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Chinese urban household energy requirements and CO₂ emissions

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Much of the literature on Chinese energy focuses on the insatiable demand of China's rapidly growing industrial sector. Given that in 2005 industry accounted for close to 70 per cent of China's energy demand that was consumed directly by the various sectors of the economy, this focus is not unwarranted. Likewise, given that residential consumption accounted for only 11 per cent of this direct energy demand in 2005, perhaps it is not surprising that there has been so little research on this aspect of China's total energy demand.¹ What tends to be overlooked, however, is that whatever is produced within China is ultimately used for household or government consumption, investment or exports. This gives rise to a number of interesting questions regarding the end users of energy. This paper focuses on one of those end users, urban households, and considers the consequences of different household consumption patterns for energy requirements and carbon dioxide emissions (henceforth carbon emissions).

Drawing on national-level energy and output data for all production sectors and on the Urban Household Income and Expenditure Survey (National Bureau of Statistics 2005), we address three related issues. First, using national-level data, we extend the notion of household energy consumption to include 'indirect' energy requirements, defined in terms of the energy inputs used in the production of goods consumed ultimately by households. Adding this to direct energy consumption yields considerably higher total energy requirements and, therefore, higher contributions to aggregate emissions, than accounting for direct energy requirements alone, supporting the findings of many others

(Wei et al. 2007; Pachauri and Spreng 2002; Cohen et al. 2005). This suggests that understanding household consumption patterns could be more important for understanding China's future energy demand than has been recognised previously.

Second, using the urban household survey data, we examine the extent of variation in total energy requirements and emissions across households with different income levels. It seems obvious that richer households should generate more emissions, simply because they have more money to spend and virtually no expenditure is emission free. More crucially though, we are concerned with household variations in energy requirements and emissions per yuan—that is, energy and emission intensities. Given that households with different levels of per capita income are likely to have different consumption bundles, and that different goods clearly require different quantities of energy in order to produce one yuan of output, variations are highly likely. A simple examination of how expenditure and emission shares of each sector vary across income brackets enables us to identify that while richer households do indeed emit more per capita, poorer households tend to be more emissions intensive—that is, generating higher emissions per yuan spent. Their heavy reliance on coal as a source of direct energy also makes poorer households significantly less 'energy efficient', as reflected in higher emissions/energy ratios.

Third, econometric analysis provides estimates of the extent of variations in energy requirements and emissions that can be attributed to household variations in per capita income and a variety of other household-specific characteristics. Beyond per capita income, other variables of interest include household size and the level of education. Smaller households might be expected to emit more per capita based on economies of scale in the direct use of energy: electricity, fuel for cooking and so on. It is possible—although perhaps overly optimistic—that higher levels of education could result in successful efforts to reduce per capita emissions. Other factors that might cause variations in household energy requirements include dwelling size, the age of household members and the province in which households are located. The combined findings that emerge give rise to some critical policy implications.

Background

First, it is necessary to clarify some key terms. 'Direct' energy requirements of households are defined as the consumption of energy carriers (coal, petroleum, natural gas and electricity) purchased by households in order to cater for energy services, such as space heating, heating tap water, lighting, appliances, cooking and motor fuel. 'Indirect' energy requirements refer to the consumption of

energy that occurs during the production process of a good or service before its use (Weber and Perrels 2000; Wei et al. 2007). Direct energy requirements are relatively easy to calculate. As long as physical quantities consumed of, say, petroleum, can be observed (which they can in the survey data used below), it is possible to convert those quantities into tonnes or grams of 'coal equivalent' using the appropriate conversion factors. The carbon emissions associated with each form of energy can be derived readily using 'carbon coefficients', which are constants that vary across different energy forms (and across countries and over time as well).² Multiplying the petroleum quantity—expressed in tonnes of coal equivalent (tce)—by the appropriate carbon coefficient provides a measure of the total amount of carbon emissions associated with that quantity of petroleum consumption.

Calculating indirect energy requirements and their associated carbon emissions is more complex. Kok et al. (2006) survey the relevant literature and note the obvious but important point that different methods, all based on input–output (IO) analysis but using different data sources and different levels of aggregation, produce different results. They identify three basic methods: first, basic IO energy analysis draws on monetary data based entirely on national accounts. The indirect energy requirements of households are calculated by multiplying 'sectoral cumulative energy intensities' with monetary data on the final demand of households, which are available from the IO table. Energy intensities do not include direct energy deliveries to households, which are calculated separately using physical energy data from energy statistics at the national level. Second, 'IO plus household expenditure' differs from the basic method in that it relies on expenditure surveys rather than IO tables to determine household expenditure. Expenditure on each consumption item is multiplied with the corresponding value of energy intensity for that item. The direct energy requirements of households are also calculated separately, but here they are based on energy-use data collected at the household level. This is essentially the methodology adopted below, and has been used by many others (Weber and Perrels 2000; Pachauri 2004; Cohen et al. 2005; Bin and Dowlatabadi 2005). The third method is called 'hybrid energy analysis', which involves a combination of process and IO analysis. In process analysis, the life cycle of a product is described in physical terms, delving in great detail into the various stages of the production process, such as distribution, storage, transport, waste and recycling, and so on. It is the most accurate and time-consuming method and, as a consequence, appears to have been used only for European analysis where such detailed data are available (see, for example, Reinders et al. 2003). This method is simply out of the question at this stage for a China-focused analysis.

This variety of methods (often referred to by different names) has been applied to address a range of issues in single-country and cross-country analyses.³ Weber and Perrels (2000) assess the energy and emissions consequences of consumer activities in West Germany, the Netherlands and France, considering how alternative lifestyles—such as slower economic growth or the adoption of cleaner technologies—impact on projected household consumption patterns. Pachauri and Spreng (2002) use a 115-sector classification of IO tables for India in three different years, enabling them to conduct cross-sectional and time-series analyses. They find that total energy consumption by Indian households is divided evenly between direct and indirect energy requirements and accounts for 75 per cent of total energy consumption in India. Their time-series analysis enables them to identify the main drivers of increasing energy requirements in total and per capita terms—namely, growing expenditure per capita and increasing energy intensity in the food and agricultural sectors. Pachauri (2004) builds on this to consider cross-sectional variations in household energy requirements in 1993–94, finding that the size of the household dwelling, the number of members in the household and the literacy level of the head of the household all effect household energy requirements—the first two positively, the last one negatively. Cohen et al. (2005) investigate the picture of equity that emerges within a developing country, using expenditure data on different income levels across 11 cities in Brazil. They show that 61 per cent of household energy is consumed indirectly and find that there are fairly constant energy intensities across income classes. Reinders et al. (2003) conduct a detailed examination of household energy intensities for a range of consumer goods in 11 European Union countries, showing that the direct energy share varies across countries, ranging from 34 to 64 per cent.

