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Structural Change and Energy Use: Evidence from China's Provinces

By

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Abstract

This paper investigates the extent to which structural change in China's economy has contributed to changes in energy intensity. It uses a new province-level data set on energy intensity over the period 1990-2004. The main findings are that energy intensity of provincial economies comes down with higher GDP per capita. Most of the reduction in energy intensity has come from intra-sectoral energy savings in industry, with sectoral shifts playing a minor role, but this role is larger in the richer provinces, which have expanded their share of services in GDP. The recent rebound in energy intensity in China's economy can in part be ascribed to a sectoral shift towards industry in the majority of provinces, but this is offset by continued efficiency gains within industry and other sectors. The exception to this trend is one province, which saw a sharp increase in energy intensity and which drives the results for China as a whole over 2001-4. Beyond structural change we find that energy intensity is negatively correlated with energy price, the efficiency within the energy sector and the share of light industry in provincial GDP, and positively with the share of state enterprises in industrial output.

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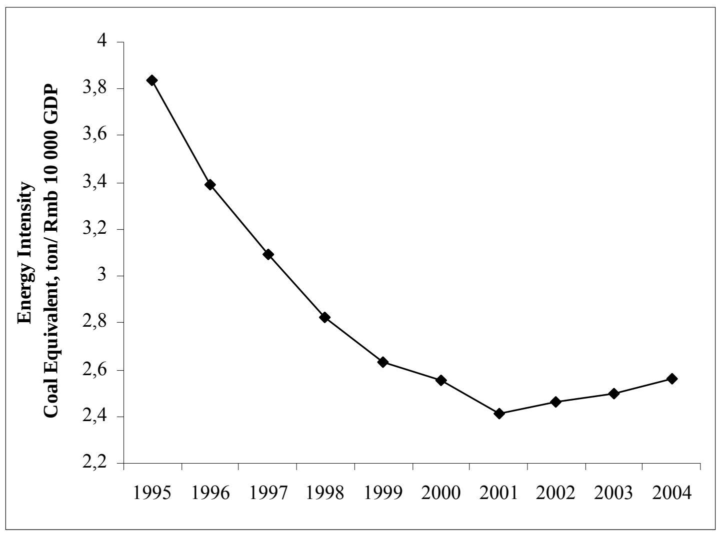
1. Introduction

China's energy use is of considerable interest to the authorities and to the world. China is already the second largest energy user in the world after the United States, and emits the second largest amount of greenhouse gases in the world, again after the United States, most of it due to energy, particularly coal, which accounts for some 70 percent of China's energy production. China's rapid growth is also putting considerable pressures on world energy prices, particularly in oil: between 2002 and 2005, about 1/3 of additional global energy demand came from China.

China's energy use per capita is still low (less than 10 percent of that of the United States) but the energy intensity of its economy is high, at least if measured in current dollars:[2] some four-six times that of advanced countries. At the level of individual processes, the discrepancy is less, but China still uses some 30-100 percent more energy in a variety of production processes. China's high economy-wide intensity can be explained by the composition of GDP, which in China is much more geared towards industry compared to all high income countries and most other developing countries. During the 1980s and 1990s, energy intensity of China's economy saw a rapid decline (Figure 1). However, in recent years, this development seems to have come to an end, or even went into reverse, as the energy intensity of the economy started to increase.

Figure 1: China's Energy Intensity 1995-2004



Source: China Energy Yearbook, Various issues, and NBS (2006)
Note: the figure uses China's revised GDP numbers (1990 constant prices) released in December 2005 by NBS and revised energy use numbers from China Energy Yearbook 2005.

The recent increase in energy intensity in China's economy has raised considerable concern in China and abroad. If recent trends prevail, China's energy needs are set to rise rapidly, could affect the country's energy security, and could become a threat for the local and global environment. In response to these trends, the Government has set ambitious targets regarding energy efficiency for the 11th Five Year Plan: over the period 2006-10, energy intensity of the

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[2] Energy intensity numbers in terms of GDP measured in Purchasing Power Parity is far lower (less intensive) than that measured in current dollar GDP. The reason for this could be that the data on China's PPP factor, which are based on partial survey results from the late 1980s are no longer reliable. Academic estimates as reported in OECD (2005) suggest that the PPP factor is lower than the World Bank's 4.5. A lower PPP factor would diminish the discrepancy between energy intensity in current exchange rates and in PPP.

economy is to be reduced by 20 percent, or some four percent per year. The target is to be achieved by a combination of energy efficiency and structural shifts towards less energy intensive sectors, notably services.

Internationally, there is some evidence that structural change affects energy use (Schäfer (2005), Lewis (2003)). In general, the service sector is less energy intensive than the industry, which is more energy intensive than agriculture. As countries develop and GDP increases, sectoral composition shifts from agriculture to industry to services, and thus one would expect that energy intensity first increases, and then decreases as countries grow richer. Residential energy use is likely first to decrease with rising income, as households shift from inefficient biomass to more efficient forms of energy, but later to rise, as people start living in larger houses and start using modern appliances, notably air conditioners in some countries. At the same time, reductions in energy intensity within sectors take place, under influence of technological progress, better management, infrastructure investments, and the like. These two factors, structural change and changes in energy intensity per sector, account for the change energy intensity of the economy.

This paper explores to what extent structural change and changes in sectoral energy intensity can contribute to China's energy saving goal. For this purpose, we analyze the sectoral shifts and changes in energy intensity that have taken place in China's provinces over the period 1990-2004. Although for most countries 15 years is too short a period to show significant structural change, for China, which has been growing with almost 10 percent a year over the last 15 years, it offers significant change in energy intensity, sectoral structure of GDP, and energy intensity per sector. Using provincial panel data greatly increases the potential for analyzing this relationship, as China's 30 provinces are at very different stages of development and therefore show considerable variety in growth rate, sectoral composition of GDP and energy use. The main contribution of this paper is the decomposition and analysis of energy intensity at the national level into regional shifts in sectors and shifts in energy intensity per sector and region. To our knowledge, this has not yet been done for China. Hu and Wang (2006) use regional data and a production function approach to assess energy efficiency per region, but do not consider underlying factors that determine the level of efficiency. Fischer-Vanden et. al. (2006) analyze China's energy intensity using enterprise level data. Garbaccio, Ho, and Jorgenson (1999) and Lin and Polenske (1995) analyze the decline in China's energy intensity with sub-sectoral data. Zhang (2006) investigates the impact on energy intensity of structural change and energy efficiency improvements for China at the national level per sub-industry, with techniques similar to Schäfer (2005) and the ones we use here, and finds that energy efficiency improvements dominate in the reduction of energy intensity. This is consistent what we find for province level data, but using our province-level dataset we find a wide variety in the importance of structural change and energy efficiency among provinces and among time periods.

The paper is organized as follows. Section two describes the data we use for our analysis. Section four briefly describes the national-level decomposition of energy intensity reduction into structural change and energy efficiency improvements. Section four describes the provincial level developments of energy intensity and structural change, and section five formally decomposes the observed changes into sectoral shifts and within sector energy intensity changes. Section six analyzes the relative importance of sectoral changes versus other variables that may affect energy intensity, including energy prices, ownership structure, and sub-sectoral composition of output. Section seven concludes.

