installations received 70% capital subsidies while grid-connected installation (300kW capacity plus) received 50% subsidies. A separate part of the programme, funded by the Ministry of Finance & Construction, provides additional subsidies for building-integrated PV. Similar incentives are available for wind power. Along with the wind power feed-in tariff, the GSP had its subsidies reduced by the 2010 amendment of the Renewable Energy Law. This also placed more responsibility and planning interaction among regional and local entities to ensure grid connection, augmenting the Ministry of Finance's renewable energy fund and guaranteed purchases of renewable energy power generated by electric utilities. It is expected that the Twelfth Five-Year Plan, 2011-2015, will establish an environment tax.

Beyond the NDRC, other government organisations provide subsidies and conduct research on renewable energy. The Ministry of Science & Technology (MOST) has also provided subsidies for renewable energy research ($3.4m), as well as funding two High-Tech R&D programs ($25m): the 863 program (commercialisation of new technologies) and the 963 program (research in basic science). In addition, the Department of Resource Conservation and Utilisation provides low-interest loans for supporting industrial development of renewable energy. Moreover, the Department of Agriculture, amongst other government institutions, has run renewable-energy based 'living lab' projects throughout the country since the mid-90s. These range from the 'Rural Marsh Gas Projects' to 'Use of Crop Stalk as Energy Source' projects. Finally, the Ministry of Finance released an EV subsidy policy in mid-2010. Unlike EV subsidies in other parts of the world that provide cash-back incentives to customers, the Chinese subsidy will be made directly to vehicle battery vendors in an effort to reduce claims of class discrimination. The subsidy will run from 2010-2012 in 5 pilot cities: Shenzhen, Shanghai, Changchun, Hefei, and Hangzhou. In late 2010 it was announced that China was planning on launching a new EV strategy entitled 'One Thousand Electric Cars'. This initiative intends to put 1,000 EVs in 10 Chinese cities per year. The government believes this initiative would make 1% of all vehicles in China electric by 2012. From the point of view of the automotive industry, such subsidies are catalysts for change and innovation; however, infrastructure to support the EVs is not mentioned in policy and it is equally important for the sustainability of the product. This is where again, the firm *Better Place* which, it will be recalled, provides infrastructure for EV as well as EV-based consumer-solutions, comes in. Noticing the rising demand in China, *Better Place* and *Chery Automobile Co.*, China's largest independent auto producer, are collaborating to provide both good quality EV cars on the market alongside the infrastructure (charging stations/battery switch points) to support them.

Conclusions

China is consolidating valued aspects of its 'world factory' reputation by facilitating expansion of enormous low-wage production platforms in contexts like the Pearl River delta. However embedded within this trend are two other counter trends. The first of these involves the move upmarket of its leading mobile telephony to smartphone producer *Huawei,* whose penetration of western markets has begun as has its location in talent pool locations in leading Nordic smartphone design and 'apps' locations in, for example, Sweden's three leading cities. The second counter-trend has been a rapid plunge into large swathes of the eco-innovation supply chain from renewable fuels to electric vehicles, green construction and the building of new eco-cities. Many of these technologies such as solar photovoltaics and LED lighting embody silicon technologies and no expense has been spared acquiring state-of-the-art wafer fabrication equipment. A different move has been exploration of adjacent possibilities from battery production, supplying the world's energy storage requirements for laptop computers and mobile phones. In these industry-specific and varied responses, Chinese firms have met the shock of market liberalisation and become global scale producers in important current and future global markets.

A second major conclusion is how well the theory outlined in the first section of the paper explains complex adaptive system evolution from the regional to the global scale. The MLP perspective of scalar interactions in time-space relations is crucial to understanding both de-stabilising shocks (Deng's Chinese economic reforms; Asian impact on EU telephony leadership; EU 'Grand Challenges' to recover from crises) and re-stabilising regulatory and industry responses (New national frameworks; *Europe 2020*, open innovation; rise of ICT KIBS). In western and Chinese platforms looking outwards from the known by exploring adjacent possible related variety to capture innovations ('apps') or 'preadapting' existing technologies for new uses (ICT for bioelectronics; silicon for LED then solar energy). In these cases, innovations occurred as novelties or as less-cost solutions often with the intersection of path dependent trajectories in specific regions or cities. This points to the extreme importance of geographical proximity compared to say non-geographical 'relational' proximity in locating innovation 'pumpstations' in the world. Thus Cambridge (UK) dominates global chip-set design while China's main river deltas accumulate mega-platforms of EMS and ODM parts or badge manufacturing. Meanwhile, *Apple, RIM, Android* and *HTC* act as principals commissioning these various agency platforms according to 'design driven innovation' norms of 'changing socio-cultural regimes' (Verganti, 2006; Shirkey, 2010) 'crowdsourcing' (Page, 2006), 'positioning' and 'eco-living'.

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