The analysis of China by Wei et al. (2007) is closest in spirit to this paper. They first quantify the direct and indirect energy requirements and related carbon emissions of urban and rural residents between 1999 and 2002. They find that 26 per cent of China's total energy consumption and 30 per cent of its emissions are the 'consequence of residents' lifestyles and economic activities to support these demands' (Wei et al. 2007:247). Using the IO plus expenditure approach, they find that for urban residents, the indirect contribution of energy consumption is 2.44 times greater than the direct contribution (accounting for 71 per cent of the total), while for rural residents it is smaller (accounting for 35 per cent of the total). The sectors covered are food, clothing, residence, household facilities and services, medicine and medical services, transport

and communication services, education, cultural and recreation services and miscellaneous commodities and services. While these sectors differ significantly from the ones used below, and the methodology is not identical, this chapter provides a useful benchmark for comparison.

Before turning to a detailed description of the methodology adopted in this chapter, a few caveats should be noted. One regards the problem of using expenditure as the key variable for calculating energy and emission intensities. As noted by Weber and Perrels (2000), calculating an average energy requirement per dollar spent on 'food' does not allow a distinction between high and low-quality product choices within that category. They argue that high quality usually comes at a high price, while the embodied energy increase is not commensurate, resulting in a lower energy intensity per monetary unit spent on high-quality products. Regardless, to improve on this would require a much more detailed treatment that is very difficult to combine with a dynamic description of consumption and production in a society (Weber and Perrels 2000). Aside from the quality issue, high levels of aggregation are also problematic. If we had data on the energy inputs for, say, rice, pork and tofu, it would be (relatively) reasonable to assume that each of these is a homogeneous group and that price is also homogeneous within each group. Given that instead all we can do is aggregate these into 'food', because that is the extent of energy data available, it is true that we could overestimate or underestimate the energy and emission intensities associated with each sub-group: rice, pork and tofu. Given data constraints, there is little to be done about this problem other than to emphasise that the discussion is necessarily about *average* intensities, and to concede the shortcomings of this approach.⁴

Other problems raised in the literature include the high level of uncertainty for countries that rely heavily on imports, where imports are assumed to be produced using the same technology and structure as domestic industries, and also the incompleteness of sectoral environmental statistics (for example, small and medium enterprises might be registered only in part and fail to be recorded accurately) (Suh et al. 2004). Hondo et al. (2002) identify numerous sources of uncertainty in carbon intensity calculations using IO tables, including data errors, multiple goods in one sector, multiple prices of one good, multiple technologies of one good and multiple producers of one good, presumably using different technologies. The household survey data used below do not indicate the share of imports in household expenditure and, likewise, it is beyond the scope of this paper to assess just how important these various sources of uncertainty might be. Instead, we simply acknowledge these issues and concede that the analysis is necessarily approximate rather than precise.

National-level energy requirements and carbon emissions

China's direct energy consumption was 2.14 billion tonnes of coal equivalent (tce) in 2005 (Table 16.1). Industry (including mining and quarrying, manufacturing and the production and supply of electric power, heat power and water) accounted for the lion's share of this consumption, at 69.8 per cent. Residential consumption accounted for the next highest share, at 10.9 per cent, with urban and rural residents accounting for 6.6 and 4.3 per cent respectively. This places aggregate residential direct energy consumption above transport, storage, postal and telecommunication services, agriculture, construction and wholesale, retail trade and catering services. The dominance of industry in terms of direct energy consumption explains why much of the literature has focused on the relationship between China's rapid industrial development and energy demand.⁵ This, however, overlooks a critical point, which is that China's households ultimately consume a large share of industrial output, and indeed the output of other sectors as well. This is where the notion of 'indirect' energy consumption comes into play.

Input–output tables provide the value of each productive sector used (either as a final product or in the production of another product) by the various sectors of the economy, which are: each of those productive sectors (agriculture, mining and quarrying, foodstuff, and so on); rural, urban and government consumption expenditure; gross fixed-capital formation and changes in inventories; and net exports. The sum of these values is equal to the total output value for each productive sector. The shares of each sector's total output consumed by rural and urban households are listed in Table 16.2. Our notion of indirect energy consumption follows from observing these shares, which are as high as 49.5 per cent of the total output in the case of foodstuffs and average 16.8 per cent across all sectors. Given that the foodstuff sector, for example, used 43.3 million tce as direct energy inputs in the production process, households indirectly consumed 21.4 million tce through their consumption of foodstuffs. In terms of total energy requirements, then, in addition to the 10.9 per cent of total energy consumed directly by urban and rural households (as shown in Table 16.1), another 16.8 per cent of China's total energy—or 360 million tce—was consumed through their expenditure on other products (Table 16.3). This implies that 27.7 per cent of China's total energy can be traced to household consumption (very close to Wei et al.'s [2007] figure of 26 per cent). For urban households, indirect energy requirements of close to 248 million tce are 1.75 times higher than their direct energy requirements (accounting for 64 per cent of total urban household energy consumption), while for rural households indirect requirements are 1.2 times higher (accounting for 55 per

Table 16.1 **China's direct energy consumption in 2005**

	'000 tonnes of coal equivalent (tce)	Share (per cent)
Total	2,144,794	100.0
Agriculture	79,783	3.7
Industry	1,496,389	69.8
Mining and quarrying	118,283	5.5
Foodstuff	43,277	2.0
Textile, sewing, leather and fur products	58,416	2.7
Other manufacturing	58,500	2.7
Production and supply of electric power, heat power and water	109,278	5.1
Coking, gas and petroleum refining	104,715	4.9
Chemical industry	244,744	11.4
Building materials and non-metal mineral products	215,151	10.0
Metal products	462,770	21.6
Machinery and equipment	81,255	3.8
Construction	34,111	1.6
Transport, postal and telecommunication services	162,793	7.6
Wholesale and retail trades, hotels and catering services	50,311	2.3
Other services	86,912	4.1
Residential consumption	234,495	10.9
Urban	142,205	6.6
Rural	92,290	4.3

Note: 'Other services' combines real estate, leasing and business services, banking and insurance and other services.

