Original Article

China's move to a Circular Economy as a development strategy

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Abstract While China's rapid growth rates have been widely admired, they have been accompanied by extensive pollution and waste. It is therefore unsurprising that China has adopted as its development model the Circular Economy (CE), encompassing notions of industrial ecology and resource reduction, reuse and recycling. This article analyses and appraises China's capacity to implement such a strategy. The article engages in a discussion of what China means by a CE and whether the policies of eco-industrial development being pursued actually fit with this general goal. We also offer our own econometric update on China's progress towards a CE. The article tests the conjecture that China is able to link its 'compressed development' strategy with industrial ecology ideas – seeing the CE as not only a source of competitive advantage, but also pointing towards a solution to global resource depletion and waste accumulation and devastation. While it must be understood that China faces enormous obstacles in implementing the CE idea, and starts from a very low base in doing so, nevertheless it has certain latecomer and administrative advantages in putting its economy on a new, closed-loop footing, as compared with more advanced countries with established industrial systems.
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Introduction

In the same week as China completed its first space walk, *ChinaDaily* published another perhaps even more important indication of China's advancement – its

adoption of the *Circular Economy Promotion Law*. This law, long discussed, was adopted by the fourth session of the 11th People's Congress in Beijing in August 2008 and came into effect on 1 January 2009.[1] China thus became the world's first country to promote an economy based on closed-loop cyclical processes as its official development strategy, drawing from the prior experiences of Germany and Japan. Whereas the practice of the 3Rs – reduce, reuse and recycle – is more technically advanced in the latter countries, they cannot claim to have adopted a closed-loop system as the image of their entire future economy. This is what China has now done.

Of course it is none too soon, as everyone acknowledges that China's growth over the past three decades has been bought at the expense of vast resource wastage and environmental spoliation. But to its credit, China is tackling these issues not, as elsewhere, in a piecemeal way, but in a root-and-branch restructuring of its economy to turn waste generation into resource creation, by fashioning links between firms that work off each others' wastes and by-products. It is a fundamentally sound ecological scenario for an economy, and one that seeks, by harnessing capitalist economic forces, to solve both the waste and resource issues at source. The only issue is whether it will really be put into effect and whether it will be in time.

Since 1979, when China opened up to the world, its economic and industrial transformation has been spectacular. Rapid economic growth and expanding international trade have driven China to become a leading economy, reducing poverty, attracting large flows of foreign direct investment, and establishing itself as the 'workshop of the world'. At the same time, it has seen the negative side of these developments, in terms of rapidly worsening pollution, waste generation and natural resource depletion. China is now the world's largest consumer of coal, while consuming half the world's cement, 30 per cent of its steel and more than 20 per cent of its aluminium. It is the world's leading consumer of fertilisers and the second largest importer of oil and petroleum products, as well as of forest products.[2] At this scale of activity, it is clear that there will simply not be enough planets to accommodate Chinese (and then Indian, and Brazilian) levels of consumption comparable to those enjoyed by the USA and Europe today. Decoupling economic growth from material consumption and its impacts on human health and ecosystem well-being is thus a major policy dilemma that China is tackling during its current 12th Five-year Plan.

While the two stories concerning China are familiar – positive growth and negative environmental impacts – the third story of China's pursuit of a Circular Economy (CE) is little known as yet, but has potentially enormous implications for China and for the world. What if China were to take seriously the closed-cycle and closed-loop ideas of industrial organization and systems theory, as developed in the disciplines of industrial ecology and ecological economics, and apply them *as a development strategy*? What if China adopted

at national as well as regional and local level *in practice* the principles of industrial interconnectedness, minimization of resource use and reuse, recycling and reduction of material and energy throughput that are labelled 'industrial ecology' in the West – as laid down in the Circular Economy Promotion Law of 2008 – but are seen in the West as an impossibly difficult goal to attain (Ehrenfeld, 2007)? What if China as a latecomer were able to build successful industries from its capture of industrial ecology principles and technologies, and leapfrog over the polluting practices developed worldwide by the western model of capitalism?

The idea of the CE as adopted and practiced in China today appears to fit this third story. There are two aspects to the story, both of which deserve the closest examination. As a latecomer to industrialization, China has shown itself to be adept at picking up advanced technologies and management systems from its predecessors – from Western countries, certainly, but even more significantly from those of East Asia, which have only recently broken into the ranks of the developed nations. So one starting point is to explore the extent to which China has been able to exploit latecomer advantages in adopting a novel industrial architecture in the form of the CE. To date, the literature on China's latecomer development or 'compressed development' (Chun, 2000) has not made this connection, nor appreciably addressed this ecological aspect.

The other aspect to the story is that the literature on China's adoption of ideas from 'industrial ecology' and the cyclical economy has not yet made much of a connection with the capture of latecomer advantages. Most of the discussion so far sees China's adoption of CE ideas as imposing extra costs on Chinese industry (Zhou 2006; Ren, 2007). But if China were able to secure competitive advantages from its adoption and promotion of Eco-Industrial Parks (EIP), and were able to attract complementary industries precisely because of official promotion of CE ideas, then the situation would radically change. The issue is: is this really happening?

