Raising Consumption, Maintaining Growth and Reducing Emissions

The objectives and challenges of China's radical change in strategy and its implications for the world economy

Nicholas Stern

Introduction

China's 12th five-year plan represents a radical change in strategy. It identifies two key new objectives: increasing the share of consumption and moving to a low-carbon and less polluting economy. The first is motivated by recognition that external sources of growth may be weaker than in the past. The second is based on recognition that both the quality of life and the growth potential are in danger as a result of pollution, including the immense risks of climate change to China and the world over this century. The plan responds to the challenge of maintaining employment and growth during these fundamental transitions but accepts that the rate of growth may have to be a little lower than in the past. Previous objectives referring to other harmonies, including inequality across regions, urban and rural areas, and across individuals, are largely maintained. This paper argues that these transitions are not only essential but also that they will be

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full of opportunity, creativity and innovation. It examines relevant policies and indicators that could guide and measure progress.

China now sees its future growth within this strategy and accordingly as driven by: a rising share of consumption; moving to a low-carbon economy; and innovation. This contrasts with the past pattern of growth led by investment, high-energy and low-cost manufacturing, and technological catch-up. The 12th plan seeks to achieve this change in growth through massive investment in seven strategic low-carbon industries, including energy saving and environmental protection, new energy, clean-energy vehicles, next-generation information technology, bio-technology, high-end manufacturing and new materials. China's goal is for these industries to achieve a 15% share of the economy by 2020, compared with 3% now.

The level of investment required in these industries is immense, possibly around US$5 trillion over the next decade. China also plans to increase research and development spending from about 1.5% of GDP to 2–2.5% by 2015.

The implications for global climate objectives and policy discussions are of great importance. Beyond these there will be profound implications for the global division of and progress in labour and skills that go far beyond the relocation of low-cost manufacturing that we have seen in the last few decades.

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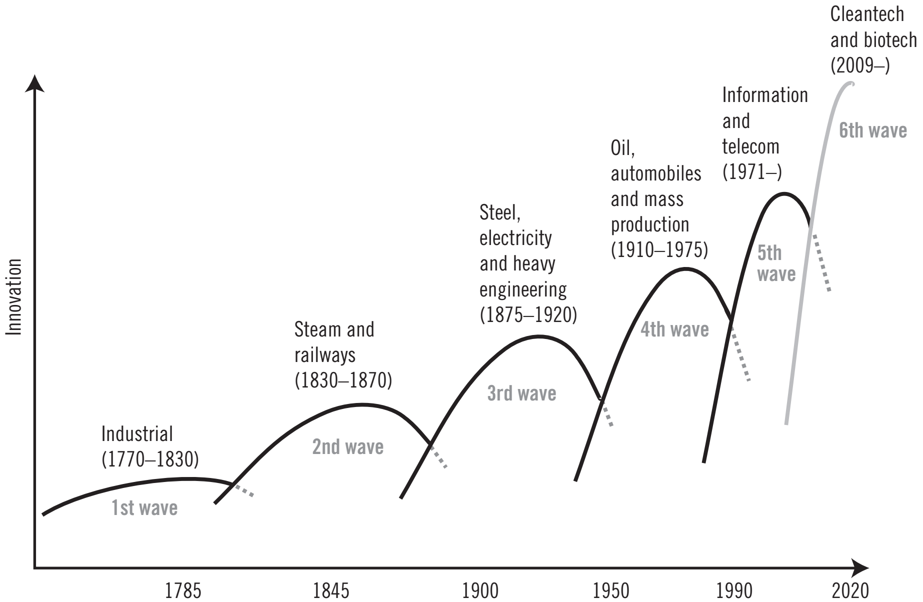
Rapid growth in China's economy may see it overtake the US by around 2025, less than 15 years from now, with the developing world as a whole accounting for around half of world income by that time. The implications from such fundamental change must be carefully considered by the world as a whole and particularly the rich countries, which should not make the mistake of assuming that they will maintain their lead in key high-tech industries, in the services sector, and in research and development. The implications of these growth rates and patterns go way beyond aggregate output.

The two indicators this paper focuses on are capital efficiency (of particular interest here is the extra capital associated with extra output, or the incremental capital output ratio-ICOR) and the relationship between greenhouse gas emissions and output (the emissions intensity). However, our focus on indicators should not disguise the reality that the transition to a low-carbon economy, characterised also by change in innovation and consumption, will involve complex but exciting dynamic processes and difficult questions on how best to promote dynamic, technical and structural change. Past transitions, which also involved innovation and complex dynamics, are illustrated in a very simple way in Figure 1, which follows the classification of waves of technological change of Freeman and Perez (see Freeman & Louçã 2001; Perez 2002).

Lessons from the economic history of waves of technological change, particularly in the Schumpeterian tradition, have much to teach us here. The scope for induced changes through public support for innovation is key (e.g. Perez 2002) and the neo-Schumpeterian approach has informed the work of economists such as Acemoglu and Aghion (e.g. Acemoglu *et al.* 2009). Other economic historians have emphasised the long lags and gradual diffusion of new general-purpose technologies (e.g. Crafts 2010) and some studies of the history of energy use have considered these issues (e.g. Huntington 2004; Fouquet 2008).

Standard economic theory has not been particularly well suited to the analysis of policy for dynamic structural change. However, there are

Figure 1: Waves of innovation



Source: DONG Energy (2009); diagram based on Perez (2002) drawing on a report by Merrill Lynch (2008) (schematic not precise quantitative vertical axis).

some promising strands developing (see, for example, Acemoglu *et al.* 2009; De Cian and Carraro 2009). Joseph Schumpeter's insights from the perspective of economic history have been enormously influential in shaping these perspectives and studies (see Schumpeter 2010). The 'public goods' aspects of innovations, endogenous learning (i.e. 'learning-by-doing') and network economies are among the reasons why policy interventions may be needed to accelerate the transition, in addition of course to the basic externality of greenhouse gas emissions, arguably the greatest market failure the world has seen.

China's coming transformation and international experience

China has had rapid growth with a high savings/investment rate over the past three decades. Simple theory in the tradition of Roy Harrod (1939) tells us that the growth rate of output is equal to the investment rate (or ratio of investment to output) divided by the incremental capital output ratio or ICOR.[1] In other words, it is the product of the rate of investment and the productivity of investment. Both the intuition and the mathematics of Harrod's result are clear.[2] Thus, one way of expressing the challenge of increasing the share of consumption while maintaining growth is that China should be seeking to increase the efficiency of capital as it reduces the investment rate. The productivity of capital can also be increased by combining it with more, or more skilled, labour and by technical progress.

China can reduce the ICOR or increase the productivity of capital in this sense, by (i) moving towards industries with a lower capital requirement, (ii) using capital, and generally producing, more efficiently in each industry, (iii) allocating capital more efficiently across industries, (iv) increasing skills and employment, and (v) technical progress.[3] Let us consider some illustrative examples of how these elements may combine to reduce the ICOR. The ICOR in China has historically (over the past 20 years) been

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1 The ICOR is $\Delta K/\Delta Y$: where ΔK is total investment, and ΔY is the increase in value of output, over a given year. Investment and output may be defined on a gross or net basis. The essence of the ICOR is that it measures the increment in capital required to produce an additional £1 of output (Walters 1966).

2 Essentially the mathematics is $(\Delta Y/Y) = (\Delta K/Y) \div (\Delta K/\Delta Y)$. In other words, the growth rate is equal to the investment rate divided by the ICOR. $\Delta K/\Delta Y$ is clearly a particular version of 'the productivity of investment': it could be influenced by how other inputs and technologies are changing, as well as by changes in the character of capital and how it is used.

3 In the jargon of production theory, producing more efficiently can be thought of as moving towards a productivity frontier and technical progress as an outward shift in that frontier. In practice these elements are likely to be intertwined with investment in ways that are difficult to distinguish.

in the range of 3 to 4, and closer to the top end of the range in recent years. Developed countries, such as the UK and US, have had a somewhat lower ICOR, on average, around 2 to 3.[4] As ICORs for the services industries as a whole are around 40% lower than the aggregate ICOR (based on US/UK data), the differences in aggregate ICORs between China and the US/UK can, in part, be explained by the greater share of services in the UK and US economy (around a 75% share compared to 45% in China).[5]

Simple numerical examples based on the obvious formula below can illustrate, where K_i and Y_i refer to capital and output in sector i, and $K = \Sigma K_i$ and $Y = \Sigma Y_i$.

$$\text{ICOR} = \Delta K/\Delta Y \equiv \Sigma_i\, \Delta K_i/\Delta Y_i \times (\Delta Y_i/Y_i\,/\Delta Y/\,Y) \times Y_i/Y$$

In other words, the overall ICOR is a weighted sum of the sectoral ICORs, where the weights are the sectoral growth rates (divided by the aggregate growth rate) times the sectoral shares. The 'relative' sectoral growth rate may be closer to one for services in rich countries, where the relative sectoral shares may move more slowly than an economy in transition such as China, but be greater than one in China.

For example, the ICOR in China is currently just over 4 and the services share is around 45% of the economy. Based on some rough calculations, if the services share of the economy were to rise to, for example, 50% over the next two or three years (assuming the services ICOR is around 40% below that of aggregate ICOR, and other factors remain constant, such as investment and growth rates), China's aggregate ICOR would fall slightly, to around 3.9. Over the next two decades if services increased to 80% of the economy, around the current share of services in developed countries such as the UK and the US, aggregate ICOR in China could fall to around 3.6 (also see aggregate ICOR calculations in Appendix A).

Therefore China could decrease the aggregate ICOR substantially over the next two decades by increasing the share of services in the economy. Allocating capital more efficiently will also reduce the ICOR, for a given

4 The calculations are based on World Bank data, which attempts to maintain consistency between countries (World Development Indicators 2010). Estimates of ICORs using country-level data are not necessarily consistent with the estimates quoted. However, exact levels are not the aim here, rather these estimates are provided to illustrate investment and growth strategies that could indicate how China might reduce the aggregate ICOR.

5 There are problems in consistency of definitions of services across countries.

growth rate, by allowing the investment rate to fall: Dollar and Wei (2007) estimate that, if capital is allocated more efficiently, China could reduce its total capital stock by around 8% without any negative impact on GDP growth. Other actions that may reduce the ICOR include improvements in energy efficiency (which will lower energy costs and increase value added), further investment in human capital, and technical progress.[6]

The World Bank (2011) indicates that 30% of China's total wealth is produced capital, around 50% is human/intangible capital (in particular the skills of its labour force), and around 20% is natural capital, compared to high-income countries where only 17% of wealth is produced capital, around 80% is human capital and 3% is natural capital. While such figures are necessarily somewhat difficult to interpret they nonetheless give a plausible impression of a very different capital structure. They illustrate how development can, and perhaps should, place increasing emphasis on human capital. However, we should note that high-income countries have eroded natural capital (both domestically and internationally) via a long period of growth of a kind that has dramatically depleted resources, has raised concentrations of greenhouse gases and has damaged the environment.[7]

Thus, based on some rough and illustrative assumptions as described above, with the strongest effects coming from structural change, by 2030 the combination of these factors could perhaps reduce the ICOR from around a little over 4 now to a little over 3. This would enable China to reduce its (net) investment rate from around 40% today, to around 30%, while maintaining the economic growth rate and increasing household consumption (see Appendix A for calculations). It could also, if it so chooses, take the 'benefits' of a lower ICOR in part through faster growth and in part through a lower savings and investment rate.

We must recognise, however, that radical transitions are likely to involve learning, dislocation and mistakes. The 12th five-year plan allows for a lower growth rate, 7% p.a., compared with the average over the past 20 years of 10% p.a., to take account of the potential difficulties of the new directions. And it must also be recognised that while policy implementa-

[6] 'Disembodied technical progress' increases output for given inputs and thus will, ceteris paribus, reduce the ICOR. But this may occur alongside increasing capital intensity or it may take a different form and be embodied in equipment.

[7] They are responsible for around 75% of total world CO_2 emissions since the mid-19th century (WRI 2011). Thus they have used up a crucial public good for the world as a whole.

tion in China is stronger than in some other countries, it is a complex and very large economy and society, and is particularly dependent on actions and strategies in its provinces, cities and countryside. The centre is not, and cannot be, in complete control of actions and outcomes at lower levels.

China's transition and the emissions of greenhouse gases

In this transition China can reduce emissions growth through greater energy efficiency and a shift towards less emissions-intensive services industries. Of course, China will not necessarily choose to maintain the same growth rate and, as we have emphasised, has indicated that a target of 7% will be used for the 12th plan. That could allow for both a further increase in consumption share and an increase in different types of investment to drive the transition to a low-carbon economy, including in human capital.

China already has a target to reduce emissions per unit of GDP (emissions intensity) by 40–45% between 2005 and 2020, with a target of 17% during the 12th plan. The 2020 target was announced for the Copenhagen Accord in December 2009 and both targets were confirmed for the Cancun Agreement in December 2010. Assuming a further 17% reduction in emissions intensity in the 13th plan, this is equivalent to a decrease in emissions intensity of around 31% (equal to $1 - (0.83)^2$) for the period 2010–2020.[8] If the growth rate for this period is in the region of 7%, output would approximately double between 2010 and 2020. The combination of this growth in output and the emissions intensity reduction would take China's current, 2010, per annum emissions of

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[8] Given the emissions intensity reduction target of 17% in the 12th plan, and assuming a similar target in the 13th, the reduction in emissions intensity 2005–2010 would need to have been slightly higher at 20% to achieve the more ambitious end of the 40–45% target 2005–2020 (0.69, corresponding to the intensity reduction factor 2010–2020, times 0.8 corresponding to 2005–2010, equals 0.55). This 20% reduction for 2005–2010 would be consistent with the target of reduction of energy per unit of output (energy intensity) in the 11th plan. The larger implied decrease in emissions intensity 2005–2010 is consistent with a widely held view of greater energy efficiency opportunities in 'earlier' stages of the reduction of energy per unit of output. However, as low-carbon energy generation capacity comes online over the next few years one might expect substantial reductions in emissions per unit of energy, which could lead to larger reductions in emissions intensity than postulated.

approximately 9 billion tonnes[9] (carbon dioxide equivalent) to around 12 in 2020. A comparable absolute increase in per annum emissions (and thus a smaller percentage increase, 25% compared to 33%) in the next decade (2020–2030) would take China to around 15 billion tonnes by 2030.

While this would represent a major reduction relative to a path with a constant emissions–output ratio (which would lead to emissions of around 35 billion tonnes CO_2e in 2030), 15 billion tonnes CO_2e in 2030 would make it very difficult for the world to achieve the 2°C target (usually interpreted as staying below 2°C with a 50% probability), since the total world budget for a 2 degree path would be around 30–32 billion tonnes in 2030 (see Bowen & Ranger 2009). China, with around 20% of the world's population, would be taking up around 45–50% of the carbon space in terms of annual flows. Other countries (unjustifiably in my view) use China's large and growing emissions as an excuse for not cutting their own, so China's increases may get magnified if some countries react in this way. If the world budget is increasingly exceeded, then the dangers escalate for us all, including for China, which is very vulnerable to climate change with its dependence on Himalayan water sources, general water scarcity and coastal populations.

China has a much smaller history of emissions than the rich countries and produces for the consumption of others, and for these two reasons could understandably argue that its future share should, from an equity perspective, be higher than those countries. Indeed, many in China do present these arguments. Nevertheless, the overall arithmetic of the world's carbon budgets, albeit grossly inequitable, is a fact of life. Thus it would be very good for the safety of the world, and for China, if China could find a way of increasing its ambitions for reducing emissions intensity with a view to peaking at around 12 or 13 billion tonnes in the early 2020s and returning to something like 9 billion tonnes of total emissions by 2030. If the global budget were to be achieved, 9 billion tonnes would leave China at 25–30% of global emissions. This implies a cut in emissions intensity by around a factor of four by 2030, or 29%, on average, over each of the next four five-year plans.[10]

[9] An approximation based on 2010 CO_2 emissions estimates (Climate Group 2011) and adjusted for other greenhouse gases (based on the share of non-CO_2 gases in total CO_2 for China in 2005 (WRI 2011)).
[10] $(0.71)^4 = 0.25$.

Let us be clear. This is not saying that a target of 9 billion tonnes for China in 2030 is in any sense fair or equitable. The rich countries, particularly countries such as the United States, Canada and Australia, with emissions per capita well over 20 tonnes CO_2e, compared to China's of around 7 tonnes per capita, should arguably be taking much stronger action to reduce emissions, particularly in the light of their history of emissions. But China's population is so large and its growth so strong that what happens in China is of enormous importance to the aggregate arithmetic. Notions of equity would point to the rich countries supporting investments to cut emissions elsewhere, particularly in the poorest developing countries, as well as making radical cuts in their own.

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Accelerating the development of the services sector is a major goal of the 12th five-year plan. A shift to services industries is desirable for a number of reasons. It would, if the history of other countries is a guide, indicate a response to consumer preferences at higher income levels as well as to market production opportunities as skills develop. It would save on capital and thus allow for extra consumption and reduce the ICOR, as discussed. And it is also an attractive way for China to further decrease its emissions intensity, as the services sector is around 60% less emissions intensive than the economy as a whole, and 90% less than the manufacturing industry (based on the UK and US).

To illustrate what may be possible, let us begin with a hypothetical or 'base' scenario, based on the above discussion, where emissions in China in 2030 are around 15 billion tonnes CO_2e and existing industry shares are fixed (around 45% services, 55% industry and agriculture).[11] Under this base scenario, emissions intensity for the economy would decrease to around 0.8 tonnes CO_2e per US$000 of GDP in 2030 (from around 1.8 tonnes today). Table 1 illustrates emissions in 2030 under the base scenario and scenarios where industry structures are allowed to vary. For example, a 35% increase in services share (from around 45% now to 80%) relative to the base scenario, by 2030, given emissions intensity for the services industry is around 60% lower than the economy as a whole, could reduce emissions to around 9

[11] This is for illustration of the potential magnitude of effects, and not a 'base forecast'.

Table 1: China – emissions and share of services

Growth and emissions	Estimate 2010	2030
GDP (estimated 2010 US$ trillions) – 7% p.a. growth rate	5	20
Total emissions (billion tonnes CO_2e) (current policies to 2030)	9	15
Emissions intensity (tonnes CO_2e per US$000 of GDP)		
Economy	1.8	0.8
Services sector*		0.3
Industry and agriculture**		1.1

Scenarios in 2030	GDP (US$ trillion)	Emissions (billion tonnes CO_2e)	
Industry share and emissions	**Sector**	**Sector**	**Total**
45% services **(current share – base scenario)**	9	2.5	
55% industry and agriculture	11	12.5	**15.0**
50% services	10	2.8	
50% industry and agriculture	10	11.4	14.2
55% services	11	3.1	
45% industry and agriculture	9	10.2	13.3
60% services	12	3.4	
40% industry and agriculture	8	9.1	12.5
80% services	16	4.5	
20% industry and agriculture	4	4.6	**9.1**

*Based on UK national accounts data where emissions intensity of services is around 60% below that of the economy (0.8 × 0.4).
**Derived. Based on existing industry shares (X = (0.8 – (0.3 × 45%))/55%). X = 1.1.
Source for current GDP and industry shares: World Bank Development Indicators, 2011.

billion tonnes CO_2e in 2030, a further 6 billion tonnes. This would increase the likelihood of achieving a peak in emissions in the early 2020s and take China back to the range where emissions would need to be in 2030 from a global perspective. While the calculations in Table 1 are only illustrative, they clearly highlight the potential for emissions reductions from encouraging sectors that have low emissions intensity.

The reductions from changes in industry structure will be complemented by further progress in reducing energy per unit of output and emissions per unit of energy. The power of this last effect is likely to grow rapidly as new low-carbon energy sources come on-stream.

The 12th plan has a target for a 16% reduction in energy per unit of output and a 17% reduction in emissions per unit of output (see Table 2). This implies emissions per unit of energy will decrease by only 1.2%

Table 2: Emissions per unit of energy and output

	Emissions/ energy (tCO_2e/ toe)	Emissions/ output (tCO_2e/'000 US$)	Output 7% p.a. growth (US$ trn)	Total emissions (bn tCO_2e p.a.)	Energy/ output (toe/'000 US$)
Estimate for 2010	4.0	1.8	5.0	9.0	0.45
Current targets					
12th plan	–1.2%	–17%			–16%
Estimate for 2015	3.95	1.49	7.0	10.5	0.38
Possible targets for each of the 12th, 13th, 14th and 15th plans:					
Each five-year plan:	–15%	–29%			–16%
Estimate for 2030	2.09	0.46	19.3	8.9	0.23
Total change 2011–2030	–48%	–75%	287%	–1%	–50%

Sources: current emissions, footnote 9; current energy use, IEA Energy Balances of Non-OECD countries, 2011 edition; current output, World Bank Development Indicators, 2011.

over the next five years.[12] Emissions per unit of energy is a key variable and, while it takes time for improvements to flow through, its potential to contribute to emissions intensity reductions is significant. For example, Table 2 illustrates that a 16% reduction in energy per unit of output, together with a 15% reduction in emissions per unit of energy, would create a 29% reduction in emissions per unit of output over the next five years.[13] HSBC (2011) indicates that energy and environmental goals in the 12th plan aim to decrease the share of coal in primary energy consumption from around 70% to 63%, and increase the share of (lower-carbon) gas from 4% to 8%. Significant investment over the next few years in hydroelectric, nuclear, wind and solar, to achieve a share of 15% of primary energy by 2020, is also planned. The combination of these factors would seem to indicate the potential for a more substantial role for reductions in emissions per unit of energy than implied by the 1.2%.

The clear story from Table 2 is that it could be possible for China to get back by 2030 to 2010 levels of overall emissions, i.e. 9 billion tonnes of CO_2e. But it will be necessary to reduce emissions per unit of output by 29% in each of the four five-year plans from now to 2030. That will require a very radical effort, but given the new path and the learning likely

[12] Emissions per unit of output is equal to the product of emissions per unit of energy and energy per unit of output. Therefore $(1 - 0.17) = (1 - X) \times (1 - 0.16)$. $X = 0.012$ (a 1.2% reduction).
[13] $(1 - X) = (1 - 0.15) \times (1 - 0.16)$. $X = 0.29$ (a 29% reduction).

to come along the way, this goal may be possible. It is of great importance for both China and the world.

The scale and composition of China's future additions to its total electrical generation capacity will have important implications for reductions in emissions per unit of energy. Electricity generation represents around 15% of total energy consumption in China,[14] and around 50% of total CO_2 emissions (WRI 2011). Total electricity generation capacity in China is currently around 900 billion watts (GW) with a range of sources indicating that an additional 450 GW of capacity will be added during the 12th plan and a doubling of capacity by 2020 (see, for example, Climate Group 2011; Tawney *et al.* 2011).[15] Such a huge projected increase in generation capacity places great importance on its composition. On the basis of China's current low-carbon energy targets, it may be possible for China to add somewhere in the region of an additional 450 GW of low-carbon electricity generation capacity by 2020, around half the projected total capacity increase. For the balance of new (high-carbon) capacity added by 2020, advances in clean coal technology and efficiency of thermal power plants may also be able to make substantial contributions to lowering emissions per unit of energy and achieving targets such as those illustrated in Table 2.

Policies and structural change

While basic arithmetic such as that embodied in Tables 1 and 2 or Appendix A is useful in understanding the scale of the challenges and possibilities, the process of transition is much more than a simple mechanical exercise. There are powerful dynamic processes underlying the structural changes that are likely to occur in China over the coming decades involving innovation, changes in technology, new industries, new skills, and the movement of people over space and over activities. These dynamic processes are probably best fostered by a combination of government policies which support relevant infrastructure, research, development and deployment (RD&D), education, incentives and finances; also by strengthening

[14] Source: EIA statistics on China, 2011. Available online at: http://205.254.135.24/countries/country-data.cfm?fips=CH.

[15] The Climate Group (2011) indicates total electrical generation capacity growth of 8.5% p.a. in the 12th plan. This is equivalent to an additional 450 GW over the 12th plan period. Growth of 5.6% p.a. is suggested for the 13th plan. These growth rates would deliver total capacity of around 1,777 GW in 2020 (calculation based on current 2010 capacity of 900 GW).

the forces of competition and entrepreneurship. Such a strategy and policies are entirely consistent with the 12th plan indication of a continuing move from administrative towards market structures.

Increasing consumption

Policies to increase consumption have been extensively discussed in China. A key feature of such policies would be a change in the pattern of income distribution from profits to individuals since a big fraction of Chinese savings and investment originate with firms. The share of employees' compensation in GDP is below 50% and the share of personal disposable income in GDP is around 57% (Citi 2010). The overall gross savings rate is above 50% in large measure as a result of the high share of profits and the high propensity to save and invest out of profits. The ownership and governance structures of enterprises imply only modest incentives to distribute income to owners/shareholders and strong incentives to retain income for investment.

Another key element in promoting consumption would be to reduce perceived future uncertainties facing households, particularly in the context of an increasing demographic representation of older people, by providing stronger pension systems and provision of healthcare. Even though the propensity to save out of household income at around 38% is substantially lower than the aggregate rate of 50%, it is still high by international standards.

As consumption grows it is important to focus on its carbon content; if, 20 years from now, China's consumption pattern and carbon content look like those of US consumers today then the world would be most unlikely to be able to have a reasonable chance of holding to 2°C. It is this understanding that has been a major motivation behind China's radical change in strategy.

Reducing emissions

Evidence shows that carbon prices and strong support for RD&D can together give powerful incentives for change (see, for example, Popp 2006; Fischer 2008; Fischer & Newell 2008; Acemoglu 2009). Carbon markets are already under strong discussion and examination in China,

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including in the planning process.[16] Although few details are confirmed it has been reported that pilot projects will begin by 2013 in selected provinces and possibly a national scheme will be operating by 2015.[17]

In March 2010, at the China Development Forum, I suggested that a tax on coal at fairly modest carbon prices (e.g. equivalent to US$20 per tonne of CO_2) could yield revenues equivalent to 2 or 3% of GDP.[18] Table 3 presents some very approximate calculations, which I shall keep in round numbers. A price of US$20 per tonne of carbon dioxide would be not far from the average for the European Union Emissions Trading Scheme (EU-ETS) over the period 2008 to 2011. This would be high enough to provide a strong boost to incentives to economise on coal. And the revenue, of around RMB1.2 trillion or US$150 billion, would make a major contribution to funding the research and development, and investment needs of the transition to the low-carbon economy.

Transformation towards low-carbon will have to take place in every part of the economy given the necessary scale of ambition: including agriculture, building, industries, transport and power. Figure 2 illustrates the sectoral breakdown of emissions in 2005. This will likely change rapidly over time – for example, as transportation grows – but shows that the scale of reductions required does call for action across the whole economy.

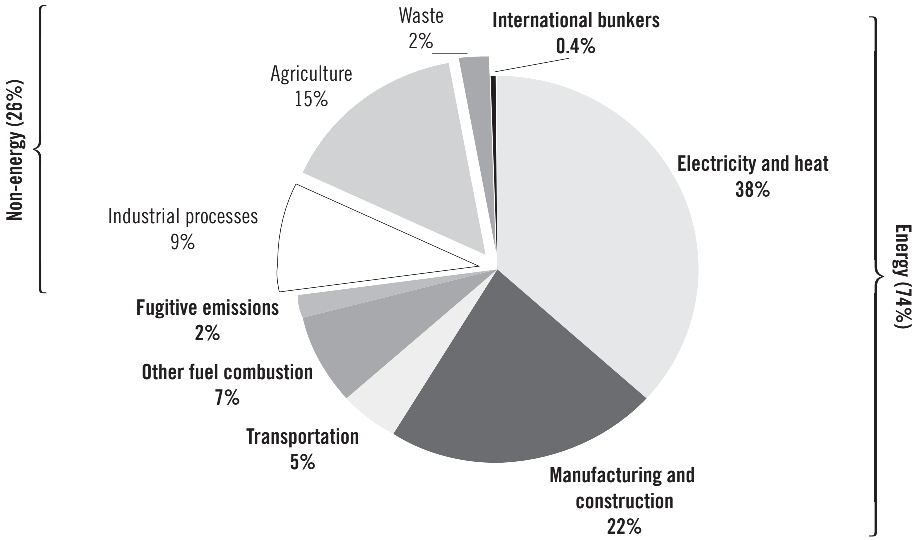
There are many exciting opportunities for innovation across the board, and many of these are being developed in China. For example, a recent

Table 3: Illustrative and approximate calculation of revenue raised from a tax on coal

Price of coal in China	RMB750–800 a tonne (US$100 per tonne)
Tax on CO_2	US$20 per tonne CO_2
Equivalent tax per tonne of coal	RMB400 (US$55)
Coal consumption	3 billion tonnes p.a.
Total revenue	RMB1.2 trillion p.a. (US$150 billion)
Total GDP	US$5 trillion
Share of GDP	3%

[16] China has trialled an SO2 trading system in Shanxi province.
[17] For example, see http://www.reuters.com/article/2011/07/17/us-china-emmission-idUSTRE76G0PI20110717.
[18] On 1 November 2011 China introduced a new national resources tax (an expansion of previous trials of oil and gas levies in selected provinces). A 5–10% volume-based tax will apply to crude oil and natural gas sales and an 8–20 yuan a tonne tax will apply to coking coal.

Figure 2: China – share of emissions by sector in 2005



Source: Climate Analysis Indicators Tool (CAIT) Version 8.0 (Washington, DC: World Resources Institute, 2011). Land use change and forestry is excluded as this figure was negative in 2005 (–47 $MtCO_2e$).

E3G study indicates that China plans to invest in the order of 2–3 trillion yuan (€230–340 billion) in the renewable energy sector by 2020, not far from the low-carbon investment needs of the EU of around €310–370 billion. This investment would see China's total non-fossil fuel generation capacity surpass the EU's by 2015. China also plans to spend 500 yuan (€57 billion) on high-voltage transmission lines and more than 4 trillion yuan (€460 billion) on smart grids over the next decade. In comparison, the EU has identified around €23–28 billion of transmission investment by 2015 and is proposing around €100 billion of investment on smart grids by 2020 (E3G 2011).

China also plans to increase economy-wide research and development spending from around 1.5% of GDP to 2 to 2.5% by 2015. If output grows at 7 to 8% p.a. over the next five years, research and development spending could exceed 1 trillion yuan (€110 billion) by 2015 (E3G 2011). The EU has a research and development spending target of 3% of GDP by 2020. Assuming output grows at 2% p.a. and, optimistically, that the 3%

target were reached by 2015, total research and development spending would be around €350 billion.

Corresponding increases in investment in education and new skills are likely to be crucial. These investments could set the stage for a dynamic transformation to a new pattern of low-carbon growth.

Priority for the seven strategic industries (energy saving and environmental protection, next-generation information technology, clean-energy vehicles, bio-technology, high-end manufacturing, new energy, new materials) in finance together with carbon pricing policy and RD&D support could help deliver the 12th plan objective of raising their share from 3% to 15% of the economy by 2020. These are sectors all of which can play a strong role in reducing ICORs, and both energy and emissions intensity. They are also sectors that are likely to generate creativity and innovation, and enhance China's comparative advantage in the new world of the energy and industrial revolution. And they are sectors that can reduce the costs in, and increase the efficiency of, the other 85% of the economy.

A drive for energy efficiency[19] will improve capital productivity (and thus reduce the ICOR) and emissions intensity. Thus the emphasis on energy efficiency in the 12th five-year plan is a key element in progress on both fronts. During the first half of the 11th plan, 2006 to 2008, the industrial sector achieved a 13% reduction in energy efficiency and a 15% decrease in emissions intensity (CPI 2011).[20] This was achieved through technological advances, updating plant, and by closing old and inefficient plant. There were also impressive efficiency gains in the power sector where the 11th-plan target for the closure of 50 GW of older and less efficient plant was achieved by 2009. China also added 90 GW of additional hydro, 25 GW of wind and 2 GW of nuclear 2005–2008 (CPI 2011). While some of the 'low hanging fruit' may have been harvested, it is likely that further impressive energy efficiency and emissions intensity improvements will be possible during the 12th plan.

A key driver of improved efficiency in allocation of investment, thus reduction in ICORs, is likely to be a stronger and more competitive finan-

[19] I am grateful for guidance on this subject by the eminent Chinese scholars and economists Professor He Jiankun, Liu He, Qi Ye and Yu Yongding. I am fully responsible for interpretations.
[20] China achieved an overall reduction in energy efficiency of 19.1% over the 11th plan, in line with its 20% reduction target.

cial sector. Overall, there should be a strong emphasis on efficiency right across the economy, particularly in the use of energy. Capital markets and a more market-orientated approach to allocation will play a powerful role here. This is a subject of great importance, which I do not have the space to discuss further here, but is surely a priority for further analytical work and policymaking.

Structural change and investment in the strategic industries

If output is to grow at 7% p.a. or so in the next ten years and the share of the seven industries in the economy is to grow from 3% to 15%, then output in those industries will have to grow by a factor of around 10: assuming overall annual output in China is currently around US$5 trillion the annual output of these industries would have to grow from US$150 billion to more than US$1.5 trillion. If the incremental capital–output ratio for these industries is in the region of 3 then, over ten years, the overall investment would have to be around US$4.5 trillion. While such estimates are very approximate it is clear that the financing requirements are immense. Venture capital and private equity flows, in 2009, in the seven strategic industries were only around US$2 billion (HSBC 2010). The necessary scale of investment indicates that this will surely need to show huge increases in coming years. We must emphasise, however, that the appropriate methods of finance will vary greatly across the industries. Now is the moment to analyse very carefully how this major expansion of these key industries can be encouraged and financed in the most efficient and creative way.

Implications for the world economy

China's rise and transition to low-carbon growth may have a major impact on world comparative advantage, especially in high-tech industries, traditionally the domain of rich countries. Work on comparative advantage (e.g. Hidalgo *et al.* 2007; Hausmann & Hidalgo 2010) suggests that this usually grows out of existing capabilities. China is fast building its capabilities in many of these high-tech areas, and rich countries should not assume they will be able to maintain their traditional lead in these key industries.

High-tech manufacturing in rich countries is currently around 3% of GDP (for each of Germany, Japan, UK and the US).[21] China's strategic industries overlap many of these high-tech industries, and their targets, if achieved, are likely to see China move ahead of many rich countries in a number of these industries. China's potential to capture significant shares in these markets should be recognised, just as over the past few decades it came to dominate low-cost manufacturing. And the rewards could possibly be huge for China as it develops capabilities in low-carbon production technologies and low-carbon industries. China's policies and actions aim to take full advantage of these growing opportunities. China's rapid rise to leader in the solar PV industry is a clear example of what it is capable of achieving in high-tech industries in a relatively short period of time.

China's actions are likely to have profound implications for growth prospects in the rich world.

China's actions are also likely to have profound implications for growth prospects in the rich world. As financial crises continue, and the balance sheets of many rich countries continue to be impaired, some of them may be (unwisely) diverted from stronger action on climate change and the transition to low-carbon growth. Therefore China may find it easier to capture new and existing markets: financially weak rich countries may find that their most important sources of, and prospects for, growth are being severely challenged and weakened by growing competition from China.

But the implications of China's ascendancy are likely to go far beyond growth, comparative advantage and market share. As China captures new and existing markets from rich countries there will be a rapid redistribution of the global division of skills. The challenges for rich countries from China's rise are immense and they need to think very carefully about how they will relate to China in a radically changing world. They will have to think through carefully where they can collaborate and where they can compete. Examples of the former could be higher education, natural

[21] Source: OECD STAN database for structural analysis (accessed 3 October 2011). Share of gross value added at current prices. Industries included in the high-tech manufacturing category include: Pharmaceuticals; Office, accounting and computing machinery; Radio, television and communication equipment; Medical, precision and optical instruments; and Aircraft and spacecraft. Many of these overlap the seven strategic industries. Limitations with industry classification codes make it difficult to compare directly to China's strategic industries.

resources and climate change. Grudging defensiveness, all too common a theme in some commentaries, is unlikely to make sense.

The challenges for China are of a completely different kind: how to manage rapid growth and rising prosperity while preserving and enhancing its natural assets and improving environmental quality. And how to manage its affairs when it has become powerful on the international stage before it is rich.

Conclusions

The 12th five-year plan is of fundamental importance to China and to the world. It will bring profound change to the Chinese and world economy. Indeed it represents a radical change in strategy for China. The 12th plan is very likely to establish China as a leader in the new energy-industrial revolution, through its promotion of the seven strategic industries that will lie at the heart of the transition, and demonstrate to the world the potential of this revolution; it will provide an intense learning process about what is possible. The implications for the rich countries from such radical change are profound – for example, the recasting of the international division of skills. Rich countries should be discussing now how they will handle and respond to such massive change.

The power of China's example will be immense in influencing the world's transition to a low-carbon economy and thus how successful the world will be in managing the huge risks of climate change. This, if we are successful as a world, will be a transition full of opportunity, creativity and innovation. It will lead to a safer, cleaner and more prosperous low-carbon future for us all.

In closing a paper on the latest five-year plan in China it is worth reflecting on how far planning processes have come since the early models of Soviet planning that followed the Feldman models of 'machines-to-make-machines', prior to the Second World War, and the later Leontief fixed-coefficient input–output models with no technical change, which dominated early Chinese and Indian planning models after the Second World War. China's planning now emphasises income distribution, regional issues, environment and climate change, quality of life, internal and external balances, technical progress, labour skills, the services sector, and the role of market-based incentives. The analytical perspective has been transformed dramatically along with the economy. The changing perspectives in China on how to foster change and what change to seek are not only important for China itself but should force the world as a whole, particularly the rich countries, to think hard about their own future.

Appendix A: ICOR estimate – illustrative calculation for China

	2009
Gross fixed investment (US$)	2,274,279,648,609
Depreciation (based on 2008 value) (US$)	523,084,319,180
Gross domestic product (GDP) (US$)	4,985,461,200,586
Net national income (NNI) (US$)	4,462,376,881,406
Real growth GDP (%)	9.2
Investment rate (net fixed investment/NNI) (%)	39
ICOR (investment rate/GDP growth)	4.3
ICOR reduced from 4.3 to 3.3 (50% of the decrease from structural shift to services, 30% from energy efficiency, 10% allocative efficiency, 10% other)	3.3
New investment rate = ICOR × growth rate = (3.3*9.1%)	30%

Source: World Bank Development Indicators, 2011; calculations.

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