2. The Data

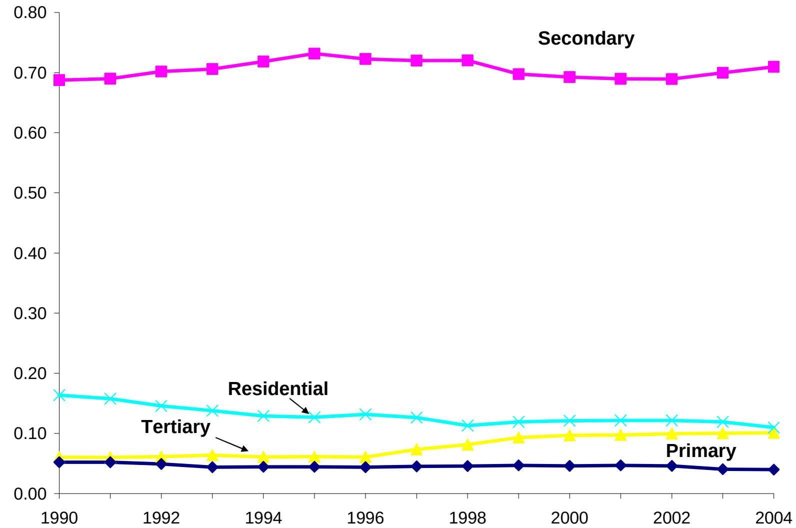
We are using panel data for 30 provinces from 1990 to 2004. Tibet is excluded from the analysis and we grouped Chongqing and Sichuan for the 1996-2004 period when it was necessary to compare before and after the 1996 periods. We used national and provincial Statistical Yearbooks, accessed through *All China Data* on-line to obtain general economic data such as GDP, shares of primary, secondary and tertiary sectors in total GDP, share of light and heavy industries in total gross output values or share of state or collective enterprises in total gross output value. China's sectoral classification differs from international convention: the "primary" sector is equivalent to agriculture, "secondary" includes mining, manufacturing and construction, and "tertiary" includes transport and other services. Gross output value data contain a structural break between the years 1997 and 1998 when the registration system for industries changed. As no correction has been done for these data in the official statistics, we will control for this break when necessary. Data on energy consumption come from the China Energy Statistical Yearbooks and from the Energy Databook (*China Energy Group*, Various Years). Energy balances for each province are available for the year 1990 and between the years 1995 and 2004. Published data include energy consumption for each energy product distributed among agriculture, industry, construction, transport, services and residential sector. Some energy data are not available for the whole period. We converted each kind of energy consumption into ton coal equivalent (TCE) using conversion factors reported in the China Energy Statistical Yearbook. For briquettes and "other petroleum product", we used the conversion factor of raw coal and the average of conversion factor for petroleum products respectively, because the yearbook does not include a separate conversion factor for these two categories .We constructed total energy consumption as the sum of all energy products consumption in TCE, with the exclusion of the category "other energy" for which we could not find a reasonable conversion factor into TCE. Consequently, there exists an approximately constant difference between the total energy consumption given by statistical yearbooks and the one we calculated. The evolutions of energy consumption calculated and energy consumption given by the statistical books are broadly the same.

3. Aggregate patterns of energy use and structural change

Over the period 1990-2004, China's energy use increased from 966 MTCE to 2032 MTCE. As already shown in Figure 1, energy intensity showed a steep drop over the whole period, but an upturn since 2001. Energy intensity throughout the period more than halved, from 5.33 TCE/RMB 10 000 GDP in 1990 to 2.56 TCE/RMB 10 000 GDP in 2004. Throughout this period, sectoral shares in energy use remained remarkably stable (Figure 2), and were dominated by the secondary sector (Industry and construction), which uses some 70 percent of all energy in China followed by Residential, whose share declined from 16 percent in 1990 to 11 percent in 2004, and Tertiary (Services and Transport) whose share increased from 6 to 11 percent in the same period, largely because of an increase in the share of transport.

The relatively stable shares in energy use mask a combination of strong variety in changes in sectoral energy intensity as well as structural change.

Figure 2: Sectoral Shares in Energy Use 1995-2004



Source: China Energy Yearbook, Various issues, and NBS (2006)
Note: The figure uses the Chinese classification of sectors. Primary is agriculture; secondary comprises industry and construction; tertiary comprises services including transport. The category "Others" which takes up some 4 percent of total energy use, I omitted from the chart. .

Table 1 provides a decomposition of the decline in energy intensity in sectoral shifts and energy intensity change. It shows that China's rapid decline in energy intensity is mainly caused by a decline in energy intensity in industry, offset by an increase in the GDP share of industry. Energy intensity in the primary and Tertiary sectors are relatively constant, whereas energy intensity in the residential sector showed a small decline.

Table 1: Sectoral decomposition of changes in China's energy intensity

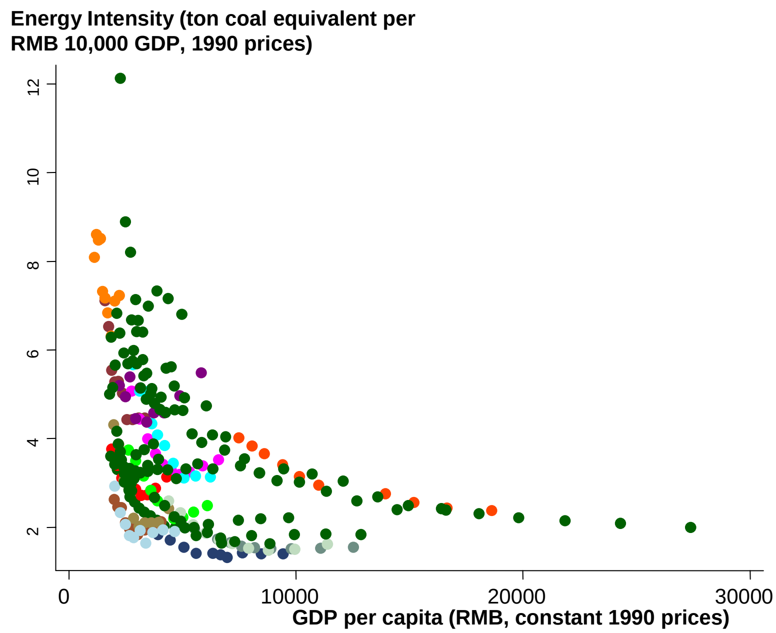
Contribution to decline in energy intensity 1990/2004	**Primary**	**Secondary**	**Tertiary**	**Residential**
Share in total consumption 1990	0.04	0.72	0.08	0.13
Change in sector energy intensity	0.97	0.53	0.96	0.84
Shift in GDP	0.96	1.17	1.01	n.a.
Sub total	0.95	0.62	0.97	0.84

Source: Author's estimates based on Provincial Statistical Yearbooks and China Energy Statistics

4. Structural Change and Energy Use in China's Provinces

Provincial patterns of energy intensity are more differentiated. The combination of different stages of development in China's 30 provinces, the variety in their production pattern, and the variety of energy efficiency within the sectors, a much more varied picture in energy intensity emerges (Figure 3).

Figure 3: Energy Intensity per Province and Regional GDP per capita 1990-2005



Source: China Energy Yearbook, Various issues, and NBS (2006)
Note: The category "Others" which takes up some 4 percent of total energy use, is omitted from the energy consumption calculated.

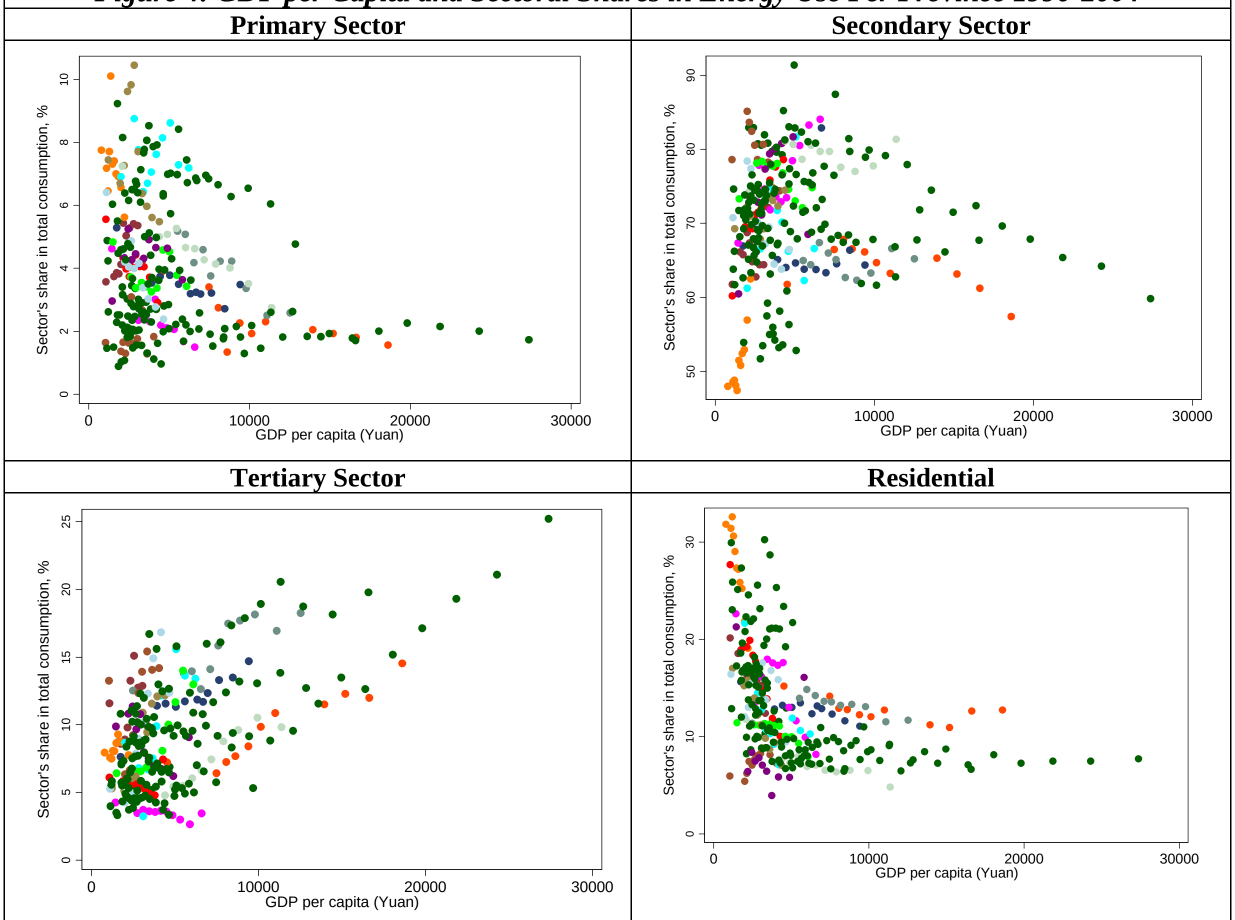
The broad pattern is that richer provinces have considerably lower energy intensity than poorer ones. Also, by and large all of the provinces show a decline in energy intensity with rising GDP per capita—the exception being Shanxi province. At every level of GDP per capita, the variation in energy efficiency among provinces is also considerable. This pattern of energy intensity and development should give some comfort to the Chinese authorities that aim to reduce energy intensity: as provinces grow richer, the energy intensity of their economies tends to drop.[3] On the other hand, in light of the variety in energy intensity at every level of income, there still seems to be considerable scope for increasing the energy efficiency of most provinces at every level of GDP.

Underlying this aggregate pattern of energy intensity and development are changes in the sectoral shares of energy and energy efficiency per sector as well as sectoral shifts in the economy. The sectoral share of energy use is plotted in Figure 4. Constrained by the Chinese sector classification, we plot 4 sectors: primary, secondary, tertiary, and residential use. The emerging patterns in the sectoral shares in energy use for China's provinces over time are remarkably similar to those presented in Schäfer (2005). The share of the primary sector shows a continuous decline as provinces grow richer, but the secondary sector shows at first a rise, and then a fall in the share of energy use. The tertiary sector shows a more mixed pattern at low levels of income, but a rising trend at

[3] It should be noted that the richest provinces are predominantly city-provinces, that are likely to have their own idiosyncrasies in production pattern and energy use that may not be achievable for other provinces.

higher levels of income. This is consistent with a pattern of development that first relies on industrialization, but at higher levels of income increasingly relies on services. Moreover, at higher levels of income, personal transport is playing an increasingly large role, and explains much of the rapid growth in energy share of this sector in the high income provinces. The residential share of energy use reflects the inefficient sources of energy for household use at lower levels of income (biomass, coal) and the switch to more efficient sources of energy at higher levels, as households get connected to the electricity and gas net.

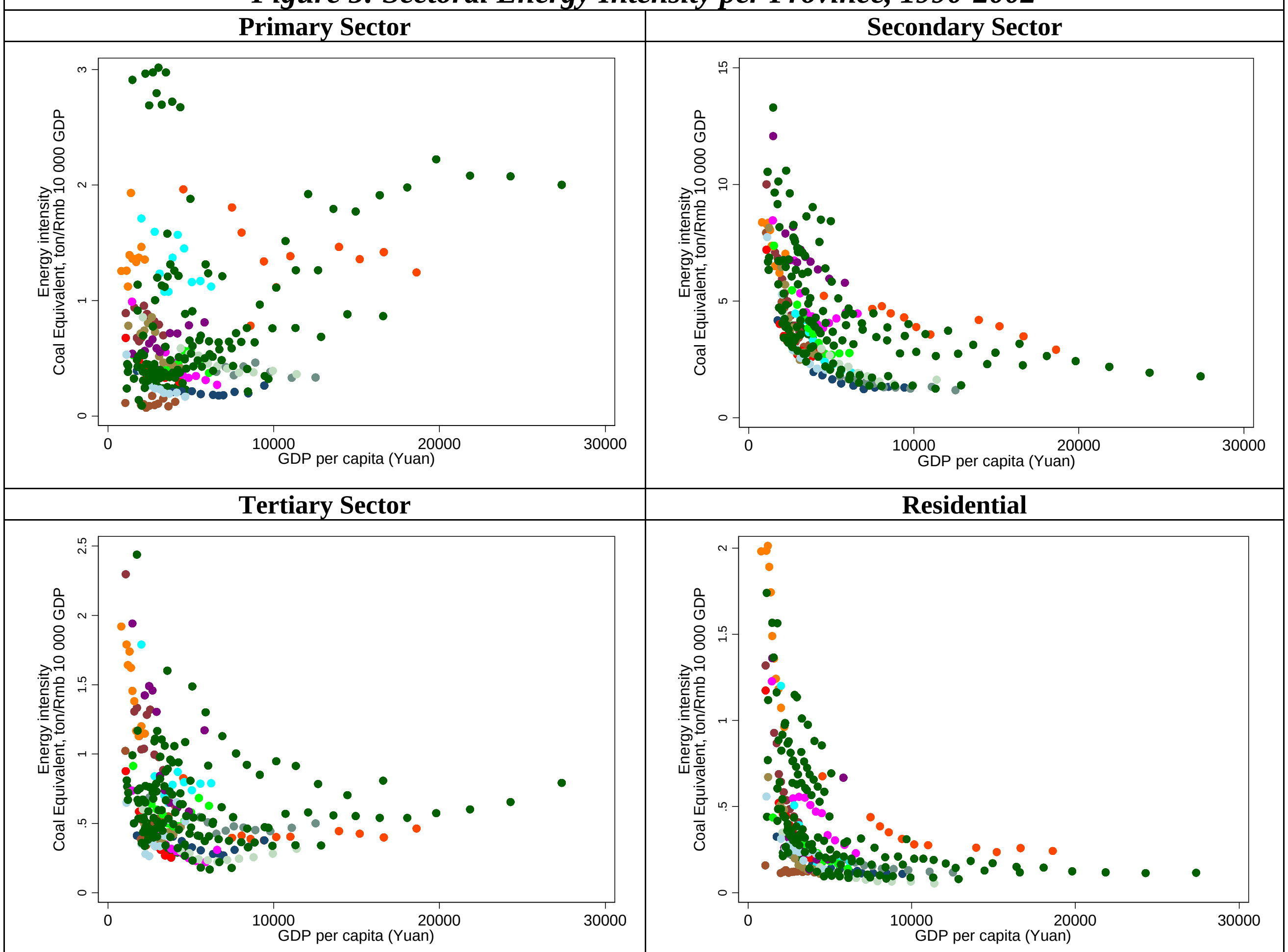
Figure 4: GDP per Capita and Sectoral Shares in Energy Use Per Province 1990-2004



Source: China Energy Yearbook, Various issues, and NBS (2006)
Note: The figure uses the Chinese classification of sectors. Primary is agriculture; secondary comprises industry and construction; tertiary comprises services including transport. The category "Others" which takes up some 4 percent of total energy use, is omitted from the chart.

The underlying dynamics in sector shares of energy use is more complex. It is the result of a change in sectoral energy intensity and sector share. Especially the sector energy intensities have changed considerably over time in China's provinces, with the rapid decline in energy intensity of the industrial sector standing out at almost every level of income (Figure 5). Energy intensity in all sectors except agriculture is strongly correlated with income levels, which also holds true for China as a whole. There is no clear pattern in the agricultural sector—basically, the energy intensity of the sector does not improve with income. In contrast, the industrial sector shows a clearly negative correlation between income and energy intensity. The services sector displays falling energy intensity up to a level of GDP of about RMB 6000 per capita, but then there is a slightly rising tendency afterwards. The strong rise of this sector's share in total energy use at high levels of income can therefore be explained with a shift in GDP towards that sector.

Figure 5: Sectoral Energy Intensity per Province, 1990-2002



Source: China Energy Yearbook, Various issues, and NBS (2006)
Note: The figure uses the Chinese classification of sectors. Primary is agriculture; secondary comprises industry and construction; tertiary comprises services including transport. The category "Others" which takes up some 4 percent of total energy use, is omitted from the chart. GDP is expressed in 1990 constant prices.

5. Accounting for the change in energy intensity

Following Schäfer (2005), we can more formally decompose the change in energy intensity into sectoral shifts in GDP and changes in sectoral intensity as:

$$\frac{(FE/GDP)_{t1}}{(FE/GDP)_{t2}} = \prod_i \left(\frac{(FE_i/GDP_i)_{t1}}{(FE_i/GDP_i)_{t2}} \right)^{FE_i/FE} \times \prod_i \left(\frac{(GDP_i/GDP)_{t1}}{(GDP_i/GDP)_{t2}} \right)^{FE_i/FE} \times \left(\frac{(FE_R/GDP)_{t1}}{(FE_R/GDP)_{t2}} \right)^{FE_R/FE}$$

where FE is the energy consumption, and i represents the various sectors. The first and third part of the equation describes the impact of a change in energy intensity in different sector on total energy intensity. The second part describes the impact of a shift in GDP from one sector to another on energy intensity.

TABLE 2: SUMMARY STATISTICS ON THE DECOMPOSITION OF PROVINCIAL ENERGY INTENSITY CHANGES 1990-2004

Contribution to decline in energy intensity 1990-2004	**Weighted Mean**	**Weighted standard deviation**	**Lowest**	**Highest**
Agriculture				
Share in total energy consumption	0.042	0.019	0.016	0.075
Change in sector energy intensity	0.983	0.244	0.928	1.020
Shift in GDP	0.969	0.241	0.920	0.993
Sub total	0.950	0.238	0.880	1.000
Industry				
Share in total energy consumption	0.724	0.187	0.517	0.815
Change in sector energy intensity	0.535	0.177	0.379	0.914
Shift in GDP	1.158	0.313	0.809	1.372
Sub total	0.617	0.217	0.435	1.110
Services				
Share in total energy consumption	0.091	0.041	0.035	0.166
Change in sector energy intensity	0.963	0.239	0.871	1.026
Shift in GDP	1.020	0.252	0.997	1.063
Sub total	0.979	0.242	0.887	1.032
Total production sector				
Change in sector energy intensity	0.503	0.166	0.369	0.880
Shift in GDP	1.135	0.303	0.819	1.357
Sub total	0.568	0.195	0.429	0.992
Residential				
Elasticity	0.118	0.052	0.072	0.275
Change in sector energy intensity	0.869	0.225	0.721	0.979
Total	*0.495*	*0.184*	*0.309*	*0.871*

Note : A value of 0.90 corresponds to a 10% decline in energy intensity over the indicated period. All subtotals and totals result from multiplying individual changes. Chongqing is considered part of Sichuan province. Hainan province has been dropped due to missing values.

The summary results of the decomposition for China's provinces are presented in Table 2. The reduction in energy intensity in industry can be as large as 62 percent whereas one province saw an increase in intensity of as much as 37 percent. While on average there was a shift towards industry, one province experienced a decline of the share of industry in GDP of 20 percent. And while in general energy intensity in agriculture and services fell, there are provinces that saw increases as well.

Table 3 presents results for the provinces aggregated in 4 incomes quartiles according to their average GDP per capita for the period 1990-2004[4].

TABLE 3: DECOMPOSITION OF ENERGY INTENSITY CHANGES PER INCOME QUARTILE 1990-2004

Contribution to decline in energy intensity 1990-2004	China	Top 25%	Upper middle range	Lower middle range	Lower 25%
Agriculture					
Share in total energy consumption	0.042	0.041	0.045	0.044	0.038
Change in sector energy intensity	0.983	0.987	0.964	0.984	0.989
Shift in GDP	0.969	0.955	0.968	0.974	0.978
Sub total	0.950	0.943	0.934	0.959	0.967
Industry					
Share in total energy consumption	0.724	0.700	0.748	0.735	0.706
Change in sector energy intensity	0.535	0.508	0.593	0.472	0.560
Shift in GDP	1.158	1.110	1.151	1.179	1.249
Sub total	0.617	0.557	0.690	0.557	0.695
Services					
Share in total energy consumption	0.091	0.121	0.069	0.072	0.080
Change in sector energy intensity	0.963	0.954	0.963	0.967	0.962
Shift in GDP	1.020	1.024	1.010	1.018	1.007
Sub total	0.979	0.976	0.972	0.984	0.968
Total production sector					
Change in sector energy intensity	0.503	0.479	0.550	0.449	0.533
Shift in GDP	1.135	1.082	1.124	1.170	1.230
Sub total	0.568	0.513	0.623	0.524	0.650
Residential					
Share in total energy consumption	0.118	0.101	0.108	0.135	0.158
Change in sector energy intensity	0.869	0.899	0.880	0.816	0.811
Total	0.495	0.462	0.556	0.434	0.527

Source: Authors' calculations based on the data describes in the text. *Note*: A value of 0.90 corresponds to a 10% decline in energy intensity over the indicated period. All subtotals and totals result from multiplying individual changes. The aggregation of provincial indices is made by weighted average, weights being each province's share of population in the total population (for China) and in the different zone's population. Quartiles are provincial income per capita quarters, the provinces classification being done for average income per capita between 1990 and 2004. Top 25% includes: Shanghai, Beijing, Tianjin, Guangdong, Zhejiang, Jiangsu, Fujian. The upper middle range includes: Liaonong, Shandong, Hebei, Jilin, Heilongjiang, Hubei, Xinjiang. The lower middle range one: Sichuan(Chongqing), Shanxi, Inner Mongolia, Anhui, Jiangxi, Hunan, Qinghai. The lower 25% one: Henan, Guangxi, Yunnan, Shaanxi, Ningxia, Gansu, Guizhou

[4] Another classification which considers the 6 regions corresponding to the standard Chinese classification of regions—with the exception of "metropolitan" which includes the city provinces of Beijing, Shanghai, and Tianjin- can be found in the Annex 1.

Table 3 suggests considerable variation in the explanation for the drop in energy intensity per income range. Overall, for each of the quartiles, the reduction in energy intensity of the secondary industry was the driving force behind the reduction in China's overall energy intensity, but with considerable variation. The richest provinces have experienced the largest reduction in industry energy intensity while the sector shift toward that sector is the lowest one. It appears that the wealthier the provinces, the lowest the shift toward secondary sector. For the tertiary sector, the upper income range provinces display the largest shift toward this sector and the largest gain in energy intensity. The rapid increase in energy use by the transport sector, which is included in the tertiary sector, explains this increase in energy intensity. Concerning the residential sector, there is a remarkable reduction in energy intensity at low levels of income, which can be explained by people switching from biomass and pressed coal for cooking and heating to electricity and gas. Notable is the absence of an increase in residential energy intensity at higher levels of income, even though they are more likely to use modern household appliances. One explanation for this could be that the higher quality of appliances bought at higher levels of income are more energy efficient than those bought at lower levels.

Because of the apparent break in the trend in energy intensity since 2001, we take a closer look at the decomposition of energy intensity for 2001-2004 (Table 4). First, it is again industry that drives the overall result, and for China as a whole, both energy intensity of the sector and the share of GDP from that sector experienced an increase. However, the breakdown per income quartile shows a more nuanced pattern: all but the upper middle income provinces still experienced a further reduction in energy intensity of the industrial sector. Even this development seems to be solely driven by Shandong province, which rapidly developed its heavy industry over 2001-4, including a more than doubling of cement and steel output, and a tripling of glass production. Without Shandong province the increase in energy intensity due to industry disappears (Table 4, Column 7).

At all income ranges, China's provinces experienced a loss in energy efficiency in the tertiary sector. This can be largely explained by the development of transports in this sector, with rapidly rising individual car ownership in recent years. Adding to the overall energy intensity of the economy is a minor shift away from the relative energy extensive tertiary sector during this period, and towards industry. This runs contrary to the trend in sectoral shares displayed before 2001, and may have to do with the renewed impetus for investment resulting from China's entry in the WTO in 2001.

TABLE 4: DECOMPOSITION OF ENERGY INTENSITY CHANGES PER INCOME QUARTILE 2001-2004

Contribution to decline in energy intensity 2001-2004	China	Top 25%	Upper middle range	Lower middle range	Lower 25%	China without Shandong
Agriculture						
Share in total energy consumption	0.037	0.035	0.038	0.042	0.036	0,037
Change in sector energy intensity	0.994	0.998	0.985	0.994	1.001	0,996
Shift in GDP	0.994	0.991	0.997	0.997	0.996	0,994
Sub total	0.989	0.989	0.982	0.991	0.997	0,990
Industry						
Share in total energy consumption	0.719	0.683	0.764	0.724	0.720	0,715
Change in sector energy intensity	1.035	0.959	1.255	0.914	0.956	0,951
Shift in GDP	1.054	1.055	1.043	1.062	1.064	1,048
Sub total	1.096	1.013	1.328	0.969	1.018	0,998
Services						
Share in total energy consumption	0.112	0.147	0.085	0.094	0.094	0,116
Change in sector energy intensity	1.019	1.021	1.017	1.022	1.012	1,015
Shift in GDP	0.994	0.992	0.995	0.994	0.995	0,994
Sub total	1.013	1.013	1.013	1.017	1.007	1,009
Total production sector						
Change in sector energy intensity	1.050	0.978	1.265	0.929	0.970	0,962
Shift in GDP	1.042	1.037	1.035	1.052	1.054	1,037
Sub total	1.098	1.015	1.327	0.977	1.023	0,998
Residential						
Share in total energy consumption	0.104	0.093	0.090	0.124	0.135	0,106
Change in sector energy intensity	0.994	0.986	1.015	0.995	0.970	0,984
Total	1.101	1.001	1.372	0.973	0.993	0,983

Source: Authors' calculations based on the data described in the text.

Note: A value of 0.90 corresponds to a 10% decline in energy intensity over the indicated period. All subtotals and totals result from multiplying individual changes. The aggregation of provincial indices is made by weighted average, weights being each province's share of population in the total population (for China) and in the different zone's population. Quartiles are provincial income per capita quartile, the provinces classification being done for average income per capita between 1990 and 2004. Top 25% includes: Shanghai, Beijing, Tianjin, Guangdong, Zhejiang, Jiangsu, Fujian. The upper middle range includes: Liaonong, Shandong, Hainan, Hebei, Jilin, Heilongjiang, Hubei. The lower middle range: Xinjiang, Sichuan(Chongqing), Shanxi, Inner Mongolia, Anhui, Jiangxi, Hunan. The lower 25%: Qinghai, Henan, Guangxi, Yunnan, Shaanxi, Gansu, Guizhou.

7. Explaining changes

The provincial panel data allow us to investigate the developments of energy intensity beyond sectoral shifts and intra-sectoral efficiency gains. This has advantages over time series models such as Li's (2006) model because it does not need to use observations from a time when China's economic management was fundamentally different from more recent decades, or from industry or enterprise data, which lend themselves less to capturing the effects of structural change we are interested in.

Since the end of the 1970s, China's economic reforms have transformed its economy increasingly towards a market-based one, with prices that are increasingly market determined, or more aligned with international ones (OECD 2005). The phase-out of restrictions on ownership forms has also made China an increasingly private economy. This transformation has by itself influenced the sectoral and sub-sectoral composition of the economy. Moreover, it is also likely to have driven an increasing drive for efficiency by non-state enterprises that faced hard budget constraints, and state enterprises that faced a hardening of budget constraints.

To capture the potential effect of the increase in energy prices, we use the relative price of coal. There is a dearth of published energy prices in China, and the only price available back to the mid-1990s for a sufficient number of provinces are coal prices. We use provincial price deflators to construct provincial real coal prices a san indicator for the price of all energy ((*ln relative coal price*).[5] We expect a negative relationship between this price and energy intensity considering that as price increases, demand decreases.

To capture the shift towards a private sector economy, we use the share of State Owned Enterprises (SOEs) in Industry Gross Value Added (*ln ratio state enterprises*). The hypothesis is that SOEs are less efficient in their energy use than non-state (domestic private, collective, and foreign invested enterprises).

We use the log of GDP per capita to see how energy intensity evolves when the country gets richer. Considering the evolution of energy consumption with the growth of income (Figure 3 presented before), the relationship between energy intensity and GDP per capita should be negative.

To capture structural change in the economy we use the ratio of secondary and tertiary sectors' GDP in total GDP (*ln ratio industry, ln ratio services*). The agricultural share is the complement of these two, and is therefore left out to avoid multicollinearity. Our hypothesis is that an increase in the share of industry in GDP increases energy intensity whereas an increase in the share of services would decrease it. We also expect the *composition* of industrial production to have an effect on energy intensity, and therefore distinguish between light and heavy industry.[6] We expect that the higher the share of light industry in total Gross Output Value (*ln ratio light industry*) the lower energy intensity.

The structure of the energy consumption is described by the log of the ratio of raw coal consumption (TCE) in total energy consumption (*ln ratio raw coal*). Energy intensity should show a positive relationship with the share of raw coal in total energy consumption, as raw coal use is a less efficient source of energy.

Finally, we noted before the reversal in energy intensity trend since 2001. We introduce a dummy variable (D0104) that takes the value of 1 for the period 2001-2004 and the value of 0 elsewhere to capture any effects not included in the other variables. We also

[5] Price information is from *CIEC data*. Thanks to Micael Chen for pointing this out.
[6] More detail on energy intensity for sub-industries is not publicly available as far as we know.

use the dummy variable multiplicatively with other variables to detect non linear time effects.

Table 5 presents results. The first column of Table 5 presents the simple correlation between our right hand side variable and our left hand side variables.

We note a negative correlation between energy intensity and energy prices, GDP per capita, services share in total GDP, light industry share in total gross output value and ratio of raw coal in total energy consumption. A positive correlation exists between energy intensity and industry share in GDP and state owned enterprises share in total gross output value. We see that the time dummy is also positively correlated with energy intensity. These correlations are in line with the expected relationships, but to determine a causal relation, we need to use econometrics.

(i) Fixed Effect Model

We are using panel data. Because of missing values for the different provinces and the different variables, we had to limit the estimation period to 1997-2004. A Hausman Test for the choice between fixed and random effect yielded a negative value, which can't be interpreted, something that is often the case with the test in the finite sample context.[7] Because provinces vary considerably in energy intensity and in the values of the explanatory variables, we believe it is reasonable to use a fixed effect model. We include a dummy for 2001-2004 in each estimation as well as interactive terms of the variables with the time dummy. Consequently, the model will be as follows:

$$\begin{aligned} lnEI_{it} = {} & \beta_0 + \beta 1.lncoalprice_{it} + \beta_2.lnGDPC_{it} + \beta_3.lnind_{it} + \beta_4.lnind_{it} * D_{0104t} + \\ & \beta_5.lnservices_{it} + \beta_6.lnservices_{it} * D_{0104t} + \beta_7.lnlight_{it} + \beta_8.lnlight_{it} * D_{0104t} + \\ & \beta_9.lnstate_{it} + \beta_{10}.lnstate_{it} * D_{0104t} + \beta_{11}.D_{0104t} + \alpha_i + \varepsilon_{it} \end{aligned}$$

where i is for provinces and t for time. α_i stands for the fixed effects and ε_{it} is the normally distributed error term. *LnEI* is the log of the energy intensity as defined before.

Results using the fixed effects model are presented in column (2) of Table 5. Insignificant interaction terms with the time dummy are not reported.

As expected, we find a negative correlation between relative price of energy and energy intensity. GDP per capita is negatively and significantly correlated with energy intensity. The richer provinces are, therefore, the lower their energy intensity. The ratio of raw coal is positively and significantly correlated with energy intensity. We also find the expected negative correlation of services' share in GDP with energy intensity. The significantly negative interactive term ($Lnservices * D_{0104}$) implies that energy intensity is more negatively correlated with the share of services in total GDP for the period 2001-2004. However, because there was a shift away from the tertiary sector during the last years for

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[7]. See StataCorp: 2001, Stata Statistical Software: Release 7.0, College Station (TX), USA for details.

TABLE 5: RELATIONSHIPS BETWEEN ENERGY INTENSITY AND STRUCTURAL CHANGES
Estimates 1997-2004

Dependent variable: Ln energy intensity	Correlation	Fixed effects	Two stages fixed effects			
	(1)	(2)	(3)	(4)	(5)	(6)
Ln relative coal price*	-0.35***	-0.1616**	-0.5648**	-0.5880**	-0.4771*	-0.5469**
	(0.000)	(-2.20)	(-2.00)	(-2.03)	(-1.79)	(-1.94)
Ln GDP per capita	-0.5270***	-0.4030***	-0.2031*	-0.1348	-0.1888*	-0.2583**
	(0.000)	(-5.56)	(-1.70)	(-1.15)	(-1.72)	(-2.55)
Ln ratio industry	0.1404**	-0.0508	-0.2499	-0.3167	-0.2959	
	(0.0155)	(-0.27)	(-1.10)	(-1.35)	(-1.30)	
Ln ratio industry * D_{0104}	-0.0708	-0.1128	-0.1831	-0.0211	-0.0845	
	(0.2238)	(-0.98)	(-1.54)	(-0.19)	(-0.90)	
Ln ratio services	-0.2787***	-0.7340***	-0.9324***	-1.0982***	-1.1323***	-0.8069***
	(0.000)	(-4.74)	(-4.83)	(-5.71)	(-6.17)	(-5.55)
Ln ratio services * D_{0104}	-0.1742***	-0.4629***	-0.5787***	-0.4304***	-0.4252***	-0.4347***
	(0.0026)	(-3.67)	(-4.19)	(-3.18)	(-3.25)	(-4.27)
Ln ratio light industry	-0.5772***	-0.0088	-0.0307	-0.0508	-0.0402	-0.0259
	(0.000)	(-0.22)	(-0.70)	(-1.13)	(-0.93)	(-0.62)
Ln ratio light industry * D_{0104}	-0.4117***	-0.0022	0.0001	0.0756**	0.0848***	0.0166
	(0.000)	(-0.06)	(0.00)	(2.25)	(2.61)	(0.45)
Ln ratio state enterprises	0.4846***	0.0056	0.0140			0.0075
	(0.000)	(0.26)	(0.63)			(0.35)
Ln ratio state enterprises * D_{0104}	0.2201***	-0.0833***	-0.0830***			-0.0694***
	(0.0001)	(-3.28)	(-3.23)			(-3.07)
D_{0104}	0.1246**	-0.5265**	-0.6764***	-0.2026	-0.2583	-0.3535***
	(0.0319)	(-2.30)	(-2.87)	(-1.05)	(-1.43)	(-2.80)
Ln ratio raw coal	0.3067***	0.0973***	0.0972**	0.1170***		0.1114***
	(0.000)	(2.63)	(2.53)	(2.99)		(3.01)
Constant		-0.1032	-0.3360	-1.0389	-1.2064	0.3842
		(-0.14)	(-1.06)	(-1.15)	(-1.41)	(0.47)
Observations	297	275	249	249	255	249
R^2		0.2565	0.2424	0.2175	0.4485	0.2698
F-test p-value $\alpha_i=0$		0.000	0.000	0.000	0.000	0.000

Note: **=significant at the 5 percent level; ***= significant at the 1 percent level

most of the provinces (see Shäfer's coefficients for the period 2001-2004) this is not positive for energy intensity. The share of industry in GDP is somewhat surprisingly not significantly correlated with energy intensity. One reason could be that for most provinces this share has been fairly strongly correlated with the share of services.

The share of state owned enterprises by itself is not significant for the sample period. However, the interactive term for 2001-4 is significantly negative. A Fisher-test for the joint significance of the two coefficients suggests joint significance. This can be interpreted as follows: for the 1997-2000 period, the effect of the share of state owned enterprises is positively correlated with energy intensity, but for the 2001-4 period, it is negatively correlated (the sum of the coefficients of direct and interactive terms is negative) . It seems, therefore, that state enterprises have become more efficient with time. This could be a result of state enterprise reforms, which over the period 1998-2001 gave strong incentives for SOEs to increase efficiency.

(ii) Two Stage Fixed Effect Model

As expected, the relationship between coal price and energy intensity was found to be negative. However, this result can be misleading as the coal price may be endogenous. Throughout the reform period and still today energy prices are determined by the government, not the market. So the authorities may set the price of coal depending on energy use in the economy—increasing it when energy intensity goes up, and decreasing it when energy intensity goes down. This could imply that the coal price is simultaneously determined with energy intensity, and is therefore endogenous.

To control for the effects of possible endogeneity of the coal price, we use a two-stage fixed effect method for our estimation. We use the lag of the log of coal price, which is highly correlated with the current coal price but which can't be correlated with the current energy intensity. The first stage equations are presented in Annex 2. Columns 3-6 (bis) in Annex 2, correspond to the two-stage estimations of Table 5 column 3-6, and present different specifications for the instrumental variables estimates, all suggesting that our instrument is highly correlated with our endogenous variable.

Results of the estimations in two stages fixed effects are presented in the columns 3, 4, 5 and 6 of Table 5. In column 3, we use the same specification as the one used with fixed effects estimator. Ownership structure is correlated with other variables that account for the economy's structure (such as the share of secondary sector). Consequently, in column 4, we drop the former variable to see the total impact of the latter. Column 5 presents the results without the structure of energy consumption (proxied by the share of raw coal in total energy consumption), because the structure of energy consumption may be influenced by the level of energy intensity.[8] Finally, we present an estimation without the variables concerning the share of industry in total GDP as it still appears to be non significant and as it is correlated with within-secondary sector's variables (such as ownership structure and light/heavy industry decomposition).

Concerning column 3 in Table 5, we note that results are close to those found with the fixed effects estimation. The relative coal price has still a negative and significant correlation with energy intensity but its marginal effect is four to five times higher than before. An increase in the relative coal price by one percent is associated with a reduction in energy intensity by 0.56 percent. The size of the price effect remains relatively stable across specifications of the two stage estimations. GDP per capita is still negatively and significantly influencing energy intensity. Nevertheless, its significance is only marginally significant, and disappears in the specification of column 4. Nevertheless, the size of the effect is approximately the same for the different regressions. As the GDP per capita increases by one percent, energy intensity decreases by approximately 0.19 percent.

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[8] The instrumentation of the variable "raw coal" could be done but we do not do it here as our study is not focused on this explanatory factor.

The impact of the share of the tertiary sector on energy intensity is similar to that in the fixed effects estimation. We again find a non-linearity of this impact with time. The negative effect is even stronger after 2001 than before. We can also see that the impact of the share of services is one of the more important one, with an increase in the share of services in GDP associated with a 1-1.5 percent decline in energy intensity, the higher values occurring in the years 2001-4. This confirms the potential role the development of the services sector can play in reducing energy intensity. In contrast to the tertiary share we find no significant impact of the share of industry in total GDP, whatever the estimation's method and the specifications chosen.

In the two-stage estimations, the share of state-owned enterprises in industrial production retains its non linear impact on energy intensity. Nevertheless, as discussed before, this variable may account for other phenomena of structural change, and we find a strong correlation with the other variables we are using in this model. If we drop the SOE share as a variable (columns 4 and 5 in Table 5) the ratio of light industry in total gross output value becomes significant and is negatively correlated with energy intensity, but only after 2001 (what we can say thanks to the multiplicative variable). Once again, we use a Fisher test for the joint significance of the two factors. As the null hypothesis of no join impact is rejected, we can interpret both coefficients. Considering the whole period, therefore, the impact of the share of light industry is negative, which is what one expects as light industries are using less energy. After 2001 the effect is smaller than before.

Finally, the ratio of raw coal material in total energy consumption remains positive and significant. Dropping the variable from the equation (because of potential endogeneity) does not significantly affect the other variables.

7. Conclusion

This paper finds significant effects of structural change on the energy intensity of the economy. Considering sectoral shifts alone suggests that the richer a province becomes the less energy intensive it becomes. These results form a combined effect of a sectoral shift to less energy-intensive services and lower energy intensity for each sector. The recent uptick in energy intensity is the result of an uptick in the share of industry in the majority of provinces rather than a loss of energy efficiency within any of the sectors—the notable exception being Shandong province. Taking into account a broader set of explanatory variables, we find that higher relative prices of energy reduce energy intensity.

The big question for China remains whether the recent upurn in energy intensity will be permanent, or temporary. If the patterns observed over the whole estimation period remain relevant going forward, China's energy intensity is likely to resume its downward path. To illustrate, assume that China's GDP per capita on average continues to grow, and assume that this growth is evenly distributed among the provinces. The direct effect according to equation (6) in Table 5 would be to reduce energy intensity by 0.26 percent for every percent growth in GDP per capita. Over the estimation period, however, the share of services is positively correlated with GDP per capita: for every percent increase in GDP per capita, the share of the tertiary sector increases with 0.17 percent. The combined effect, using equation (6) would therefore yield a reduction in energy intensity of 0.47 percent.[9] If China's GDP per capita were to grow with 8 percent per year over the next 5 years, energy intensity would then drop with about 3.8 percent. While encouraging, this falls far short of the 20 percent target that the authorities have set themselves. Fortunately, our estimates suggest that an increase in the relative price of energy can strongly reduce energy intensity in the economy. Again assuming equation (6) would hold, to meet the targets of the authorities, the relative price of energy would have to increase by about 30 percent to make up for the remaining 16 percent reduction in energy intensity beyond the reduction achieved through structural change.[10]

[9] Over 2001-4 the estimated coefficient for the effect of services on intensity is -1.23 (-0.8069-0.4347). Thus the additional effect of sectoral shift is 0.17*(-1.23)=0.21.

[10] 16/(-0.5469).

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ANNEX 1: DECOMPOSITION OF ENERGY INTENSITY PER REGION 1990-2004.

Contribution to decline in energy intensity 1990/2004	**Metropolis**	**Northeast**	**Coast**	**Central**	**Northwest**	**Southwest**	**China**
Agriculture							
Share in total consumption	0.02	0.04	0.05	0.05	0.04	0.03	0.04
Sector energy intensity	1.00	0.98	0.97	0.97	1.00	1.01	0.94
Shift in GDP	0.98	0.98	0.95	0.97	0.98	0.98	0.92
Sub total	0.97	0.96	0.92	0.94	0.98	0.99	0.90
Industry							
Share in total consumption	0.68	0.76	0.72	0.74	0.66	0.71	0.69
Sector energy intensity	0.59	0.48	0.56	0.50	0.59	0.49	0.52
Shift in GDP	0.86	1.03	1.20	1.21	1.23	1.20	1.10
Sub total	0.50	0.49	0.67	0.60	0.73	0.58	0.60
Services							
Share in total consumption	0.14	0.08	0.09	0.07	0.10	0.08	0.09
Sector energy intensity	0.93	0.94	0.97	0.97	0.98	0.96	0.92
Shift in GDP	1.05	1.01	1.01	1.02	1.00	1.02	0.97
Sub total	0.98	0.95	0.98	0.98	0.98	0.97	0.93
Total production sector							
Sector energy intensity	0.55	0.44	0.52	0.47	0.58	0.47	0.48
Shift in GDP	0.88	1.02	1.15	1.19	1.21	1.20	1.08
Sub total	0.48	0.44	0.60	0.56	0.70	0.56	0.55
Residential							
Share in total consumption	0.09	0.10	0.10	0.13	0.16	0.15	0.11
Sector energy intensity	0.90	0.85	0.90	0.83	0.85	0.82	0.83
Total impact	0.43	0.38	0.55	0.46	0.60	0.47	0.48

A value of 0.90 corresponds to a 10% decline in energy intensity over the indicated period. All subtotals and totals result from multiplying individual changes. Metropolis: Beijing, Tianjin, Shanghai; Northeast: Heilongjiang, Jilin, Liaoning; Coast: Fujian, Guangdong, Hebei, Jiangsu, Shandong, Zhejiang; Central: Henan, Hubei, Hunan, Jiangxi, Shanxi; Northwest: Gansu, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Xinjiang; Southwest: Guangxi, Guizhou, Sichuan (Chongqing), Yunnan. Hainan province has been dropped due to missing values. This classification is from Demurger et al. (2002). The aggregation of provincial indices is made by weighted average, weights being the average on the whole period of each province's share of GDP in the total GDP (for China) and in the different zone's GDP.

ANNEX 2: FIRST STAGE EQUATION FOR COAL PRICE INSTRUMENTATION

Ln coal price	(3)bis	(4)bis	(5)bis	(6)bis
Lag ln relative coal price	**0.2622***** **(4.30)**	**0.2630***** **(4.33)**	**0.2748***** **(4.57)**	**0.2619***** **(4.29)**
Ln GDP per capita	0.2088*** (3.08)	0.1983*** (3.09)	0.1957*** (3.18)	0.1554** (2.56)
Ln ratio industry	-0.3015* (-1.72)	-0.2998* (-1.73)	-0.3071* (-1.80)	
Ln ratio industry * D_{0104}	-0.0635 (-0.66)	-0.0563 (-0.65)	-0.0632 (-0.86)	
Ln ratio Services	-0.3695*** (-2.69)	-0.3679*** (-2.80)	-0.3861*** (-3.08)	-0.2273** (-2.06)
Ln ratio Services *D_{0104}	-0.1353 (-1.28)	-0.1362 (-1.37)	-0.1383 (-1.42)	-0.0408 (-0.49)
Ln ratio light industry	-0.0591* (-1.70)	-0.0630* (-1.87)	-0.0631* (-1.90)	-0.0479 (-1.42)
Ln ratio light industry * D_{0104}	0.0123 (0.38)	0.0154 (0.58)	0.0157 (0.61)	0.0122 (0.40)
Ln ratio state enterprises	0.0117 (0.65)			0.0109 (0.62)
Ln ratio state enterprises * D_{0104}	-0.0038 (-0.18)			-0.0039 (-0.21)
D_{0104}	-0.0891 (-0.47)	-0.0762 (-0.52)	-0.0847 (-0.60)	0.0513 (0.49)
Ln ratio raw coal	0.0118 (0.38)	0.0115 (0.37)		0.0147 (0.49)
Constant	0.9221 (1.33)	0.9904 (1.49)	0.9219 (1.44)	1.7715 (3.57)
Observations	249	249	255	249
F-test p-value β_i=0	0.000	0.000	0.000	0.000