While the characterization of China's development strategy as compressed and latecomer in character is well attested, seeing potential advantages in such a strategy that help to account for China's rapid rise, the link between compressed development and industrial ecology has yet to be tested in any serious study. And in complementary terms, while the ideas of industrial ecology have penetrated deeply among China's policy elite, they have not yet been connected in any fundamental way with China's compressed development strategy. There is a two-way connection to be made here. An ecological economic approach to industrial development has the potential to be of great significance both domestically and internationally: it could well become the most successful aspect of China's overall development strategy.

This article, then, proposes to explore the idea that China is of all countries the most likely to make a success of CE ideas, precisely because it has the

largest problems to tackle, and can tackle them as a latecomer, laying down a new architecture of industrial inter-linkages and dematerialization that has proven elusive in the West, with its 'carbon lock-in' (Unruh, 2000). The article is focused on an exploration of the uptake of CE ideas in China and a test of the connections of such ideas with industrial strategy generally. The aim is to discover the extent to which China is adopting these ideas, in practice and not just in name. We provide our own calculations of the extent to which it really is moving its economy towards circularity, based on Material Flow Analysis (MFA). We demonstrate trends that make China's CE-based development strategy to be a credible proposition, precisely because it appears to be based on the prior experiences of Germany and Japan, the two countries that have taken 3R ideas farthest. China has clearly studied these experiences intensively.

Background to the CE Concept

The CE concept was first introduced by Chinese scholars into China in the 1990s, drawing ideas from industrial ecology and ecological economics as well as the experiences of resource management and recycling in developed countries, notably Germany and Japan. Discussions among Chinese academics draw on several emerging fields of research, including ecological economics, industrial ecology and environmental economics (Zhou, 2006; Ren, 2007; Geng and Doberstein, 2008). It is widely accepted that the objective of CE, based on ecological economics, is to minimize throughputs of both energy and materials, rather than maximize GDP. GDP growth will of course continue to be extremely important for China, as for other mid-range developing countries, as it is the passport out of poverty. But the CE concept promotes policies and strategies that reduce the material and energy demands of growth, to an (ideal) point where the economy grows, but material and energy flows remain constant or even fall. This is what Daly (1980) originally meant by a 'steady-state economy'. The methods for promoting CE in China are largely inspired by research in the area of industrial ecology, such as EIP, material and energy flow analysis, and life-cycle assessment (Yuan *et al*, 2006; Ren, 2007).

In one sense it would be hardest for China to move to adopt the CE concept, in that it is still in the process of building industries rather than the comfortable position of already enjoying wealth. There is a firmly held conventional wisdom that sees the development process in terms of the western experience, whereby you 'pollute first' and 'clean up later'. According to this wisdom, it would be the developed countries of the OECD, led by the USA, that would move to a 'circular economy' first, followed several decades later by the newly industrializing countries. But the strategy of compressed development being pursued in China means that these issues can all be tackled

simultaneously – indeed, they have to be tackled simultaneously if China is to successfully emerge as a fully developed nation.

Industrial ecology

Since the 1970s, there has been an increasing concern to find new ways of representing industrial processes, so that there will be less emphasis on 'free resources' from nature and 'free disposal of wastes' in a limitless sink called 'nature' (Erkman, 1997; Frosch, 1997; McDonough and Braungart, 1998; Lawn, 2000; Cohen-Rosenthal, 2004). The idea of the economy as a closed cycle of material and energy flows was spurred by concepts such as Boulding's 'economics of Spaceship Earth' (1966) and Daly's (1980) notion of the 'steady-state economy', meaning not an economy at rest, but one that is highly dynamic, yet neither expanding nor contracting in terms of its material and energy flows.

The terms 'industrial symbiosis', or 'industrial ecology' or 'industrial metabolism', were utilized to bring out the essential interconnectedness of industrial activities and the possibilities of reducing material and energy flows through taking cognizance of these connections (Richards and Pearson, 1998; Ayres, 2004; Chertow, 2007). A seminal article by Frosch and Gallopoulos (1989) envisaged 'industrial ecosystems', where 'the consumption of energy and materials is optimized and the effluents of one process … serve as the raw material for another process'. With this perspective there have been a series of studies of inter-related industrial processes developing spontaneously over several decades in locations such as Kalundborg in Denmark (Grann, 1997; Chertow and Ehrenfeld, 2001; Jacobsen, 2006), the Austrian province of Styria (Schwartz and Steininger, 1997), or the minerals processing regions of Kwinana and Gladstone in Australia (Van Beers *et al*, 2007). Until recently, however, few studies had been conducted in Asia outside Japan, where ideas of resource reduction, recycling and reuse had made little headway. This is now changing, and the pessimistic outlook painted by Chiu and Yong (2004) is shifting. While much of the literature on Industrial Ecology is critical of grandiose claims (for example Hukkinen, 2003), the adoption of these ideas by China and their implementation as an economy-wide strategy now puts them in a totally new context.

The latecomer effect and its capture

The situation facing countries that arrive late on the industrial scene is one that combines apparently hopeless drawbacks, difficulties and inadequacies with advantages that flow precisely from being 'late' and not having to go through all the previous steps that incumbents have had to endure (compressed

development). It is convenient to call countries in this position 'latecomers', adopting the usage introduced by the Russian social scientist Alexander Gerschenkron with regard to firms (Gerschenkron, 1962; Lee and Lim, 2001; Mathews, 2005, 2006). This idea has been applied to Korea, Taiwan, Singapore and now China through a series of industry-level studies, where the capture of such latecomer effects has been a central concern for strategists (Mathews, 2009). The fundamental idea behind such capture is that the latecomer can turn disadvantages into sources of advantage by making 'institutional compensations' for elements that are lacking, notably technology.

In the case of the CE idea, we have what is probably the ultimate 'latecomer advantage' – the redesign of an economy along eco-industrial lines in order to capture advantages unavailable to economies that are 'locked-in' to carbon-intensive and resource-intensive flows. China is looking to build an industrial economy according to a different ecology than that followed by earlier industrialized countries, and to capture latecomer advantages by doing so. A central issue then is to discover the ways in which it is seeking to identify and capture such advantages from its manner of formulation and implementation of CE. A central theoretical task will be to appraise and account for its success or failure in this regard.

What Is Meant by 'Circular Economy' in Chinese Discussions?

A preliminary analysis reveals that discussions among Chinese scholars now agree on a number of features highlighting a CE: (1) CE is a closed system (resource-product-renewed resource), as opposed to the traditional 'resource-product-waste' linear system; (2) there are three main means for promoting CE, termed the '3Rs principle', *viz*. Reducing, Reusing and Recycling; and (3) CE can be carried out at three levels, *viz*. the micro-level of enterprises, meso-level of EIP and macro-level of industries, regions and even nation. The taskforce, set up by the State Council to study the strategy and mechanisms of promotion of the CE and cleaner production, has identified best practices for all three levels of CE around the world, consisting of the DuPont corporate-level 3Rs programme, the industry-cluster/EIP CE in Kalundborg, and the macro-level CEs of Germany and Japan (CCICED, 2003).

In late 1980s, DuPont creatively adapted '3R' principles to the chemical engineering industry, and established its '3R' manufacturing system, which joins DuPont's various productions into a mini-CE, aiming for environmentally sound production outcomes. While DuPont's achievements are impressive, an enterprise-level closed system has limitations in that production wastes or by-products cannot be fully recycled within the producing enterprise; a much larger external utilization system is necessary.

An industry-cluster or an EIP-based *meso-level CE* is a manifestation of such a broader concept. As an example, a cluster of businesses in the industrial town of Kalundborg in Denmark pioneered, with town council support, an internal network of by-product exchanges to trade steam, hot water and other by-products and wastes such as gypsum, sulphuric acid and biotech sludge. A similar and larger industrial recycling network was also founded in Austria. These networks have inspired researchers and businesses around the world to carry out further investigations and establish industrial ecosystem projects and EIPs (Lowe, 1997). Notwithstanding its merits, CE implementation through meso-level EIPs suffers from limitations in terms of coverage and processing capacity – hence the need for a macro-level industrial, regional and country-wide CE implementation, as in the German and Japanese models (CCICED, 2003).

On the policy front, the Chinese leaders of both previous and current administration have made key speeches on the topic. In 2002, the then President of China, Jiang Zemin, addressed the Members' Assembly of the Second Global Environment Facility, stating that 'a sustainable economy can only be achieved with a Circular Economy approach based on utilization of resources effectively and on environment protection' (Jiang, 2002). The then Premier of China, Zhu Rongji, also spoke to the Members' Assembly of the Third China Symposium on Environment and Development of Global Cooperation, stating that 'China will emphasize the development of CE so that environment protection and economy growth will stimulate each other' (2002). In 2003, the President, Hu Jintao, addressed the Central Committee Meeting on Population, Resources and Environment, calling for an acceleration of China's modernization through application of the CE concept, and this was reinforced in 2004 when the Premier, Wen Jiabao, introduced the notion of 'scientific economic development', calling for a production and consumption model that would promote resource-saving, pollution reduction and ecological protection. These speeches were not only symbolic of the fact that the CE concept had been formally recognized by the State, but also a signal that the government was serious about making it a national policy priority (Yan, 2005).

Since then, the country's prime planning agency, the National Development and Reform Commission (NDRC), has been designated as the lead agency to develop and implement the CE idea through a range of programmes, taking it out of the hands of the Environmental Commission. In 2007, a draft *Basic Law on the Implementation of the Circular Economy* was circulated; subsequent debates saw the term *Implementation* replaced by *Promotion*. On 29 August 2008, it was signed into law as the *Law on Promotion of the Circular Economy* by the National People's Congress, containing 58 clauses, and took effect on 1 January 2009 (NPC, 2008). This legislation represents a milestone and the

first significant step in China's long march towards eventual establishment of national-level CE. According to NDRC's master plan, China was due to have established by 2010 a comprehensive system supporting CE development, consisting of laws and regulations, government policies, new innovative technologies, a mechanism of stimulation and control, and several trial and demonstration sites, at eco-industry park, city and regional levels.

There has been noticeable development of systematic adoption of the CE concept at both enterprise and industrial-cluster/EIP levels. The former consists of well-attested cases such as the Guitang and Nanning sugar groups (Feng and Yan, 2007; Zhu *et al*, 2007; Yang and Feng, 2008) and the Huaneng Energy Group's Beijing Cogeneration power plant (site of China's first pilot post-combustion carbon capture project, and a Sino-Australia co-operation, in the battle to reduce CO_2 emissions). As for EIPs, up to December 2008 no fewer than 30 EIPs had been chosen by the government as demonstration sites, with three approved for completion and 27 approved for construction (MEP, 2009). According to a progress review by the MEP (2009), all but three of the sites under construction were making sustainable progress as assessed by the standards and procedures established by the government. These include EIP such as the electronics and TFT-LCD value chains at the Suzhou industrial park and Shanghai Chemical industry park (Zhang *et al*, 2009) and the Tianjin Economic-Technological Development Area (Geng *et al*, 2007; Shi *et al*, 2010). These examples demonstrate China's concrete efforts to establish industry-cluster level CE EIPs around the country, and they are now attracting notable interest from scholars and policy advisers (Fang *et al*, 2007). EIPs have also been set up or planned in various regions of China such as the Ziya CE EIP in Tianjin, one of China's four metropolises focusing on recycling electronic wastes (to be completed by 2010); the Jingzhou CE EIP in China's most populated Sichuan Province, focusing on the textile and dye industry (to be completed by 2012); the Lubei EIP (Huo and Chai, 2008); and the Caofeidian CE Industrial Zone , a major hub on the Baohai coast including the Binhai New City development. It is promising that all these practical efforts are backed by strong initiatives from the universities to provide basic grounding in industrial ecology ideas and practices, and to create links between the universities and companies engaged in eco-industrial activities (Ning *et al*, 2007).

Progress towards a CE in China

Because economics still works with a linear model of economic flows, it is not possible to apply analytic tools to capture the real extent of China's move towards interconnectedness and circular flows. But a proxy can be obtained by

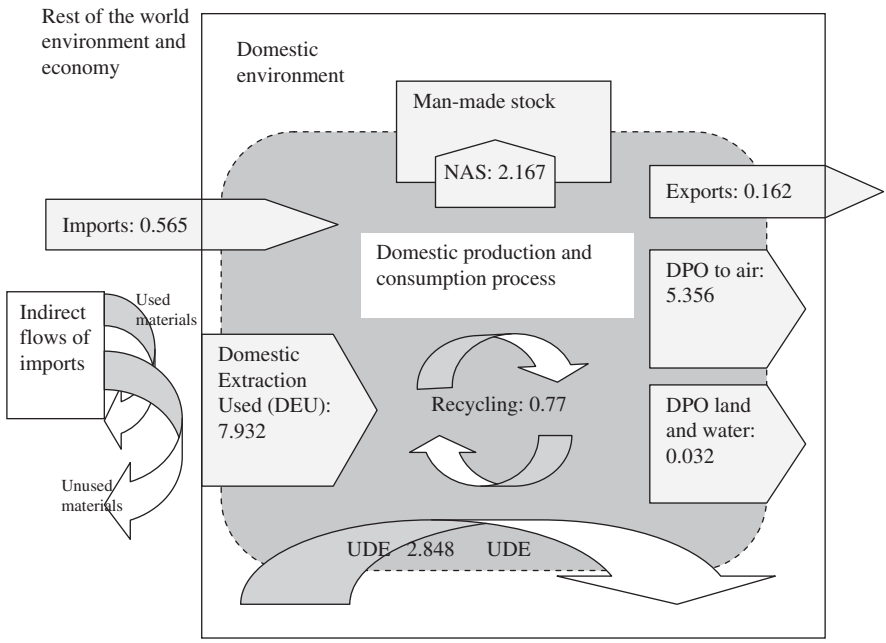

Figure 1: Material flow balance of China, 2005, unit: billion tonnes.
Source: Authors' calculation based on the framework provided in OECD (2008) and Eurostat (2001).

using the tools of resource flows, as measured by the framework of MFA and associated indicators, now adopted by the OECD (2008) and European Union (Eurostat, 2001) – a first step towards introducing ecological realism into national economic accounts. In the field of industrial ecology, the Economy-wide Material Flow Accounting and Analysis (MFA) approach has emerged as a 'primary methodological framework' in studying industrial ecology (or industrial metabolism, or industrial symbiosis) (Daniels and Moore, 2001, p. 70), and is therefore a natural choice for our analysis of the CE. By quantifying biophysical flows between the natural and socio-economic system, MFA provides a methodological bridge for economic and environmental studies, which is the key for understanding CE (Hashimoto and Moriguchi, 2004; Moriguchi, 2007).