Source: National Bureau of Statistics (NBS), 2006. *China Energy Statistical Yearbook*, China Statistics Press, Beijing.

cent of the total). As urbanisation progresses in China, this is indicative of the fact that indirect energy demand will become an increasingly dominant source of China's consumer-driven emissions trends.

In order to look more closely at the energy requirements and carbon emissions of households in China in the next section, it is first necessary to calculate the 'energy intensity', defined as the energy requirements per yuan of output in each sector, and the 'carbon intensity', defined as the carbon emissions per yuan of output in each sector. Dividing the total energy consumed in each sector by the gross value of output in that sector gives sector-level energy intensities, which are provided in Table 16.4 in terms of grams of coal equivalent (gce) per yuan for each of the sectors for which data are available for 2005.⁶ One point that is immediately clear is that energy intensities vary substantially across sectors, ranging from 1,178 gce per yuan in the 'mining of other ores', to just 5.47

Table 16.2 **Shares of household consumption expenditure in total output (per cent)**

	Rural	Urban	Subtotal
Total	5.2	11.6	16.8
Agriculture	17.3	19.4	36.6
Mining and quarrying	0.8	2.0	2.8
Foodstuff	17.2	32.3	49.5
Textile, sewing, leather and fur products	4.2	16.5	20.7
Other manufacturing	1.8	7.8	9.6
Production and supply of electric power, heat power and water	2.7	12.3	15.0
Coking, gas and petroleum refining	0.6	3.9	4.5
Chemical industry	2.3	4.4	6.7
Building materials and non-metal mineral products	1.7	7.9	9.6
Metal products	0.4	1.5	1.8
Machinery and equipment	1.4	5.3	6.6
Construction	0.0	0.0	0.0
Transport, postal and telecommunication services	3.2	8.9	12.1
Wholesale and retail trades, hotels and catering services	5.8	20.0	25.8
Real estate, leasing and business services	12.8	18.9	31.7
Banking and insurance	7.3	12.9	20.2
Other services	5.4	21.1	26.5

Source: National Bureau of Statistics (NBS), 2007. *China Statistical Yearbook*, China Statistics Press, Beijing.

Table 16.3 **Indirect energy requirements for rural and urban households ('000 tonnes of coal equivalent)**

	Rural	Urban	All
Total	111,347	248,397	359,744
Agriculture	13,771	15,441	29,212
Mining and quarrying	893	2,377	3,269
Foodstuff	7,440	13,998	21,439
Textile, sewing, leather and fur products	2,428	9,643	12,071
Other manufacturing	1,037	4,551	5,588
Production and supply of electric power, heat and water	2,952	13,471	16,423
Coking, gas and petroleum refining	674	4,066	4,741
Chemical industry	5,653	10,774	16,427
Building materials and non-metal mineral products	3,689	17,061	20,750
Metal products	1,640	6,875	8,514
Machinery and equipment	1,128	4,272	5,399
Transport, postal and telecommunication services	5,220	14,516	19,736
Wholesale and retail, hotels and catering services	2,931	10,054	12,985
Other services	6,952	16,773	23,726

Note: 'Other services' combines real estate, leasing, business, banking, insurance and other services.

Source: Tables 16.1 and 16.2 and authors' calculations.

gce per yuan in the 'manufacturing of communication, computers and other electronic equipment'. In aggregate, the construction sector has the lowest energy requirements per yuan of output at 9.87 gce, compared with 20.22 gce in agriculture, 58.25 gce in manufacturing and 79.36 gce in mining.⁷

Calculating the carbon intensities is a little more involved because not all forms of energy are associated with the same carbon emissions. To resolve this, we first need to know how much of each type of energy is used by each production sector. These data are available from the *China Energy Statistical Yearbook* (National Bureau of Statistics 2006) and provide the energy requirements (that is, direct energy inputs) for production in 48 sectors. Eighteen different fuels are specified, which we then aggregate into six categories: coal, coking products, petroleum products, natural gas, heat and electricity.⁸

Since the data are measured in consistent units, it is possible to calculate the share of energy from each category used in production in each of the 48 sectors.⁹ For example, agriculture consumed 79.8 million tce in 2005. Of that, 30.1 per cent was coal, 1.5 per cent was coking products, 50.4 per cent was petroleum products, 0 per cent was natural gas, 0.05 per cent was heat and 17.9 per cent was electricity. Based on data from the Energy Information Administration (EIA 2008) of the US Department of Energy, Table 16.5 provides the carbon emission coefficients for China in 2005, measured in tonnes of carbon equivalent (tcae).¹⁰ It is then straightforward to calculate the carbon intensity for each sector by multiplying each emission coefficient by the proportion of each fuel used in production and summing over all fuels, giving the emissions intensities in grams of carbon per yuan reported in Table 16.4. Given that different sectors use different types of energy in different proportions, there is not a perfect correlation between energy intensity and emissions intensity. Although the correlation at this sectoral level is extremely high, at 0.999, a closer look at the household data below reveals important differences in across-income deciles.

Urban household energy requirements and carbon emissions

The data used in this section are drawn from the Urban Household Income and Expenditure Survey (National Bureau of Statistics 2005). Although the survey covered all 31 provinces in China, we have access only to the data for 16 provinces. In the survey, household expenditure is divided into seven categories: current-period consumption; expenditure on housing building or purchasing; transfer expenditure (including tax, donations, buying lottery tickets, paying for expenditure of non-coresiding family members [parents or children], expenditure on non-saving insurance, and other transfer expenditure); interest-only mortgage repayments; social welfare savings; saving and

Table 16.4 Energy and carbon intensities by sector in 2005

	Energy intensity (grams/yuan)	Carbon intensity (grams/yuan)
Agriculture	20.22	11.51
Industry	59.47	37.68
Mining and quarrying	79.36	48.13
Mining and washing of coal	98.95	66.32
Extraction of petroleum and natural gas	57.09	28.57
Mining and processing of ferrous metal ores	95.75	57.54
Mining and processing of non-ferrous metal ores	58.27	34.63
Mining and processing of non-metal ores	114.13	72.04
Mining of other ores	1,178.23	665.47
Manufacturing	58.25	37.09
Processing of food from agricultural products	19.21	12.36
Manufacture of foods	30.97	20.24
Manufacture of beverages	28.50	18.90
Manufacture of tobacco	8.38	5.34
Manufacture of textiles	39.33	25.22
Manufacture of textile apparel, footwear and caps	11.00	6.74
Manufacture of leather, fur, feather and related products	8.97	5.34
Processing of timber, manufacture of wood products	37.83	24.43
Manufacture of furniture	9.04	5.29
Manufacture of paper and paper products	78.80	51.97
Printing, reproduction of recording media	19.04	11.00
Manufacture of articles for culture, education and sport activity	13.23	7.47
Processing of petroleum, coking, processing of nuclear fuel	87.26	47.17
Manufacture of raw chemical materials and chemical products	134.52	80.93
Manufacture of medicines	26.43	17.17

Manufacture of chemical fibres	51.50	32.12
Manufacture of rubber	49.20	30.40
Manufacture of plastics	28.59	16.71
Manufacture of non-metallic mineral products	206.47	136.47
Smelting and pressing of ferrous metals	171.72	117.28
Smelting and pressing of non-ferrous metals	90.49	55.30
Manufacture of metal products	33.91	19.90
Manufacture of general-purpose machinery	19.49	12.13
Manufacture of special-purpose machinery	20.43	12.80
Manufacture of transport equipment	12.41	7.53
Manufacture of electrical machinery and equipment	8.58	4.92
Manufacture of communication and other electronic equipment	5.47	3.01
Manufacture of measuring instruments and office machinery	6.99	4.02
Manufacture of artwork and other manufacturing	61.17	37.31
Recycling and disposal of waste	11.67	6.99
Electric power, gas and water production and supply	57.88	35.85
Production and distribution of electric power and heat power	54.94	34.46
Production and distribution of gas	90.05	49.53
Production and distribution of water	119.52	76.78
Construction	9.87	5.25

Source: Authors' own calculations and National Bureau of Statistics (NBS), 2006. *China Energy Statistical Yearbook*, China Statistics Press, Beijing; National Bureau of Statistics (NBS), 2007. *China Statistical Yearbook*, China Statistics Press, Beijing.

Table 16.5 **Carbon coefficients by fuel**

Coal	0.7018
Oil	0.4876
Gas	0.3999
Electricity	0.5631

Source: Authors' calculations and Energy Information Administration (EIA), 2008. *International Energy Annual*. Available from www.eia.doe.gov/iea (accessed 15 January 2008).

mortgage repayments (principles only); and end-of-period cash in hand. The part of household expenditure that we are able to convert into direct and indirect energy consumption and carbon emissions is the first category: current-period consumption, which, on average, accounts for 75 per cent of total household expenditure (see column 5 in Appendix Table A16.1). To the extent that any of the other categories require energy inputs and therefore generate emissions, the calculations below will underestimate households' indirect contributions to China's energy demand. The survey provides details of household current-period consumption on a range of highly disaggregated goods. We aggregate these according to the sectors in Table 16.4, and are therefore able to calculate the urban household energy requirements and carbon emissions that occur indirectly via each household's consumption bundle.¹¹ This is the notion of indirect energy introduced above, but now applied to household-level expenditure data. In addition to these indirect energy requirements, each household also consumes energy directly, in the form of coal, gas, petroleum and electricity. The survey data provide the quantities of each of these consumed by each household, which are readily converted into tonnes of coal equivalent (tce), from which the carbon emissions can be obtained. We also have expenditure data for each of these forms of direct energy consumption, from which energy and emission intensities can be obtained.

Three important assumptions are made in calculating household energy consumption and carbon emissions. First, a sizeable amount of household food consumption comes from eating out. We assume that one-third of the cost of eating out is due to food consumption, while the remainder is service cost.¹² We further assume that half of the cost of food eaten out stems from food processed from agricultural products, while the other half stems from manufactured food. Second, we assume that 25 per cent of total expenditure on public transportation fees, such as expenditure on taxi, bus, air and train tickets, is related to petrol consumption, while the rest is attributed to services.

Third, all service fees are assumed to be energy free, due to data limitations. Excluding service costs, the proportion of current-period consumption that is counted for as direct and indirect energy consumption is about 73 per cent of current-period consumption and 55 per cent of per capita total household expenditure (see Table A16.1). As with the above excluded categories in total household expenditure, omitting services from the analysis will mean that we underestimate households' indirect contributions to China's energy demand.

Table 16.6 presents summary statistics by income deciles for urban households' total energy consumption, carbon emissions, direct and indirect emissions, per capita energy consumption and carbon emissions, and direct emissions by different energy sources. The table shows that the urban Chinese households surveyed consume an average of 1.71 tce per annum, which in turn generates an average of 0.9 tonnes of carbon emissions (tcae). Average per capita energy consumption across all households is 0.61 tce per annum, which generates 0.32 tcae. Energy consumption and carbon emissions are much higher for richer households than for poorer ones. Households in the top-10 percentile income group (the tenth decile) consume an average of 2.48 tce, some 86 per cent more than the amount consumed by households in the poorest group (the first decile), at 1.34 tce. Similarly, the richest decile emits, on average, 66 per cent more carbon than the poorest.

By separating total energy consumption into direct and indirect sources, it is revealed that only 32 per cent of household energy consumption is from direct sources.¹³ Nevertheless, with regard to carbon emissions, indirect sources account for a larger proportion, especially for the richest decile, in which close to 40 per cent of carbon emissions are from indirect sources.¹⁴ This compares with just 20 per cent for the poorest decile (see Table A16.3). Why does indirect energy demand account for a higher proportion of total emissions generated by richer households than by poorer ones? When comparing carbon emissions across income groups, it is clear that rich households emit more per capita than poor households; however, if comparing direct emissions, the poor generate only slightly less carbon than the rich. Further investigation shows that the high direct emissions for poor households are due mainly to their relatively high levels of coal consumption—the most emission-intensive form of energy. The poorest income decile's carbon emissions from coal consumption are about seven times as high as the richest decile's. This, in turn, is due to the fact that the price of coal is one-third of the price of gas, one-ninth of the price of electricity and one-tenth of the price of petrol, as shown in Table 16.7.

A closer look at the data reveals some interesting points regarding variations in the level of carbon emissions per unit of energy consumed across households.

Table 16.6 Average energy consumption and carbon emissions by income decile

	Household emissions (tcae)		Household energy (tce)	Per capita emissions (tcae)	Per capita energy (tce)	Direct energy (tce)	Indirect energy (tce)
	emissions (tcae)	emissions (tcae)	emissions (tcae)	emissions (tcae)	emissions (tcae)	emissions (tcae)	emissions (tcae)
First decile	0.77	1.34	0.24	0.42	1.09	0.24	0.24
Second decile	0.81	1.46	0.26	0.47	1.15	0.31	0.31
Third decile	0.84	1.54	0.28	0.51	1.18	0.35	0.35
Fourth decile	0.80	1.51	0.28	0.52	1.13	0.38	0.38
Fifth decile	0.85	1.61	0.30	0.57	1.19	0.41	0.41
Sixth decile	0.86	1.63	0.31	0.59	1.19	0.44	0.44
Seventh decile	0.90	1.74	0.33	0.64	1.26	0.48	0.48
Eighth decile	0.93	1.80	0.35	0.68	1.28	0.53	0.53
Ninth decile	1.00	1.95	0.39	0.76	1.36	0.59	0.59
Tenth decile	1.28	2.48	0.50	0.97	1.68	0.80	0.80
Average	0.90	1.71	0.32	0.61	1.25	0.45	0.45
	Direct emissions (tcae)	Indirect emissions (tcae)	Emissions (coal) (tcae)	Emissions (oil) (tcae)	Emissions (electricity) (tcae)	Emissions (gas) (tcae)	
First decile	0.61	0.16	0.35	0.02	0.07	0.17	
Second decile	0.61	0.20	0.28	0.03	0.08	0.22	
Third decile	0.61	0.23	0.24	0.04	0.09	0.24	
Fourth decile	0.56	0.24	0.17	0.04	0.10	0.25	
Fifth decile	0.59	0.26	0.17	0.05	0.10	0.27	
Sixth decile	0.57	0.28	0.13	0.06	0.11	0.28	
Seventh decile	0.59	0.30	0.11	0.06	0.12	0.31	
Eighth decile	0.60	0.34	0.09	0.06	0.12	0.32	
Ninth decile	0.63	0.37	0.07	0.09	0.13	0.34	
Tenth decile	0.77	0.50	0.05	0.18	0.16	0.38	
Average	0.61	0.29	0.17	0.06	0.11	0.28	

Source: Authors' calculations and National Bureau of Statistics (NBS), 2005. *Urban Household Income and Expenditure Survey*, China Statistics Press, Beijing.

Table 16.7   **Price per tonne of coal equivalent**

	Yuan/tonne	Proportion of coal price
Coal	374	1
Gas	1,070	2.9
Electricity	3,246	8.7
Petrol	4,033	10.8

Source: Derived from National Bureau of Statistics (NBS), 2005. *Urban Household Income and Expenditure Survey*, China Statistics Press, Beijing.

This emissions/energy ratio provides a measure of the extent of the carbon intensity of energy, or energy efficiency, with lower levels implying that energy use is relatively energy efficient. To sum up the discussion of Table 16.6 and further examine this energy efficiency, we present a group of graphs that provide visual relationships between energy and emissions on the one hand, and income on the other. Figure 16.1 presents per capita total energy consumption, carbon emissions and the ratio of carbon emissions over energy consumption, by income percentile. The figure shows that while rich households consume more energy and produce more carbon emissions per capita, their emissions/energy ratio is lower than poor households'. That is, richer households are relatively energy efficient.

We then plot separately direct and indirect energy, emissions and their ratio in Figures 16.2 and 16.3a. The two figures indicate that the major source of lower energy efficiency for the poor is direct energy consumption, which generates substantially more emissions for the poor than for the rich. For indirect energy consumption and emissions, there is almost no difference across income groups.

The data presented in Table 16.6 indicate that the main reason for high levels of direct energy consumption and carbon emissions for people in poor households is their high level of coal consumption. We therefore exclude coal from direct energy consumption and consequent emissions and plot the remaining direct energy and emissions by income group again (Figure 16.3b). The new figure shows almost the same level of energy efficiency for poor and rich households. In fact, there is a slightly higher emissions/energy ratio for the top income decile compared with the other income groups.

The next question of interest is whether there is any variation in rich and poor households' per yuan carbon emissions. Figure 16.4 plots average emissions

Figure 16.1 **Total energy, carbon emissions and energy efficiency, by income**

Figure 16.2 **Indirect energy, carbon emission and energy efficiency, by income**

Figure 16.3a   **Direct energy, carbon emission and energy efficiency, by income**

Figure 16.3b   **Direct energy, carbon emission and energy efficiency excluding coal, by income**

divided by total expenditure per household. The top solid line in Figure 16.4 is total emissions per yuan. The figure indicates that every yuan spent by the poorest household generates 120 grams of carbon equivalent (gcae), while one yuan spent by the richest household generates only 20 gcae. Almost the entire difference in these emissions intensities is due to direct energy consumption, as can be seen by the fact that the curve for direct emissions per yuan follows the total emissions curve closely while the curve for indirect emissions per yuan is almost flat. This, in turn, is due to the high level of coal consumption by the poor (as seen by the curve for direct emissions excluding coal, which is also very flat). In other words, the most important discrepancy between rich and poor households lies in the different shares of expenditure allocated to direct coal consumption and the emissions generated as a result.

This is not to say that the sources of indirect emissions do not vary across income brackets. For example, food (processed from agriculture, manufactured and eating out combined) accounts for 75 per cent of the poorest decile's emissions, compared with just 48 per cent for the richest decile, while 10 per cent of the richest decile's indirect emissions stem from the manufacturing of raw chemicals and chemical materials, compared with 5 per cent for the poorest decile. These differences do not, however, amount to significant differences in emissions per yuan spent for each of these income groups. Instead, it is all

Figure 16.4 **Yuan carbon emissions by income percentile (kg)**

about direct emission shares, and those generated from coal consumption in particular: 58 per cent of the poorest households' direct emissions stem from coal consumption compared with just 6.5 per cent for the richest households.¹⁵ While rich households therefore consume more energy and produce more carbon emissions than poor households, poor households produce more emissions per unit of energy consumption and more emissions per yuan spent than rich households.

An econometric analysis

The above analysis is based entirely on simple averages by income group. Energy consumption and emissions can also be affected by other factors, such as household composition and dwelling size. Further, households' residential location can also have a significant effect due to weather conditions and regional energy price variations. In this section, we estimate simple energy and emissions determination equations, which allows us to tease out other factors and to identify the pure income effect of urban household energy requirements and emissions.

In our econometric model, in addition to per capita income and its squared term, we control for household size, the gender, age and years of schooling of the household head, a group of household composition variables relating to gender and age, dwelling size, and dummy variables for each of the 15 provinces other than Beijing, which is the benchmark province and therefore the omitted dummy variable.

Tables 16.8 and 16.9 present the results for the determinants of per capita energy consumption and per capita emissions respectively. We observe almost the same pattern of determinants in both and therefore focus the remaining discussion on the energy consumption results in Table 16.8. On average, larger households consume less energy per capita, verifying an economy-of-scale effect. Cooking for five people should consume less energy than cooking for one person five times. Similarly, five people watching TV requires the same amount of energy as one person watching TV. Our results also show that males and older household heads are associated with higher energy consumption, while households with more educated heads consume less energy. This last effect is, however, applicable only to total energy and direct energy consumption.¹⁶ This lends some support to the optimistic claim that people with higher levels of education are more aware of the impact of their energy consumption on total emissions and account for this in their consumption decisions. The household composition variables indicate that relative to the omitted category (male and female adults aged 20–65), children in most age groups consume less energy, while older people (male and female above 65) consume more energy. This could

Table 16.8 Determinants of household per capita energy consumption

	Per capita total energy	Per capita direct energy	Per capita direct energy excluding coal	Per capita indirect energy
Per capita income/104	0.203 (0.006)***	0.114 (0.006)***	0.175 (0.005)***	0.089 (0.001)***
(Per capita income/104)2	-0.006 (0.001)***	-0.003 (0.001)***	-0.009 (0.001)***	-0.003 (0.000)***
Number of household members	-0.084 (0.003)***	-0.068 (0.003)***	-0.046 (0.003)***	-0.016 (0.001)***
Number of male household heads	0.009 (0.005)*	0.007 (0.005)	0.016 (0.004)**	0.002 (0.001)*
Household head age/103	4.724 (0.294)***	4.491 (0.280)***	3.731 (0.227)***	0.233 (0.057)***
Household head years of schooling	-0.002 (0.001)*	-0.002 (0.001)**	0.005 (0.001)***	0.000 (0.000)
Percentage of household members aged 0–5	-0.043 (0.032)	-0.038 (0.030)	-0.042 (0.024)*	-0.005 (0.006)
Percentage of household members aged 6–10	-0.083 (0.025)***	-0.079 (0.024)***	-0.075 (0.019)***	-0.005 (-0.005)
Percentage of household members aged 11–15	-0.099 (0.022)***	-0.108 (0.021)***	-0.077 (0.017)***	0.009 (0.004)**
Percentage of household members aged 16–19, female	-0.148 (0.027)***	-0.134 (0.026)***	-0.069 (0.021)***	-0.014 (0.005)***
Percentage of household members aged 16–19, male	-0.109 (0.026)***	-0.115 (0.025)***	-0.049 (0.020)**	0.006 (0.005)
Percentage of household members aged above 65, female	0.090 (0.021)***	0.090 (0.020)***	0.067 (0.016)***	0.000 (0.004)
Percentage of household members aged above 65, male	0.133 (0.022)***	0.132 (0.021)***	0.052 (0.017)***	0.002 (0.004)
Housing size (square metres/103)	0.443 (0.073)***	0.355 (0.069)***	-0.108 (0.056)*	0.088 (0.014)***
Shanxi	0.356 (0.017)***	0.412 (0.016)***	0.319 (0.013)***	-0.056 (0.003)***
Liaoning	0.06 (0.015)***	0.074 (0.014)***	0.151 (0.011)***	-0.014 (0.003)***
Heilongjiang	0.126 (0.015)***	0.17 (0.015)***	0.035 (0.012)***	-0.044 (0.003)***
Shanghai	0.324 (0.016)***	0.308 (0.015)***	0.359 (0.012)***	0.016 (0.003)***
Jiangsu	-0.082 (0.015)***	-0.063 (0.014)***	-0.019 (0.012)	-0.019 (0.003)***
Anhui	0.040 (0.015)***	0.068 (0.014)***	-0.006 (0.011)	-0.029 (0.003)***
Jiangxi	-0.023 (0.017)	0.009 (0.016)	0.050 (0.013)***	-0.031 (0.003)***
Shandong	-0.003 (0.014)	0.036 (0.013)***	-0.006 (0.011)	-0.040 (0.003)***
Henan	0.062 (0.015)***	0.110 (0.015)***	0.049 (0.012)***	-0.049 (0.003)***
Hubei	-0.010 (0.015)	0.020 (0.014)	0.036 (0.011)***	-0.030 (0.003)***
Guangdong	-0.026 (0.014)*	-0.046 (0.014)***	0.014 (-0.011)	0.020 (0.003)***

Chongqing	0.190 (0.017)***	0.201 (0.016)***	0.279 (0.013)***	-0.011 (0.003)***
Sichuan	0.165 (0.014)***	0.184 (0.014)***	0.249 (0.011)***	-0.019 (0.003)***
Yunnan	0.000 (0.017)	0.035 (0.016)**	0.094 (0.013)***	-0.035 (0.003)***
Gansu	-0.067 (0.020)***	-0.031 (0.019)	-0.001 (0.015)	-0.036 (0.004)***
Constant	0.355 (0.027)***	0.236 (0.025)***	0.003 (0.021)	0.119 (0.005)***
Observations	33,358	33,358	33,358	33,358
R-squared	0.24	0.18	0.26	0.46

* significant at 10 per cent
** significant at 5 per cent
*** significant at 1 per cent
Note: Standard errors in parentheses.

Table 16.9 Determinants of household per capita carbon emissions

	Per capita total emissions	Per capita direct emissions	Per capita direct emissions excluding coal	Per capita indirect emissions
Per capita income/104	0.092 (0.003)***	0.036 (0.003)***	0.079 (0.002)***	0.055 (0.001)***
(Per capita income/104) ²	-0.001 (0.001)***	0.000 (0.000)	-0.004 (0.000)***	-0.002 (0.000)***
Number of household members	-0.046 (0.002)***	-0.036 (0.002)***	-0.020 (0.001)***	-0.010 (0.000)***
Number of male household heads	0.001 (0.003)	0.000 (0.003)	0.007 (0.002)***	0.001 (0.001)**
Household head age/103	2.214 (0.166)***	2.041 (0.157)***	1.508 (0.094)***	0.173 (0.035)***
Household head years of schooling	-0.003 (0.000)***	-0.003 (0.000)***	0.002 (0.000)***	0.000 (0.000)
Percentage of household members aged 0–5	-0.018 (0.018)	-0.015 (0.017)	-0.017 (0.010)*	-0.003 (0.004)
Percentage of household members aged 6–10	-0.037 (0.014)***	-0.034 (0.013)**	-0.031 (0.008)***	-0.003 (0.003)
Percentage of household members aged 11–15	-0.048 (0.012)***	-0.053 (0.012)***	-0.032 (0.007)***	0.005 (0.003)*
Percentage of household members aged 16–19, female	-0.084 (0.015)***	-0.075 (0.015)***	-0.029 (0.009)***	-0.009 (0.003)***
Percentage of household members aged 16–19, male	-0.063 (0.015)***	-0.066 (0.014)***	-0.019 (0.008)**	0.003 (0.003)
Percentage of household members aged above 65, female	0.044 (0.012)***	0.044 (0.011)***	0.028 (0.007)***	0.000 (0.002)
Percentage of household members aged above 65, male	0.079 (0.012)***	0.077 (0.012)***	0.021 (0.007)***	0.002 (0.003)
Housing size (square metres/103)	0.367 (0.041)***	0.313 (0.039)***	-0.012 (-0.023)	0.054 (0.009)***
Shanxi	0.156 (0.009)***	0.191 (0.009)***	0.126 (0.005)***	-0.036 (0.002)***
Liaoning	0.002 (0.008)	0.011 (0.008)	0.065 (0.005)***	-0.008 (0.002)***
Jilin	0.084 (0.009)***	0.112 (0.008)***	0.017 (0.005)***	-0.028 (0.002)***
Shanghai	0.118 (0.009)***	0.107 (0.008)***	0.143 (0.005)***	0.011 (0.002)***
Jiangsu	-0.052 (0.008)***	-0.040 (0.008)***	-0.009 (0.005)*	-0.012 (0.002)***
Anhui	0.031 (0.008)***	0.049 (0.008)***	-0.003 (0.005)	-0.018 (0.002)***
Jiangxi	-0.031 (0.009)***	-0.011 (0.009)	0.018 (0.005)***	-0.020 (0.002)***
Shandong	0.002 (0.008)	0.027 (0.007)***	-0.003 (-0.004)	-0.025 (0.002)***
Henan	0.031 (0.009)***	0.062 (0.008)***	0.019 (0.005)***	-0.031 (0.002)***
Hubei	-0.014 (0.008)*	0.004 (-0.008)	0.016 (0.005)***	-0.019 (0.002)***
Guangdong	-0.017 (0.008)**	-0.031 (0.008)***	0.011 (0.005)**	0.013 (0.002)***

Chongqing	0.052 (0.010)***	0.059 (0.009)***	0.114 (0.005)***	-0.007 (0.002)***
Sichuan	0.042 (0.008)***	0.054 (0.008)***	0.100 (0.005)***	-0.012 (0.002)***
Yunnan	-0.025 (0.009)***	-0.003 (-0.009)	0.038 (0.005)***	-0.022 (0.002)***
Gansu	-0.044 (0.011)***	-0.021 (0.011)**	0.000 (0.006)	-0.023 (0.002)***
Constant	0.248 (0.015)***	0.171 (0.014)***	0.008 (-0.009)	0.077 (0.003)***
Observations	33,358	33,358	33,358	33,358
R-squared	0.19	0.13	0.27	0.47

* significant at 10 per cent

** significant at 5 per cent

*** significant at 1 per cent

Note: Standard errors in parentheses.

be related to the fact that old people spend more time at home. Further, the larger the size of the house, the more energy consumed. On average, every 100 square metres requires 44.3 kg of coal equivalent energy. This is due mainly to direct energy consumption and, in particular, coal consumption; however, larger housing is associated with higher indirect energy consumption as well.

The final part of Table 16.8 presents results for the provincial dummy variables. Relative to Beijing, the following provinces (cities) consume more energy (in descending order): Shanxi, Shanghai, Chongqing, Sichuan, Heilongjiang, Henan, Liaoning and Anhui. This order is almost the same for direct energy consumption. For non-coal direct energy consumption, there is a slight difference in consumption orders. For example, Shanghai ranks first, while Shanxi ranks second. In terms of indirect energy consumption, only Guangdong and Shanghai exceed Beijing, while the remaining provinces all consume less direct energy than Beijing. These energy consumption differences across provinces could be related to the differences in energy price levels and resource reserves across regions. For example, it is understandable that households in Shanxi would consume more energy, especially coal, given its abundance in Shanxi. Richer regions appear to be the largest consumers of indirect energy, as evidenced by the positive coefficients on Shanghai and Guangdong in the final column. This compounds the earlier claim that as Chinese households and regions become richer, indirect energy patterns become increasingly important.

To capture potential diminishing marginal energy requirements and carbon emissions as income increases, we include a squared term for the latter in the regressions. The results indicate that the relationship between energy consumption/carbon emissions and income for urban Chinese households is essentially linear across the income range of our sample. For example, with regard to total per capita energy consumption, every additional yuan of income increases energy consumption by 20 gde, but the rate of increase falls by just 0.00006 gce. For indirect energy consumption, the diminishing point is not reached until 158,000 yuan per capita, which is more than five times the current average per capita income level. For total energy consumption, the points of diminishing marginal energy requirements and carbon emissions are reached at income levels of 174,000 and 363,000 yuan respectively. To visualise the estimated relationship between energy consumption/carbon emissions and income, Figures 16.5 and 16.6 plot the predicted relationship for 99 per cent of the range of income levels in our sample (100–42,100 yuan). The figures show that within our sample income range, the relationship between income and all types of energy/emissions is almost linear. One of the interesting results is that income has a stronger effect on non-coal direct energy consumption

and carbon emissions than on total direct energy consumption and carbon emissions, confirming yet again that coal is mainly a poor peoples' energy.

Conclusions

This chapter focused on three interrelated issues. First, we drew on national-level data to establish the notion that the total energy requirements of households are substantially higher when their indirect energy requirements are added to their direct energy consumption. Indeed, the calculations showed that this allocated an additional 16.8 per cent of China's total energy demand to households, 11.2 per cent of which was attributed to urban households. If the eleventh Five-Year Plan succeeds in its objective of shifting the Chinese economy towards consumption-led growth, indirect energy shares are likely to rise in the future, thereby becoming increasingly important for understanding future energy demand and consumer-driven emissions trends.

Second, using urban household survey data, we examined the extent of variation in total energy requirements and emissions across households with different income levels. While there were clear differences in the shares of indirect emissions attributable to the different consumption bundles of rich and poor households, these were overshadowed by overwhelming evidence that the share of emissions attributed to direct energy consumption matters most: poorer households are more emissions intensive because of their heavy dependence on coal. The most critical implication is, therefore, that poor households are given the opportunity to reduce this coal dependence. This could occur as a consequence of income growth, given our observation that richer households consume less coal; therefore, policies targeting poor household income growth remain crucial. It is equally important, however, to ensure that adequate investment is directed towards cleaner energy alternatives in the near future so that the switch away from coal is a feasible option.

The survey-based analysis produced a share of indirect energy for urban households of 32 per cent, just half the share that we found using national-level aggregate data. This discrepancy stemmed from a number of issues, including the need to use per capita consumption rather than expenditure and the exclusion of services from the survey-based analysis. Moreover, throughout the chapter, we overlooked the processes that deliver final goods to household doorsteps, including the storage and distribution of goods—all of which require considerable energy inputs. These inadequacies only strengthen the claim that the indirect energy requirements of Chinese households matter more to the future of China's contributions to global environmental pressures than

Figure 16.5 **Predicted relationship between household energy consumption per capita and income**

Figure 16.6 **Predicted relationship between household carbon emissions per capita and income**

many people realise, and that more detailed research in this area is therefore warranted.

Third, the econometric analysis focused on the determinants of variation in per capita energy requirements and emissions. The virtually linear relationship between per capita income and energy demand is indicative of the dilemma China is facing as per capita incomes continue to grow, since there is no indication of diminishing marginal energy requirements happening over the wide range of current income levels. This finding stresses the need for policymakers to promote ways to reduce the emissions intensities of all of the goods consumed by Chinese households and, for that matter, used by the other end users as well. The higher energy requirements of richer provinces even after controlling for per capita income further compound this need, as poorer provinces continue to grow and strive towards living standards comparable with their richer neighbours. While there is some evidence that households with higher levels of education consume less energy per capita, this result does not hold up in the regression using indirect energy only. Whether or not education has a role to play in promoting cleaner consumption patterns in the future therefore remains an open question, although it is hard to think that such efforts would prove detrimental. This point extends to thoughts about whether 'green' consumption policies stand any chance of reducing China's emissions path below current trajectories.

To end on a bright note, assuming that services are relatively energy efficient (which is certainly the case compared with direct coal consumption) and noting the above evidence that richer Chinese households spend a higher share of their income on services, the future for China could well look cleaner if incomes can be raised across the board to the point at which services dominate consumption patterns. That future cannot arrive quickly enough.

Notes

- 1 Wei et al. (2007) and Liang et al. (2007) are the only English-language papers we have found, after an extensive literature search, that focus explicitly on Chinese household energy consumption.
- 2 By focusing on carbon intensities only, we overlook other greenhouse gases, such as methane, nitrous oxide and chlorofluorocarbons. While these other greenhouse gases could be equally, or even more, important for certain environmental problems, data restrictions prevent a more holistic analysis at this stage.
- 3 For example, Kok et al.'s IO plus household expenditure approach is referred to by Bin and Dowlatabadi (2005) as 'environmental IO life-cycle analysis', while Weber and Perrels (2000) refer to the same method as the 'mixed monetary energetic approach'.
- 4 See Suh et al. (2004) for further discussion of this point.
- 5 See, for example, Liao et al. (2007) and Fisher-Vanden et al. (2006).

- 6 Unfortunately, this precludes 'transport, postal and telecommunication services', 'wholesale and retail trades, hotels and catering services' and 'other services', as the gross value of output for these sectors is not available. Expenditure on transport will be accounted for in the direct energy calculations, discussed further below. Services are, however, omitted from the analysis as there is no alternative given data availability at this stage.
- 7 As mentioned earlier, the sectors are not comparable directly with those used by Wei et al (2007). Note, however, that they calculate energy and carbon intensities in their 'food' sector of 28 grams and 23 grams per yuan respectively. This sector incorporates the food processing, manufacturing and beverages sectors used above and, taking simple averages across these sectors, reassuringly puts our calculations in the same ballpark as theirs.
- 8 Coal includes raw coal, clean coal and other washed coal. Coking products include coke, coke oven gas, other gas and other coke products. Petroleum products include crude oil, gasoline, kerosene, diesel oil, fuel oil, petroleum liquid gas, refinery gas and other petroleum products. Natural gas, heat and electricity stand alone.
- 9 To complicate matters slightly, the relevant table in the *China Energy Statistical Yearbook* (NBS 2006) reports total final energy consumption in each sector in two consistent forms: coal equivalent calculation and calorific value calculation. It provides, however, only the breakdown of energy sources in terms of calorific value calculations, so we use these to calculate the shares of each source. In terms of shares, the results are equivalent whichever measure is used.
- 10 The electricity coefficient is a weighted sum of the coal, oil and gas coefficients, based on the shares of coal, oil and gas used in China's electricity generation being 78 per cent, 2.4 per cent and 1 per cent respectively (IEA 2007). The remainder of China's electricity is fuelled by hydro-power (16 per cent), nuclear (2.1 per cent) and wind, biomass and other renewables (0.5 per cent). These are all assumed to have zero carbon coefficients. Coking products and heat are assumed to have the same carbon coefficient as coal.
- 11 See Table A16.2 in the Appendix for details. Due to the data limitations discussed in previous footnotes, not all sectors in Table 16.4 are included in the analysis in this section.
- 12 Although the nutrition literature normally assumes a 50 per cent premium to reflect processing margins, studies also find that this assumption is not sensitive to the estimated income elasticity of nutrition intake (see, for example, Subramanian and Deaton 1996 and Gibson and Rozelle 2002).
- 13 This is quite a departure from the aggregate figures in the preceding section, which show that direct energy demand accounts for only 36 per cent of urban households' total energy demand. Two obvious reasons why we understate indirect energy demand are that we do not incorporate all sectors or all expenditure in our analysis. The figure also differs significantly from Wei et al. (2007), who find that direct energy accounts for just 29 per cent of urban household energy requirements. