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Analysis

# Lifestyles, technology and $CO_2$ emissions in China: A regional comparative analysis

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ABSTRACT

With rapid economic development, higher income levels, urbanization and other socio-economic drivers, people's lifestyles in China have changed remarkably over the last 50 years. This paper uses the *IPAT* model (where *I* = Impact representing $CO_2$ emissions, *P* = Population, *A* = Affluence, and *T* = emission intensity) to analyze how these main drivers contributed to the growth of $CO_2$ emissions over this time period. Affluence or lifestyle change has been variously recognized as one of the key factors contributing to $CO_2$ emissions. Through comparative analysis of the development of five regions in China, we trace lifestyle changes since the foundation of the People's Republic of China (PRC) in 1949 until 2002. We find that household consumption across the five regions follows similar trajectories, driven by changes in income and the increasing availability of goods and services, although significant differences still exist between and within regions due to differential policies in China and different possibilities for social mobility. There are considerable differences between the southeast and northwest and between urban and rural areas. We also found that technological improvements have not been able to fully compensate for the increase of emissions due to population growth and increasing wealth, which is also in line with results from other studies. Finally, this paper emphasizes that developing countries such as China, which is home to 22% of the world population and a growing middle class, and which is on a fast track to modernization, need to ensure that people's lifestyles are changing towards more sustainable ways of living. China has been investing heavily in infrastructure and thus creating the emissions of tomorrow. Thus investing, for example, in public transport and low energy building today will help reduce emissions in the future and will support more sustainable lifestyles.



## 1. Introduction

In China carbon dioxide emissions have shown an increasing trend over the last 50 years, particularly during the high economic growth periods of the last two decades (Guan et al., 2008, 2009). In 2003, carbon dioxide emissions in China accounted for 15.5% of the world's total (EIA, 2006), and China has become the largest $CO_2$ emitter in the world exceeding the emissions of the US in 2006 (Auffhammer and Carson, 2008). Similarly, the International Energy Agency (2006) reported that China's $CO_2$ emission intensity per GDP was 658.1 t per million dollars in 2003, which was 27.8% higher than the world average, and 41% higher than the EU average. In response the UN Climate Change Conference 2007 in Bali proposed that China, as a large emitting country, will be expected to take on future targets to mitigate Greenhouse Gases emissions (ERM, 2007). Since then, China has unveiled a climate change action plan but at the same time is stressing that it will not sacrifice economic ambitions to international demands to cut greenhouse gas emissions. Given its position as the world's largest emitter and one of the largest growing economies it plays a major role in any global effort (Brahic, 2007). Fig. 1 shows the trend of $CO_2$ emissions during the last five decades.

$CO_2$ emissions increased gradually from 1952 to 1962, did not change significantly between 1962 and 1965, and then more than tripled by 1978. There was a short break between 1978 and 1980, before China entered its rapid economic growth, with further increases of 150% between the beginning of the open door policy in 1978 and 2002. For each of these periods different drivers contributed to emissions.

A large number of studies investigating energy consumption and $CO_2$ emissions in China were carried out especially analyzing the more recent past (e.g. Auffhammer and Carson, 2008; Fisher-Vanden et al., 2004; Guan et al., 2008; Hubacek et al., 2007; IEA, 2007; Lin et al., 2008; Peters et al., 2007; Sinton and Levine, 1994). The aim of this paper is to investigate the driving forces of $CO_2$ emissions in China since 1952. We employ the Impact ($CO_2$) = Population × Affluence × Technology model to evaluate the significance of each factor contributing to $CO_2$ emissions. In Section 2 we give a brief overview of the development and usage of the *IPAT* model. Acknowledging the significant regional differences in China, we select five very divergent provinces as case studies, situated in the east (Shanghai), south (Guangdong), centre (Henan), north (Heilongjiang) and west (Gansu). These selected

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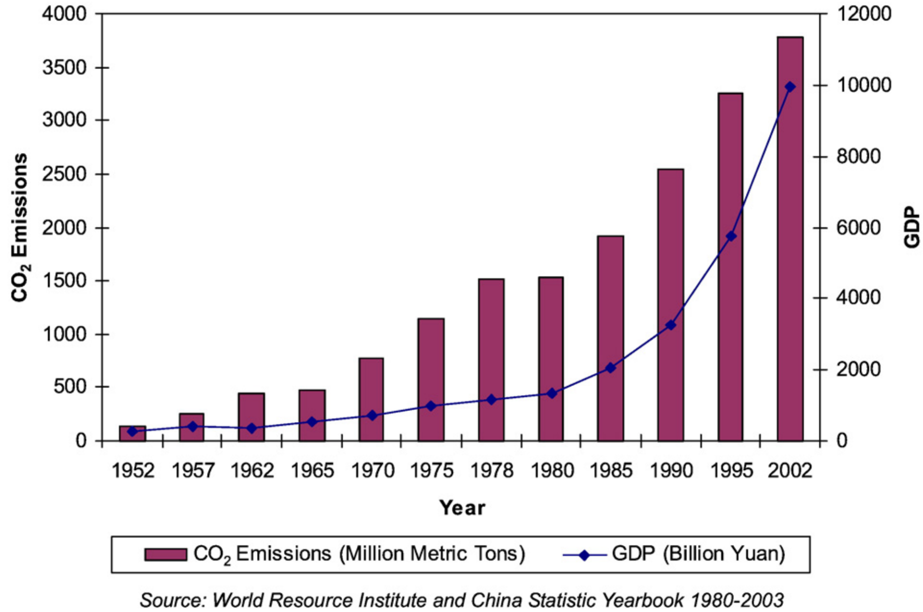


**Fig. 1.** China's $CO_2$ emissions and GDP from 1952–2002.

regions have very different attributes and development paths that make them interesting for this study: Shanghai is the most developed region in China with a very high population density. Guangdong is located in the southeastern coastal area and is a quickly developing and designated as special economic zone; it is very close to other southeastern Asian countries and has very close trading links to other economic growth centers. Henan has been a cultural and political center for the last thousand years, and also shows very high population density and economic growth (CZCRD, 2004); Heilongjiang is the most northern region of China, with significant structural changes in both agriculture and heavy industry; and finally Gansu is a typical rural province in western China with low economic growth and relatively low living standards. In Section 3, we apply the *IPAT* model to identify and analyze the main drivers (*P*, *A*, or *T*) for carbon dioxide emissions in these five provinces. In Section 4, we further analyze and compare these lifestyle changes through decomposition of consumption patterns into eight major consumption categories for these provinces from 1985 to 2002. We then compare them to Japan as a benchmark for a developed country and as an indicator of where China's lifestyles might be heading in the future (see Hubacek et al., 2007). The eight major consumption categories included in this study are food, clothes, household facilities, medicine and medical service, transportation and communication services, recreation, education and cultural services, residence, and miscellaneous items.

## 2. Review of the IPAT model

### 2.1. IPAT and its variations

The *Impact* = *Population* × *Affluence* × *Technology* or *IPAT* equation was developed in the early 1970s to further a debate between Paul Ehrlich and John Holdren, on one side, and Barry Commoner on the other side. The debate was concerned with which driver is the most important in contributing to environmental degradation (Commoner, 1972a, 1972b; Ehrlich and Holdren, 1972a, 1972b; Ehrlich and Ehrlich, 1990). The approach that was applied in this debate, the *IPAT* model, is based on index number calculations. A significant early contribution to this body of literature was made by Fisher (1922) who developed the well known Fisher index. Ang et al. (2004) extended the conventional two-factor Fisher index formula to the *n*-factor case, which provides a way of generalizing the earlier *IPAT* framework. The *IPAT* identity has been regarded as an easily understandable, widely utilized framework for analyzing the driving forces of environmental change (e.g. Chertow, 2001; Dietz and Rosa, 1994, 1997; Harrison, 1993; Hubacek et al., 2007; Raskin, 1995; York et al., 2002), but has also been criticized for some of its assumptions on the proportional relationship between factors and environmental indicators (York et al., 2003). One of the most relevant studies in the study context is the IPCC special report on emission scenarios which discussed the *IPAT* and the *Kaya* identity and their application to $CO_2$ emissions (IPCC, 2001). Ang and others have created a substantial amount of literature on index decomposition analysis for energy use and environmental emissions (e.g. Ang and Liu, 2001; Ang et al., 2004; Ang and Zhang, 2000). In recent years, much research has been done to further develop the IPAT framework by incorporating more factors into the equation (e.g. Waggoner and Ausubel, 2002) through further disaggregating technology (*T*). Rosa and Dietz (1998) reformulated the *IPAT* equation into a stochastic model, referred to as *STIRPAT* for Stochastic Impacts by Regression on Population, Affluence and Technology, which allows for non-proportional effects from the driving forces; this model had been applied to analyze the effects of driving forces on energy consumption and $CO_2$ emissions by York et al. (2003).

In this study we choose the IPAT model because it allows 1) to explicitly identify the relationship between the driving forces and environmental impacts; and 2) to show the impact as a result of the interaction of the driving forces through the multiplication of factors. In other words, the *IPAT* identity implies that no one factor can be held singularly responsible for environmental impacts (York et al., 2003).

### 2.2. Logarithmic IPAT

The IPAT method is simple, but appropriate for showing the main drivers of increasing $CO_2$ emissions in China. The amount of carbon dioxide emissions can be represented by an *I* = *PAT* type decomposition Eq. (1)

$$I = P \cdot \frac{E}{P} \cdot \frac{I}{E} \tag{1}$$

Where *I* represents the amount of carbon dioxide emissions, *P* represents population, and *E* stands for private expenditure. Thus, *A* = *E*/*P* is expenditure per person in yuan indicating affluence, and

$T = I/E$ is emission intensity, which is the carbon dioxide emissions per unit of expenditure in yuan. There are mainly two reasons for the change in emission intensity in China: technological progress and sectoral shifts between high intensity and low intensity sectors[1] (Fisher-Vanden et al., 2004).

Thus, we can analyze the role of each factor and its contribution to $CO_2$ emissions in China during different time periods through using the *IPAT* model. We will further explain this in our applications on five regions in China in Section 3.

In order to facilitate understanding and analysis, we convert all variables to logarithmic form which allows seeing the respective contributions as a share of the total. These modifications yield the following model:

$$log\, I_t = log\, P_t + log\left(\frac{E_t}{P_t}\right) + log\left(\frac{I_t}{E_t}\right) \tag{2}$$

We then distinguish between two points in time:

$$log\, I_{t_1} = log\, P_{t_1} + log\left(\frac{E_{t_1}}{P_{t_1}}\right) + log\left(\frac{I_{t_1}}{E_{t_1}}\right) \tag{3}$$

$$log\, I_{t_2} = log\, P_{t_2} + log\left(\frac{E_{t_2}}{P_{t_2}}\right) + log\left(\frac{I_{t_2}}{E_{t_2}}\right) \tag{4}$$

The subscripts $t_1$ and $t_2$ indicate the quantities ($I$, $P$, $A$ and $T$) in year $t_1$ and year $t_2$. After subtracting Eq. (3) from Eq. (4) we receive:

$$log\left(\frac{I_{t_2}}{I_{t_1}}\right) = log\left(\frac{P_{t_2}}{P_{t_1}}\right) + log\left(\frac{\frac{E_{t_2}}{P_{t_2}}}{\frac{E_{t_1}}{P_{t_1}}}\right) + log\left(\frac{\frac{I_{t_2}}{E_{t_2}}}{\frac{I_{t_1}}{E_{t_1}}}\right) \tag{5}$$

This ensures that the logs of the various components add up to the log of $I_{t_2}/I_{t_1}$. This conversion to additive form allows determining each component's fraction of the total. This formulation assures that all factors add to 100% by taking the logarithm. We can then attribute the percentage contribution of each driving force, i.e. population, affluence and emission intensity to the change in carbon emissions during the time period under investigation (Herendeen, 1998). Because this study carries out an analysis of 50 years of changes in China, the results will not only identify the main drivers for $CO_2$ emissions, but also present some reflection on the different stages of China's economic development from a centrally planned system to a transition economy comprising a variety of components of different economic systems.

### 2.3. Data

This research is based on two sets of time-series data at the national as well as the provincial levels: socio-economic data including population and private expenditures; and energy consumption and carbon dioxide emissions data. The socio-economic and energy consumption data are extracted from the following official government publications and other authoritative sources: China's Statistical Yearbook from 1978 to 2003, the Statistical Yearbook of Heilongjiang, Shanghai, Guangdong, Gansu, and Henan during 1980–2003, the Almanac of China's Population 1985–2003, China's Energy Statistical Yearbook 1989–2000, and Japan's Statistical Yearbook 2005. China's $CO_2$ emissions data at the national level comes from the World Resource Institute. The carbon dioxide emissions at the provincial level are converted from energy consumption data also provided by China's Statistical Yearbook from 1978 to 2003.

[1] Similarly, Grossman and Krueger (1993) stated that the environment will be affected due to a reduction in trade barriers through enlarging the scale of the economy, changing the composition of economic activity, and through importing production technology.

### 2.4. Shortcomings of this approach

There are also some limitations specific to such a highly aggregated approach. First of all, the *IPAT* equation is based on only very aggregate information (i.e. for the economy as a whole). Therefore, it does not make explicit the economic structural shifts and interactions among different sectors (Hoekstra and van den Bergh, 2003), on the other hand, it requires less data to perform the analysis, which explains probably part of its appeal. Secondly, it does not clearly identify the various drivers behind the concepts represented in the framework and cause and effect are not always clear, e.g. technical change contributing to economic growth affecting both $A$ and $T$; in other words affluence is partly driven by factor accumulation and partly by technological progress. A growing economy is accompanied (caused) by structural changes, changes in consumption patterns and new technologies, the dynamic interplay of these is not well captured in a comparative static analysis such as the IPAT approach (e.g. Grossman and Helpman, 1991; Grossman and Krueger, 1993) but this shortcoming can partly be remedied by choosing smaller time periods and adding further components to the equation. Thirdly, an IPAT analysis over such a long time period is obviously influenced by changes in prices and the very different range of products and qualities that money can buy. The value of the *yuan* has been kept artificially low due to China's attempt to keep exports cheap; thus the differences over time especially with regards to affluence might be less pronounced. Fourthly, policy variables and components of the *IPAT* model are very different in a centrally planned economy versus market driven economy. But both systems share the problem that the underlying policy drivers cannot be presented in detail through a highly aggregated *IPAT* model. However, the *IPAT* equation gives an indication of the relative importance of the three key factors ($P$, $A$, $T$). Finally, the reliability of Chinese official statistics has been frequently questioned (Peters et al., 2007). However, it is still the main source for China's economic and energy data, and thus these data are frequently used for studying China's economy and environment (e.g. Auffhammer and Carson, 2008; Fisher-Vanden et al., 2004; Liu and Ang, 2007).

## 3. Drivers of $CO_2$ emissions in China's regions

This section applies the *IPAT* identity to analyze the contributions of the three main driving forces behind the increase of $CO_2$ emissions in China for five selected provinces over more than 50 years.

### 3.1. Pre-reform period

China's economic development showed large fluctuations during the pre-reform period. China was not only the most populous nation, but also one of the poorest countries in the world in 1949 (Yao, 2005). In the 1950s and 1960s, China's economic structure was converting sharply from agricultural towards industrial production. The share of agriculture in gross domestic product (GDP) declined from 57 to 28% during the 1960s and 1970s (Nolan and Dong, 1990). The rapid growth of industrial production using highly inefficient technologies inevitably caused fast growth of carbon emission.

#### 3.1.1. The initial stage of socialist construction (1952–1957)

In order to recover from the damage during the war and generate new economic development, China developed a Soviet-style 'Socialist Planning System' with an emphasis on rapid industrialization, and strict centralization of control over all aspects of industrial enterprise management and budgeting (Gabriel, 1998b). In this period, the size of China's economy steadily increased, and GDP grew by approximately 8.5% annually, while $CO_2$ emissions doubled.

From Table 1 we can observe that during these five years *affluence (A)* and *technology or emission intensity (T)* were both strong factors in the growth of $CO_2$ emissions in China, respectively contributing 35%

**Table 1**
$CO_2$ emissions and driving forces in China from 1952 to1957.

| 1952–1957 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | 27% | 3% | 70% | 100% | 4,438 |
| Guangdong | 77% | 6% | 17% | 103% | 5,191 |
| Heilongjiang | 37% | 39% | 24% | 117% | 9,336 |
| Henan | 16% | 10% | 74% | 87% | 6,273 |
| Gansu | 27% | 68% | 5% | 85% | 1,539 |
| China | 17% | 35% | 48% | 100% | 130,126 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

**Table 2**
$CO_2$ emissions and driving forces in China from 1958 to1962.

| 1958–1962 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | 91% | −111% | 120% | 60% | 5,338 |
| Guangdong | 27% | −81% | 154% | 34% | 3,455 |
| Heilongjiang | 50% | −38% | 88% | 63% | 10,925 |
| Henan | 6% | −48% | 142% | 41% | 5,591 |
| Gansu | −3% | −82% | 185% | 61% | 2,029 |
| China | 10% | −53% | 143% | 71% | 184,229 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

and 48% of total emissions. In this period, industrialization was occurring in Shanghai and Henan, which caused a large amount of $CO_2$ emissions due to the use of inefficient technologies. Therefore, emission intensity was the main driving force in these two regions. On the other hand, due to wide ranging 'Land Reforms[2]', agricultural production increased considerably in Gansu and Heilongjiang, two typical agricultural provinces, during the time period. Thus, living standards improved substantially in these two regions, so that *affluence* became the main contributor to $CO_2$ emissions. In addition, population also increased quickly in all regions during this period. In Guangdong, population growth contributed to 77% of the additional $CO_2$ emissions. At the national level, the increase of *emission intensity* was the main driver for the increase of $CO_2$ emissions, while there were different main drivers at the regional level.

During 1958 to 1978, China's economy stopped growing due to events such as the Great Leap Forward, natural disasters, and the Cultural Revolution. People's living standard got worse. At the same time, $CO_2$ emissions increased much more than before driven by both population growth and high emission intensity.

### *3.1.2. Great Leap Forward and natural disasters (1958–1962)*

The years from 1958 to 1962 fell into the period of the 'second five year plan'. In this period, the Great Leap Forward (1958–1960) and three years of natural disasters (1959–1961) destroyed the economic success that was achieved in the first five year plan. By the end of the 1950s, economic conditions were back to levels of the beginning of the decade (Gabriel, 1998a).

Although people's living standards had not improved, $CO_2$ emissions still kept increasing at a fast pace (71% over a 5 year period). However, population grew very slowly, because of the dire economic situation and natural disasters. It is estimated that 18.5 million people died and there were estimated 30.1 million fewer births during the famine (Yao, 1999). During this time period the main reason for the growth of $CO_2$ emissions were both poor technology and sectoral shifts from agriculture to industry, which caused a rapid increase of emission intensity. This can be traced back to Mao's call to catch up with the West mainly through expansion of the perceived key industries iron and steel production (Lu, 2003). There were thousands of small steel-making furnaces being set up throughout the country in response to Mao's call of 'Take steel as the key link; leap forward in all fields'. However, only 4.5 million tons of iron and steel were produced by the end of August 1958, 6.2 million tons short of the target. By the end of 1958, around 11 million tons of iron steel were produced, while three million of them were completely useless dross (Lin, 1998; Wang, 2003). This unprecedented high waste of labor, materials, and money irrevocably caused negative growth of the economy. Therefore, *T* became a strong driver for the growth of $CO_2$ emissions in all five regions contributing more than 90% to total growth in emissions (see Table 2), while the decline of China's economy contributed to a decrease in $CO_2$ emissions. For instance, in Shanghai, *A* contributed −111% to total growth in $CO_2$ emissions, which means *A* was to drive the emissions down, but it was more than compensated by a 120% increase from emission intensity and 91% from population.[3] During this period, the population in Shanghai still increased rapidly due to a large number of migratory workers. In contrast, Gansu had a declining population in these five years, because it suffered the most from natural disasters.

### *3.1.3. Adjustive period of the economy (1963–1965)*

In order to rectify the situation of famine and the recessionary economy, Liu and Deng started to implement an economic recovery program in 1962 (Yao, 2005). The main approach of the recovery program was an institutional reform comprising two main policies: modification of the 'commune system[4]' and establishment of the 'household responsibility system[5]' (Yao, 2005). In fact, decision-making became significantly less centralized under the new system, and agricultural production started to recover in 1962. The famine was over by the end of 1962, and by 1965 grain outputs had fully recovered to their pre-famine level (Yao, 2005). During this period, China's GDP increased by 40%, while $CO_2$ emissions grew only slightly by 9%.

Mao's call of "more people, more power" led to a peak birth rate during this period. As a result, population growth became a strong factor in China. In the meantime, the improvement of people's consumption levels significantly contributed to the growth of $CO_2$ emissions as well. Nevertheless, emission intensity had not changed significantly during this period, so that it became a less important driver. In Guangdong, Heilongjiang and Henan, population contributed to more than 50% of the increase in $CO_2$ emissions, while in this period affluence was the main driver in Gansu, mainly driven by the recovery of agricultural production from the effects of natural disasters. Compared to other regions, Shanghai further enhanced its industrial capacity. The increase of $CO_2$ emissions in Shanghai was mainly driven by growth of emission intensity due to economic structural change from agriculture to industry (see Table 3).

### *3.1.4. Cultural revolution (1966–1975)*

The Cultural Revolution was launched soon after the country recovered from the famine. The Cultural Revolution led China's economy into

[2] Land Reform was abandonment of the feudal land ownership system, and institutionalization of the system of land ownership by peasants.

[3] Note that these percentages are in relation to the change thus can be higher than 100% but all together explain the total change.

[4] Workers were accredited with work points for the jobs that they performed every day. At the end of a year the net team income, after deductions for state taxes, public welfare fund, and so on, was distributed according to the work points that each one accumulated during the year (Lin, 1998).

[5] The household responsibility system has been established with the intention to restore the autonomy of the individual household and to replace the production team system as the unit of production and accounting in rural areas. The so-called responsibility contract is "equivalent to the granting of private property rights through a state lease of land. Ownership is not relinquished by the state, the rights to use and to obtain income are exclusively assigned to the lessee (Cheung, 1990)."

**Table 3**
$CO_2$ emissions and driving forces in China from 1963 to 1965.

| 1963–1965 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | 18% | 14% | 68% | 20% | 2,826 |
| Guangdong | 53% | 40% | 7% | 16% | 2,192 |
| Heilongjiang | 75% | 9% | 16% | 17% | 4,892 |
| Henan | 77% | 12% | 11% | 7% | 1,504 |
| Gansu | 29% | 70% | 1% | 33% | 1,758 |
| China | 51% | 39% | 10% | 9% | 37,082 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

**Table 5**
$CO_2$ emissions and driving forces in China from 1976 to 1978.

| 1976–1978 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | 7% | 48% | 45% | 35% | 15,438 |
| Guangdong | 14% | 59% | 27% | 36% | 10,166 |
| Heilongjiang | 19% | 29% | 52% | 34% | 22,579 |
| Henan | 17% | 101% | −18% | 30% | 19,552 |
| Gansu | 10% | 69% | 21% | 33% | 6,474 |
| China | 15% | 59% | 26% | 32% | 368,075 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

relatively low GDP growth rates, which were less than 4% annually; the majority of the rural population continued to suffer from poverty (Yao, 2005). However, during this period $CO_2$ emissions grew by 139% in China and 229% in Henan.

During the ‘Cultural Revolution', population, affluence and emission intensity contributed at similar degrees to the rise in $CO_2$ emissions at the national level. However, from Table 4 we can see that population in Shanghai decreased slightly between 1966 and 1975. The main reason was that Mao called for a ‘Down to the Countryside Movement’. A large number of urban youth were sent to mountainous areas or farming villages of other provinces, so that the main driver of $CO_2$ growth became affluence and emission intensity in Shanghai. In Heilongjiang, population was playing the main role, because a large number of people migrated from the south to the north for more cultivated land. Nevertheless, Henan showed the highest increase in $CO_2$ emissions due to the accelerating growth of industry with poor technology. Thus, $CO_2$ emissions per unit living expenditure kept increasing in this period and emission intensity was still the main contributor to the growth in $CO_2$ emissions.

### *3.1.5. Brief transition period in the economy (1976–1978)*

After Mao died, the transitional period from 1976 to 1978 was a period of uncertainty of how China should develop. The key issue was to break free from Mao's doctrines. Ultimately, the goal was the improvement of people's living standards and the modernization of the economy (Yao, 2005). The annual growth rate of $CO_2$ emissions slowed down from 14% to 10% while the economy was growing by about 20% in these three years.

In this period China's economy began to recover, and people's living standards also improved. Affluence started to become the strongest factor for the growth of emissions in China, accounting for 59% of the total change at the national level. Although population and emission intensity were still a positive driver for growth in $CO_2$ emissions, their contribution to the total was much lower than before. After this period, China went into another economic reform period, and the economy began to undergo huge growth (Table 5).

## *3.2. Economic reform period: the open door policy*

After the economic reforms in 1978, China's economy followed an unprecedented growth which has also led to increasing inequality between the regions. During the economic reform period China not only achieved rapid improvement of living standards, but also showed a comprehensive modernization of large sectors of the economy and fast improvement of technologies. At the same time, due to the implementation of the one-child policy, the population growth rate in China had steadily decreased. However, the $CO_2$ emissions growth rates remained at a high level, due to more and more energy being consumed to satisfy the rapid growth of the economy and especially the improvement of living standards.

### *3.2.1. Rural and urban reforms (1979–1990)*

Agricultural reforms were achieved through decentralization of production units, the fostering of the ‘individual economy’ and free markets during 1978 to 1984; an urban reform was undertaken through the expansion of private and mixed owned enterprises (Yao, 2005). The ‘*Household Production Responsibility*’ in the farming sector greatly raised productivity and farm income. *Township and Village Enterprises* (TVEs) were strongly encouraged, with their share in China's GDP rising from almost nothing in 1978 to 13% in 1985 and later to its peak of 34% in 2002 (Yao, 2005). The fast development of TVEs significantly contributed to fast economic growth which caused a huge amount of $CO_2$ emissions. During this period, $CO_2$ emissions increased sharply by 1 billion metric tons in China, while the average annual growth rate of GDP was around 10%. China's total GDP increased by approximately 2.5 times within these 10 years.

Although there was much improvement in emission intensity (−114% of the total change), the improvement was overwhelmed by fast growth of affluence (180% of total change). Thus affluence became the major contributor in all regions of China. In this time period, the decline of emission intensity is mostly driven by the technical progress from real energy intensity saving rather than structural change (Aden and Sinton, 2006; Sinton and Levine, 1994). From Table 6 we observe that Guangdong and Gansu had the highest increase in $CO_2$ emissions between 1978 and 1990. During these years,

**Table 4**
$CO_2$ emissions and driving forces in China from 1966 to 1975.

| 1966–1975 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | −2% | 50% | 52% | 130% | 25,217 |
| Guangdong | 39% | 45% | 16% | 79% | 12,475 |
| Heilongjiang | 50% | 42% | 8% | 92% | 31,650 |
| Henan | 21% | 32% | 47% | 229% | 46,102 |
| Gansu | 38% | 45% | 17% | 117% | 8,318 |
| China | 28% | 35% | 37% | 139% | 669,033 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

**Table 6**
$CO_2$ emissions and driving forces in China from 1979 to 1990.

| 1979–1990 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | 55% | 293% | −248% | 33% | 19,603 |
| Guangdong | 22% | 117% | −39% | 163% | 62,623 |
| Heilongjiang | 26% | 93% | −19% | 60% | 53,639 |
| Henan | 45% | 170% | −115% | 56% | 48,006 |
| Gansu | 19% | 68% | 13% | 155% | 33,968 |
| China | 34% | 180% | −114% | 67% | 1,017,958 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

**Table 7**
$CO_2$ emissions and driving forces in China from 1991 to 2002.

| 1991–2002 | P | A | T | ΔI (in %) | ΔI (abs) |
|---|---|---|---|---|---|
| Shanghai | 6% | 151% | −57% | 97% | 76,922 |
| Guangdong | 19% | 92% | −11% | 191% | 193,604 |
| Heilongjiang | 44% | 620% | −564% | 18% | 26,014 |
| Henan | 20% | 185% | −105% | 71% | 94,452 |
| Gansu | 37% | 162% | −99% | 47% | 26,018 |
| China | 30% | 240% | −170% | 49% | 1,247,076 |

*P*, *A*, and *T* are the percentage of contribution to $CO_2$ emissions from population (*P*), living expenditure per person (*A*) and $CO_2$ emissions per yuan (*T*); Δ*I* (in %) is the change of $CO_2$ emissions in percentage; Δ*I* (abs) is the change of $CO_2$ emissions in thousand metric tons.

Guangdong was one of the first regions to launch the 'open door' policy, and quickly reached high rates of economic growth. Hence, affluence became the main driver with contributing 117% to $CO_2$ emission growth, while the decline in emission intensity reduced it by 39%. However, Gansu was still one of the poorest regions in China. Although affluence was also here the main driver for the carbon emissions growth, Gansu displayed slow economic growth coupled with a high emissions rate. In contrast, there was rapid economic development and a large improvement of emission intensity in Shanghai, which was one of the most developed regions in China. Thus, $CO_2$ emissions showed a much lower growth rate, but technological advancement was unable to keep pace with increasing emissions due to economic growth and affluence levels.

#### 3.2.2. Macroeconomic structural reforms since 1990

With the establishment of Deng's '*socialist market economy*', the economic reforms were extended to all regions. In addition, China adopted an open door policy for international trade and investment allowing foreign direct investments (FDI) in order to help restructure the industrial sector and improve competition and technologies (Yao, 2005). In order to reduce the development disparities between eastern and western China, the 'Western Development' policy was launched in 2000 (China Internet Information Center, 2006). Table 7 shows that the increase in $CO_2$ emissions in China was more than 1.2 billion metric tons between 1990 and 2002, but the average annual growth rate had declined to 4%. During the same period, China's GDP still maintained a high annual growth rate of around 10%.

Since the 'open door' policy was launched, affluence was by far the strongest driving force behind the increase in $CO_2$ emissions (*I*). In China, the growth of the economy accounted for more than 200% of total growth of $CO_2$ emissions which was tempered by a decrease of emission intensity (−170% of total) due to the improvement of technology and the decline of coal consumption during this period (Fisher-Vanden et al., 2004). At a regional level, Guangdong showed the fastest growth rates of $CO_2$ emissions, which were mostly caused by impressive economic growth rates driven by the significant amounts of Foreign Direct Investment (FDI), primarily from Hongkong and Taiwan (Li and Yang, 2003). Therefore, in Guangdong *A* was the main contributor for $CO_2$ emissions with slow improvement of emission intensity in this period. From Table 7 we can see that in Heilongjiang affluence was also a large contributor to $CO_2$ emissions (620% of total change), which were mostly compensated by emission intensity with −564%. In Heilongjiang, the fast economic growth was mainly led by further increase in the number of TVEs and private firms and competitive low-cost production (Muldavin, 1997), while the rapid improvement in emission intensity was induced by increased energy efficiency in both industry and households. During this period, driven by 'China's western development' policy, Gansu started to rapidly develop its economy while its $CO_2$ emissions increased by 47%, with affluence as the key driver (162% of total growth) responsible for the rise in $CO_2$ emissions. At the same time, emission intensity showed obvious improvements. Consequently, in this period most of the regions were on their way with fast economic development coupled with considerable improvements in emission intensity.

From the analysis and discussion above we can see that the driving forces for $CO_2$ emissions change from population and emission intensity dominating the pre-reform periods to affluence dominating the economic reform period since the inception of the open door policy. During the last five decades, larger segments of China's society have experienced a shift from poverty to having the financial ability to spend their rising income on luxurious products (Hubacek et al., 2007). Therefore, it is very important to investigate in more detail the changes in people's lifestyles in China, in order to further understand the economic dynamics leading to the growth of $CO_2$ emissions.

## 4. Decompositon of lifestyle and consumption patterns in modern China

From the above analysis we can see that the growth in consumption (*A*) has become the dominating driving force for the growth in $CO_2$ emissions since 1978. In this section, we analyze how lifestyle and consumption patterns have changed over the last 30 years by decomposing lifestyle and consumption patterns (*A*) into eight categories: food; clothing; household facilities; medicine and medical services; transportation and communication services; recreation, education and cultural services; residence (including housing and fuel consumption); and miscellaneous commodities and services. Furthermore, this section provides a comparison of consumption patterns between urban and rural China as well as a comparison across regions. Before 1978, the standard of living for the vast majority was under the poverty line, and most people struggled to afford adequate food and clothing. Thus, people's lifestyles and consumption patterns do not show clear variation during the pre-reform period in China. In this section, we only concentrate on consumption patterns since the economic reforms in 1978 using Japan as a benchmark as it is one of the most developed countries in Asia, with similar lifestyles to many western countries.

### 4.1. Consumption patterns in 1985

From 1980 to 1985, the economic reforms were implemented throughout China. In this period, more diversified consumption patterns started to emerge in urban areas, whereas in rural areas many people were still fighting poverty. Also, regional disparities had become much larger, due to differential policies favoring economic zones.

Fig. 2 shows that the consumption level of urban residents was more than twice the consumption level of rural residents in China (1521 yuan versus 717 yuan). In urban areas, there were no significant differences in expenditure patterns across the five regions. Food and clothing were still dominating accounting for approximately 70% of total living expenditure, but culture, education and recreation and household facilities also started to become important consumption items accounting for 8.2% and 8.6%, respectively. However, there were obvious regional disparities in living standards amongst rural areas. From Fig. 2 we can see that the living standards of rural residents in Shanghai were much higher than in other regions, for example, twice the total expenditure of Guangdong and nearly three times the expenditure in the other three regions. Not surprisingly, the proportion of expenditure on essential items, food and clothing, in Shanghai was lower than in other regions, while housing facilities and other commodities and services became more dominant consumption items. During this time period, which was characterized by a slow improvement of living standards in rural areas, people spent larger shares of their income to improve their living situations by rebuilding or refurbishing their houses. Climatic differences show up in varying expenditure shares of clothing. In particular, the northern-most region Heilongjiang, but also Henan and Gansu, show higher expenditure for

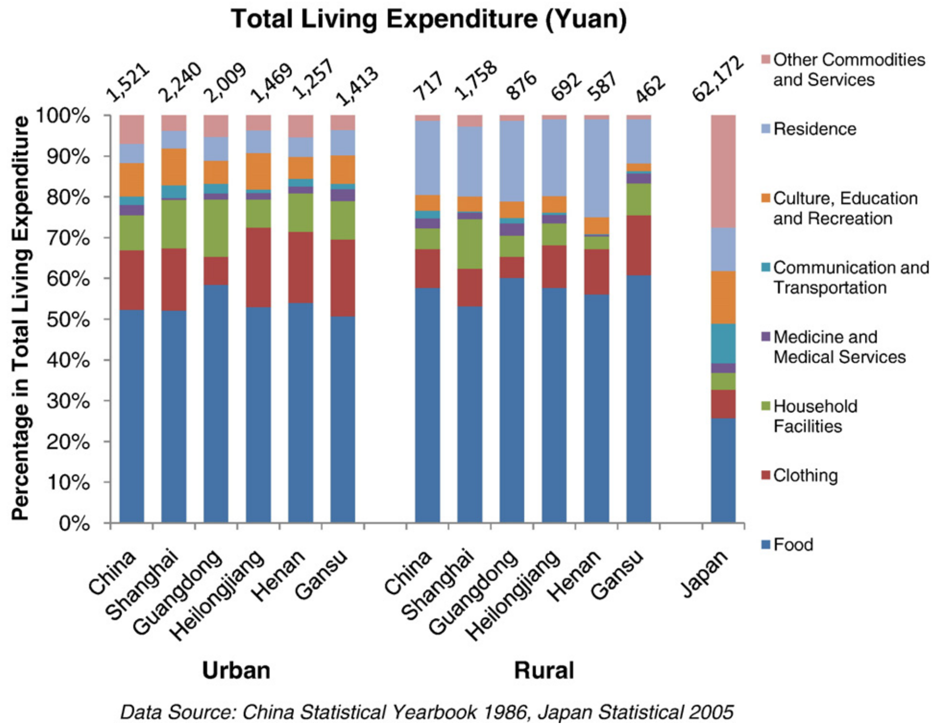


**Fig. 2.** Consumption patterns in 1985 (in constant 2000 yuan).

clothing than the warmer regions Shanghai and Guangdong. In comparison, in Japan, at that time, expenditures for Food and Clothing accounted for about 25% of total living expenditures, whereas the average Chinese had spent around 50–60% on these items. In Japan the largest share of total consumption was for education and recreation (13%), communication and transportation (10%), and other commodities and services (27%), whereas the average Chinese spent only about 6%, 2% and 8%, respectively, on these consumption categories.

### *4.2. Consumption patterns from 1985–1995*

Between 1985 and 1995, China experienced high economic growth rates and income levels never experienced before. People's lifestyles changed and diversified dramatically; the urban–rural divide in living expenditure per capita widened from a factor of 2 in 1985 to a factor of 3 in 1995. Following consumption patterns in developed countries, the expenditure shares for food, clothing, and household facilities gradually decreased whereas the money spent on medicine, transportation and education increased in China's cities. With the rapid growth of income, urban people had more spare money to enjoy recreational or educational activities rather than just scrambling to fulfill their basic needs. Surprisingly, in rural areas of the northern, central and western regions, the proportion of food increased slightly as people used additional income to consume a higher share of meat, fish and varieties of vegetables. Furthermore, the proportion of expenditures on medical services, transportation, education and recreation increased considerably in rural areas. In comparison, consumption patterns in a mature economy such as Japan did not show any dramatic changes within these broader consumption categories over the observed time period.

Fig. 3 shows that the consumption patterns of urban residents were not dramatically different amongst the five regions in 1995. However, the regional inequality in living standards in rural areas widened between the south and east and north and west from 1985 to 1995. Remarkably, people's consumption levels in the rural areas of Shanghai and Guangdong were equivalent to other regions' urban consumption patterns, reflecting their higher income levels. Overall, the proportion of food and clothing showed a decreasing trend in both urban and rural areas. Despite some commonalities there are pronounced differences in some areas. For example, in Shanghai, due to rapid growth in house prices, residential expenditures accounted for 22.6% of total household expenditure, which was much higher than in other regions, reflecting Shanghai's special status as a more developed economy with higher income levels. On the other end of the spectrum was rural Gansu, one of the poorest regions in China; the average expenditure level was just 998 yuan and about 80% of the spending was on food and clothing.

### *4.3. Consumption patterns from 1996–2002*

From 1996 to 2002, the total living expenditures in both urban and rural areas had doubled. Both urban and rural areas in China had similar trends of changes in consumption patterns with a pronounced reduction of food and clothing and a gradual growth of shares for education and recreation, medical services, and communication and transportation. In this period, food and clothing still accounted for 48% (versus 53% in 1985) of household expenditure in urban China, while the total proportion for education, recreation, transportation and medical services had increased to more than 30% in 2002 (from 12% in 1985). The proportion of food and clothing expenditures also decreased gradually by 13.5% in rural China. During this period the gap in the standard of living between urban and rural areas continued to widen, as reflected by the widening income gap of a factor of 3, (i.e. 6030 yuan in urban China and 1834 yuan in rural China).

The consumption patterns in the urban areas across the five regions had converged in 2002, although the total living expenditures in eastern and southern regions were much higher than in northern, central and western regions. People's lifestyles in rural areas of Shanghai were much different from other areas. Differences due to higher housing prices, in the case of Shanghai or higher expenditure shares on clothing in the colder regions continued to exist (see Fig. 4).

In comparison, in Japan we detect a further minor decrease in the proportion of food and clothing, but overall consumption patterns did not show any significant variations. At the same time we observe that consumption patterns in urban China more closely approximate consumption patterns in Japan.

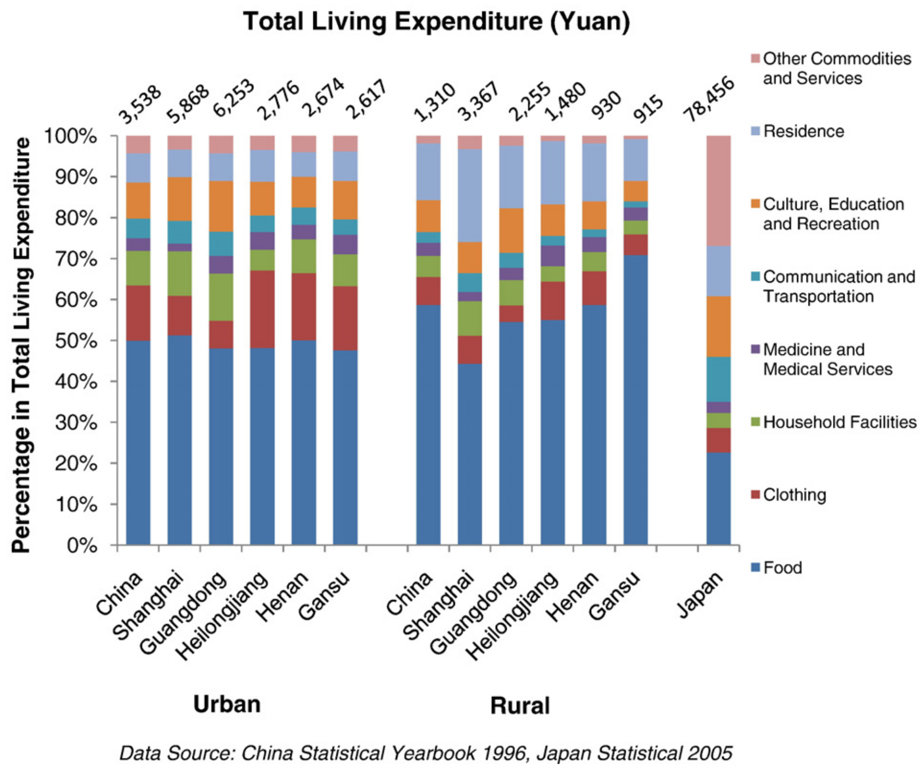


**Fig. 3.** Percentage share of total living expenditure in 1995 (in constant 2000 yuan).

### *4.4. Housing and household categories*

The fast increasing expenditure on housing in both urban and rural areas since 1980 shows that people were eager to improve their living conditions. Rural households rebuilt and extended their bungalows using building materials such as concrete, bricks and tiles instead of marl and wood. Meanwhile, average per capita living space expanded from 8.1 $m^2$ to 24.2 $m^2$ (Hubacek et al., 2007).

In China the urban housing shortage was much more severe than in rural areas. The per capita net living space for urban residents was

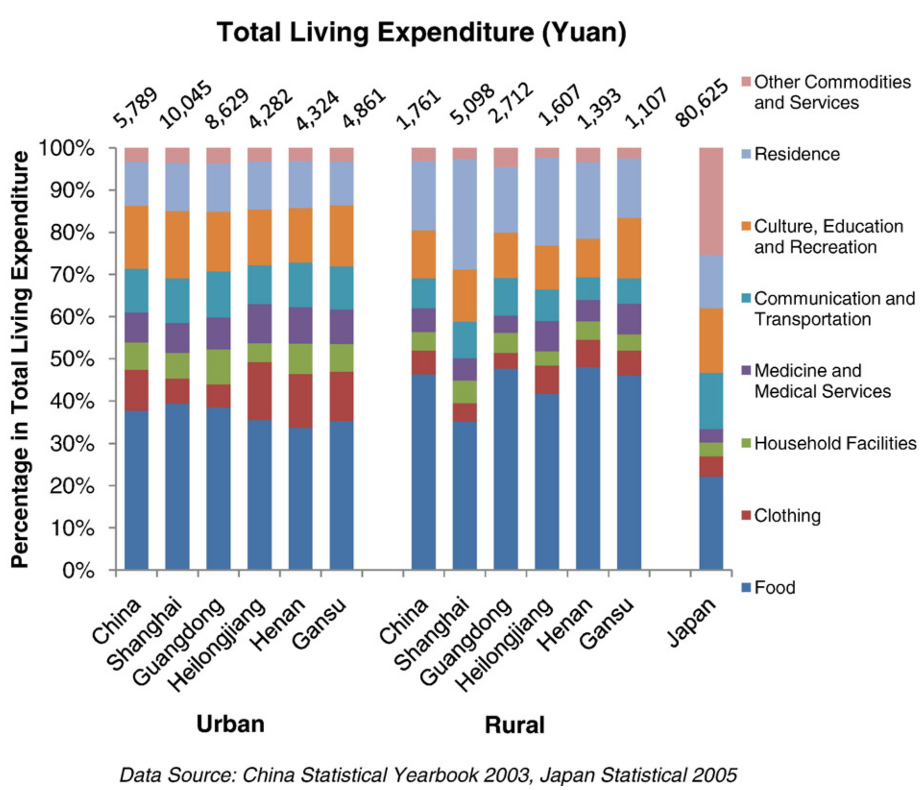


**Fig. 4.** Percentage share of total living expenditure in 2002 (in constant 2000 yuan).

**Table 8**
Number of durable consumer goods in % in China.

| Items | 1985 | | 1995 | | 2002 | |
|---|---|---|---|---|---|---|
| | Urban | Rural | Urban | Rural | Urban | Rural |
| Washing machine (unit) | 48.2 | 1.9 | 88.9 | 16.9 | 92.9 | 31.8 |
| Refrigerator (unit) | 6.6 | 0.10 | 66.2 | 5.2 | 87.4 | 14.8 |
| Colour TV set (unit) | 17.2 | 0.8 | 89.8 | 16.9 | 126.4 | 60.4 |
| Air conditioner (unit) | – | – | 8.1 | – | 51.1 | 2.3 |

Data source: China Statistical Bureau, 2006.

only 3.6 m$^2$ prior to 1978. In the early 1980s the Housing Reform Policy had been launched to solve the problems of urban housing shortages and poor housing conditions (Hubacek et al., 2007; Zhang, 2003). This policy promoted commercialization of the housing sector and private ownership allowing people to buy their own apartments. Meanwhile the government, state owned enterprises, domestic private companies and oversea developers invested significant funds into the urban housing development (Hubacek et al., 2007). Consequently, urban residents started to move from tiny bungalows or apartments to new multi-story apartment blocks, which led to increasing per capita floor space. Consequently, per capita floor space in both urban and rural areas increased steadily from 10 and 14.7 m$^2$ in 1985 to 22.8 and 26.5 m$^2$ in 2002 (China Statistical Bureau, 2006).

With the growth of living space and disposable income, people could afford to buy and store more household facilities and other durable goods. For instance, both urban and rural residents spent increasing amounts on large durable furniture (e.g. wardrobes, beds and sofas). Moreover, increasing sales of household electrical appliances were enabled with the connection of many rural households to the electrical grid, most of which were not connected until the 1990s. From Table 8 we can see that it was very rare to have electrical appliances in rural China in 1985, while in 2002 coverage of electrification had increased dramatically to 32% for washing machines, 14% for refrigerators, and 60% for color TV sets. Table 8 also shows that the purchase of washing machines doubled in 2002 as compared to 1985 in urban China. Color TVs are now present in most urban households and over half of rural households. The number of refrigerators increased by 10 times between 1985 and 1995, and climbed by another 30% between 1995 and 2002. In addition, the latest consumer items such as air conditioners, personal computer, mobile phones and automobiles, which were previously the sign of the wealthy, increased significantly as well. Air-conditioners and personal computers have become essential household items for many urban families. Mobile phones are extremely popular in cities. In 2005, every household had on average 1.37 mobile phones (China Statistical Bureau, 2006). The dream of owning a car is a reality for a small share of households and is still only a remote possibility for mid/low income households. There is also a clear disparity in household appliance ownership between urban and rural areas (Table 8). Washing machines are three times more common in urban areas than in rural areas, and air conditioners are still rarely used in rural China.

## 5. Conclusion

From the analysis above, we can see that there are three main contributions of this study. Since we identified affluence/lifestyles as one of the major driving forces we further disaggregated that aspect by looking into 8 different consumption items. The second difference to other such studies is our regional scope. This study selects five quite divergent provinces as case studies to show the regional inequality as well as the divide of urban and rural China. The third contribution is the time horizon. Our study covers 50 years of changes in China from 1952–2002, which gives a fairly comprehensive image of a centrally planned economy, its transition to a market economy and the associated $CO_2$ emissions. Based on the *IPAT* analysis, we see that the main driving forces for the changes in $CO_2$ emissions in the pre-reform period (until 1978) shifted between population growth (1963–1965), a growing level of affluence (1966–1975), and industrial structure change (1952–1957, 1958–1962 and 1976–1978). Only at later stages did improvement of emission intensity start to offset some of the increase in $CO_2$ emissions caused by the other drivers. With the economic reforms, an increase in consumption became the dominant driver of $CO_2$ emissions growth completely overwhelming technical advancement. From decomposing affluence, we observe a shift from household budgets dominated by expenditures on food and clothes to increasing shares of expenditures for services, housing and luxury items. At the same time we could observe increasing inequalities in living expenditure between urban and rural areas. In addition, we see that household consumption across the five regions follow similar trajectories, driven by changes in income and the increasing availability of goods and services, although significant differences still exist between and within regions due to differential policies in China and different possibilities for social mobility.

The comparison with Japan shows how lifestyles in urban China are beginning to resemble Western lifestyles making it likely that China will follow western trajectories with regards to $CO_2$ emissions. It makes $CO_2$ emissions easier to predict as China's regions move to Western lifestyles. We will thus probably observe a further move to services, a continuation of the housing boom and infrastructure development but eventually a decline in the share of capital investment as infrastructure reaches Western levels (Peters et al., 2007).

However, in addition to the apparent inefficiencies in terms of production technologies there is also a lot of room for improvement on the consumer side as well as an awareness of the interaction of infrastructure and consumption. Future expenditures and consumer behavior depend to a large extent on the infrastructure that is built today. Consumers' choices are bound by the availability of alternatives (such as public transport). Thus, the trajectory of future emissions needs to be addressed by the infrastructure choices of today (Hubacek et al., 2007). In terms of the composition of the major consumption items there are little alternatives in sight as Chinese consumers try to emulate Western lifestyles and thus, inadvertently, western levels of emissions. This study emphasizes the need to guide people's lifestyles towards more sustainable ways of living; this is also true for a developing country such as China, which is home to 22% of the world population and a growing middle class, and which is on a fast track to modernization.

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