A general scheme of MFA is shown in Figure 1 (Eurostat, 2001; OECD, 2008) together with our estimates of China's resource flows. The MFA of the economy at a certain time generates a material flow balance, involving physical inputs into an economy, material accumulation in the economy and outputs to other economies or back to nature. A number of indicators can be derived

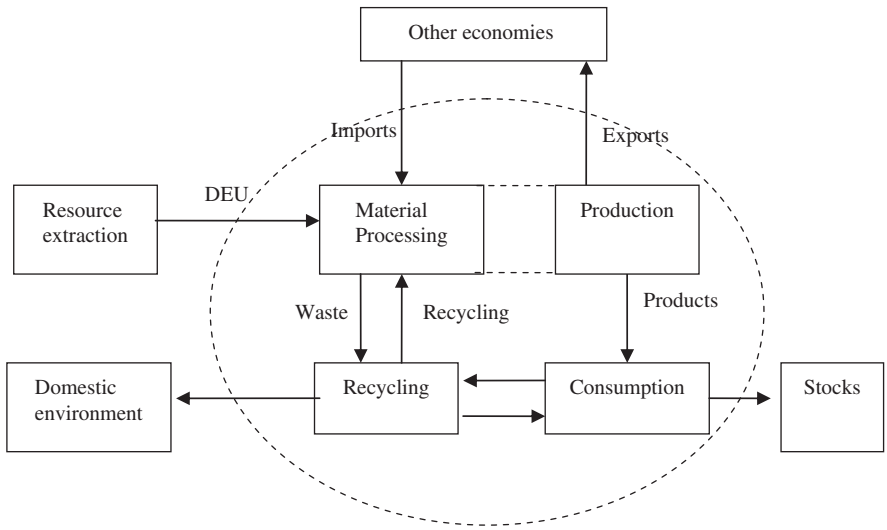

Figure 2: Circular material flows.
Source: Based on Wang and Wang (2007).

from the MFA, which can be classified into three categories: input, output and consumption indicators. We shall explore these aspects for China in a companion paper. However, in connection with our discussion of CE, we are interested in particular in whether it can be said that China is generating more or less circularity in its current economic development. In addition, we derive two recycling indicators from the MFA, based on the proposal of Wang and Wang (2007), in order to further measure circularity of the economy over time. While an initial estimate of some indicators in China up to 2002 has been provided by Xu and Zhang (2007), we have been able to update the indicators to 2005 from more comprehensive data sources, including the newly available Global Resource Extraction Database (www.materialflows.net) established by the Sustainable Europe Research Institute.

We derive two indicators for an assessment of circularity of the economy, a topic that has not (to the best of our knowledge) been previously investigated in Chinese MFA analyses. The indicators are based on a framework as shown in Figure 2.

If we view material processing and production as a combined system, the amount of materials flowing into the system should be equivalent to that flowing out, as per the law of mass conservation, that is

$$\text{DEU} + \text{Imports} + \text{Recycling} = \text{Products} + \text{Exports} + \text{Waste} \qquad (1)$$

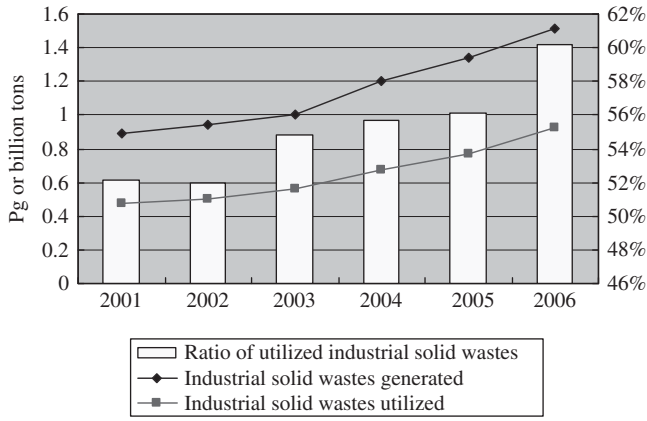

Figure 3: Industrial solid waste generated and utilized, 2001–2006.
Source: of primary data: NSBC.

In practice, there will be a difference between the quantities of input items and output items.[3] Therefore, we calculate two recycling indicators based on input items and output items, respectively, using formulas:

$$\mathrm{RI} = \mathrm{Recycling}/(\mathrm{DEU} + \mathrm{Imports} + \mathrm{Recycling}) \quad (2)$$

$$\mathrm{RO} = \mathrm{Recycling}/(\mathrm{Products} + \mathrm{Exports} + \mathrm{Waste}) \quad (3)$$

We extract material recycling and waste data from the environment database of National Statistical Bureau of China (NSBC); and estimate the quantities of products based on the sum of main manufacturing goods, agricultural goods, forestry goods, livestock goods and marine goods (in physical terms), also available from the NSBC. According to this data source, the recycling ratio of industrial solid waste has been increasing, reaching about 60 per cent in 2006, as shown in Figure 3.[4]

Figure 4 shows the results of our calculation for RI and RO for the period 2001–2006. It may be observed that RI increased from 6.6 to 8.3 per cent over this 5-year period, while RO rose from 8.7 to 9.2 per cent. While these figures suggest that China's CE is still at a very early stage, the trend is certainly in the right direction as regards evidence that the degree of 'cyclicality' of the Chinese economy is increasing over the years.

If our basic hypothesis is correct, and China is embarked on a strategy where cyclicality will be viewed as a first line of defence against ecological catastrophe, as well as a source of competitive advantage, then this trend

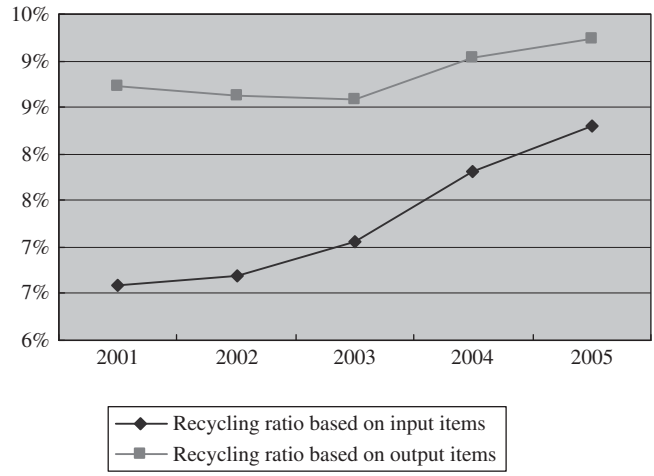

Figure 4: Recycling indicators for China, 2001–2005.
Source: Authors' calculation.

line towards cyclicality can be expected to continue its upward path. This raises the issue of the prior experiences of the most advanced countries, particularly Japan and Germany, as well as other countries in Asia in the historic shift towards a circular flow economy.

International Experiences

There has now been over a decade of experience with eco-industrial ideas in developed countries, notably Germany and Japan. The legislation implemented in these two countries, for example, Japan's *Basic Law for Establishing Promoting the Creation of a Recycling-oriented Society* (2000) and Germany's *Closed Substance Cycle and Waste Management Act* (1996), have served as pioneering statutes and policy models for China.

Japan has been a world leader in bringing ideas of sustainability into the mainstream of its industry strategies (Hashimoto and Moriguchi, 2004; Moriguchi, 2007; Yoshida *et al*, 2007). The Ministry of Economy, Trade and Industry adopted the concept of Sound Material-cycle System as the platform for not only bringing Japanese industry to a point where it makes substantial savings in terms of material and energy flows, but through innovation in these aspects of industry it seeks a world-leading position in terms of competitive advantages. Japan is bringing whole industries to the point where they agree

on recycling measures in such a way that they are viewed as the foundation for global competitive advantages instead of cost burdens. China has clearly been deeply influenced by this aspect of Japan's policy, through its adoption of the concept of EIP and industry-wide recycling initiatives.

Germany too has been a strong proponent of 3R principles to foster sustainable materials management (Rennings *et al*, 1997). The national goals are embodied in the Closed Substance Cycle and Waste Management Act, first published in 1994, with the aim of integrating product responsibility into product design, to build a closed-cycle life-cycle economy based on waste minimization. The Act establishes a hierarchy of avoidance, recovery and disposal that emphasizes waste avoidance through reform of product design and the creation of linkages between industrial activities. There has been a proliferation of university-based collaborative research programmes linking Chinese with German institutions, underlining China's capacity to adopt the best features of these ideas. While recognized as a European and world leader in 'waste management', it seems that Germany has been unable to take the ideas further to become the inspiration for a new industrial economy design. China may well succeed where Germany has fallen short.

Other East Asian experiences

While East Asian countries, apart from Japan, have been slow to develop economic reform ideas based on industrial ecology, seeing these as unnecessary for industrial catch-up and industrialization generally, the scope for incorporating such concepts as low-carbon technologies, renewable energies and industrial interconnectedness along ecological lines is now being seen in a new light, with low-carbon technologies being viewed as potential sources of major competitive advantages. In Korea, for example, the vast industrial parks established to drive industrialization around heavy industry are now being seen as potential foci of EIP, where outputs from one process (viewed originally as waste) can become inputs for another process, with the industrial system as a whole reaping savings, as well as ecological benefits. The Ulsan industrial complex is one example where common flows and interconnections are being created to mutual advantage (Park *et al*, 2008), while the EIP at Daedok Technovalley represents a newer fresh start at such thinking (albeit with little practical result as yet) (Oh *et al*, 2005). In Singapore there is already evidence that eco-industrial design principles have been pursued, at Jurong petrochemical complex (Yang and Lay, 2004). It can only be a matter of time before these linkages are promoted as a central aspect of industrial policy by Korean and other East Asian government agencies, through tax incentives, subsidies and carbon credits.

Why the CE Is a Practical Idea – For China and for the World

It is perhaps easy to say that the CE idea is an intellectual fantasy, that it will never happen, or that it is other-worldly and offers little practical advice in meeting such pressing issues as global warming. Far from being other-worldly, CE is in fact profoundly practical in focusing attention on the choices that really matter, such as favouring renewable energy sources over conventional fuels. There is also the charge that CE is other-worldly because people can't just abandon the entire existing economy and 'start again' by building a new economy along circular lines, for example the idea of 'carbon lock-in' and its globalization (Unruh and Carrillo-Hermosilla, 2006). But no-one is arguing for a totally new start. The CE will certainly not be created overnight by replacing the existing economy in any jurisdiction, and certainly not in China. Rather it will be built step-by-step, as processes that are currently linear are joined together and given cyclic characteristics – as some inputs are shared, or as some outputs are taken up elsewhere as inputs, or as some natural capital squandering processes are eliminated in favour of others that are less expensive, according to individual business decisions taken in new settings that internalize processes previously allowed to fester as externalities. The CE idea is thus to provide an image that guides such steps – not an image of a perfectly formed economy that can be redesigned and imposed as a fresh totality. It is a work in progress, and that is its strength, not a source of weakness.

The alternative to this image of a CE is a series of *ad hoc* measures that somehow 'mimic' nature, or are simply measured in terms of reducing carbon footprint. Laudable as this is, there are other aspects of unsustainable current practices that do not involve an expansion of carbon footprint – such as overfishing – that nevertheless must be opposed and eventually outlawed in any sustainable economy. It is in making these distinctions between what takes the economy in a direction of sustainability, and what takes it away from sustainability, that the CE idea proves its worth.

This is also how the CE idea goes well beyond the already established 3R recycling approaches. The application of these approaches in advanced form in Germany and Japan is admirable, but such initiatives seem to have little connection with the range of ideas of industrial ecology. In some instances, strict regulation of waste generation and disposal actually prevents its re-utilization, because of restrictions on sale or transport of wastes. China's CE, by contrast, seems to be primarily concerned with creating eco-industrial systems that go beyond the 3Rs and beyond Cleaner Production in individual firms. If the past 30 years of industrial development in China can serve as a guide, then its current system of economic management is capable of setting new directions and following through with policies and regulations. The turn to a 'Circular Economy' is the latest and most ambitious

of these shifts, and much interest attaches to China's potential success in implementing the new strategy.

Barriers to CE and China's Measures to Overcome these Barriers

For any country to establish CE, there are significant barriers in political, economic, technological and legal arenas. Politically speaking, a country needs to have strong political and policy support in order to promote CE. In a western country with a multi-party democracy, receiving political support and building consensus from all political sides is often difficult to achieve. The current Australian federal government's failure to adopt a comprehensive policy on an Emissions Trading System may be viewed as an example of such difficulty. Ironically, China's one-party system may be viewed as an asset; China seems to be in a political situation to make progress on CE much more quickly than western countries.

Economically speaking, there is no doubt that there are costs associated with establishing circular processes within an economy – for example, the need to stimulate closed-loop processes through tax concessions. In addition to the carbon tax currently being debated in various countries, a government's financial position should also be considered as a key issue in meeting such costs. Thanks to continuous trade surpluses over its 30-plus years of economic reform, China now holds US$2.4 trillion of foreign exchange reserves, the highest held by any country in the world, more than double that of second-place Japan. Such a position no doubt provides China with a degree of cushioning to ease its financial burden in building CE. In its most recent economic stimulus plan, the Chinese government budgeted RMB350 billion (US$50.74 billion) for ecology and environmental protection, and RMB160 billion (US$23.2 billion) on promoting indigenous innovation and industrial restructuring to curb high-polluting manufacturing processes (NDRC, 2008).

In fact, HSBC Global Research's most recent report on climate change shows that China currently leads the world's major economies in disbursing climate-related stimulus spend, having disbursed over 70 per cent of its fund pledged in 2008. In addition, private sector climate-related investment in China has grown 30-fold since 2004 (Tasker, 2010).

Technologically speaking, there is significant need for China to adopt new, clean technologies in order to drive CE policy. China's approach on this front is a multi-measure strategy, consisting of adopting foreign technology, promoting development of indigenous technology, and addressing pollution problems in existing production systems through targeted legislation. The first pilot project of post-combustion capture (PCC) at Huaneng Beijing Co-generation Power Plant,

one of China's key state-owned power companies, is a good example of its efforts in introducing foreign (Australian) technology. PCC, a process capturing from power-station fuel gases, is a key technology that can potentially reduce CO_2 emissions from coal-fired power stations by more than 85 per cent (CSIRO, 2008) and create further downstream closed-loop linkage possibilities.

Legislatively, the Chinese government has made progress by adopting CE-related laws, including the *Cleaner Production Promotion Law* in 2002 (www.chinacp.com/EN/PolicyDetail.aspx?id = 39, accessed 2 September 2010) and the *Circular Economy Promotion Law in* 2008 (www.faegre.com/showarticle.aspx?Show = 8647, accessed 10 November 2009). On 26 November 2009, China announced its ambitious target for a 40–45 per cent reduction from 2005 levels of unit-GDP CO_2 intensity by 2020 (www.gov.cn/ldhd/2009-11/26/content_1474016.htm, accessed 5 September 2010). Through these laws, China aims to make both existing and especially new businesses able to achieve the new sustainability standards – a significant measure contributing to CE building.

Several official channels have also been established to disseminate both policy initiatives and examples of best practice in China, including a designated official CE website (www.xhjj.net/) set up and run by the Ministry of Education, and mechanisms set up at the various EIPs and other economic development areas across the country at the provincial and local level. These channels disseminate the latest developments, including best practices, on a real-time basis to businesses and researchers around the country.

Administrative means is one of China's strengths in implementing CE policy initiatives such as providing incentives via industry clusters. One successful example is in Shenzhen, one of China's first generation of Special Economic Zones. Shenzhen established Recycling Economy Promotion Rules in 2006, enforcing specific procedures and systems in evaluating environmental-friendliness and energy-efficiency of business performance and planning, and in providing government procurement and policy support for industry clusters development (Guo and Feng, 2007).

Implementation of these regulations must be carried out at enterprise level. China has made considerable effort in putting this into practice. A more specific analysis of China's efforts in implementing its CE policy at various enterprises and EIPs is found in Mathews and Tan (2010). A challenge for China could be in the area of effective enforcement of these policies. Rather than relying solely on central government regulations and on administrative means, China has also started a process of building eco-cities alongside EIPs, empowering eco-city residents to monitor the quality of sustainable development. A prime example is Tianjin Eco-city in Tianjin Baohai Economic Development Area. This Sino-Singapore joint venture strategically

demonstrates the Chinese government's commitment to sustainable development and living in harmony with the environment (Guo, 2009).

Notwithstanding the seriousness of the above challenges, our analysis suggests that China is in a strong position to deal with them in the process of building its CE. Ultimately, successful establishment of CE in China depends on successful implementation of such national policies at enterprise level. As such, future research should examine the effectiveness of China's specific measures in implementing its CE policy, and identify best practices in such implementation.

Concluding Comments: Building the CE as a Mainstream Economic and Industrial Policy

The conventional linear model of an economy, through which it is assumed that resources can be secured in endless supply at one end, and allowed to build up in the environment as waste at the other end, is already reaching its limits in the developed world. In China it offers an impossible ideal – and catastrophic impact if pursued to the point that China's resource utilization starts to match that of developed countries. Dematerialization under these circumstances starts to look more like a survival strategy than a worthy goal. The arresting feature of China's adoption of the CE idea, and the principal hypothesis of this article, is the extent to which China has been able to link its adoption of CE with its overall development strategy.

While the first agency to adopt the CE concept was the State Environmental Protection Administration, the predecessor of the Ministry of Environmental Protection, and the projects pursued were conceived as environmental protection projects, the next stage of adoption has involved the central planning agency, the NDRC. In addition, the current CE EIPs in China are strategically located around the various key regions in the country. In this fashion, China appears to have registered an advance on all other countries that are also looking to introduce ideas of industrial ecology and sustainability through changes made to their industrial structure and processes. Japan has already adopted an eco-industrial strategy of linking industries and reducing, reusing and recycling material flows and the image of the 'sound material-cycle society'. Germany likewise developed an early intellectual lead, but appears to have stalled in its implementation. Other East Asian countries are starting to discover industrial ecology ideas and their potential competitive advantages. The United States, by contrast, has been slow to develop the potential of industrial ecology, due perhaps to a long tradition of firms acting individually and lacking an institutional framework that enables them to seek collective, or interactive, competitive advantages. Our argument is that China's adoption of

CE is essentially a business and a national policy decision and is being implemented as part of its industrial strategy.

The CE is an idea that is now in the process of becoming mainstream. From being an exclusively ecological concept it is becoming a business and competitive concept, where benefits are experienced not by firms acting on their own so much as in concert with each other, reducing their collective costs and making systemic gains that reduce the ecological toll of industrial activities. The idea of the CE presents a vibrant image of a future eco-industrial system that works with, and not against, its ecological setting. The issue is whether China can pursue such an approach in time, and whether it has the institutional capacity to do so.

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Notes

1 Available at http://www.gov.cn/flfg/2008-08/29/content_1084355.htm (Chinese); http://www.fdi.gov.cn/pub/FDI_EN/Laws/GeneralLawsandRegulations/BasicLaws/P020080919377641716849.pdf (English).
2 See the Country Analysis Brief (China) at http://www.eia.doe.gov/emeu/cabs/China/Full.html for some statistics.
3 Differences between the quantities of input and output items are common in MFA and normally can be eliminated by introducing a memorandum item, as Eurostat (2001) recommends.
4 Admittedly, the figure reflects the industrial recycling only and excludes recycling of domestic wastes, which hypothetically only constitute a small proportion of overall recycling.

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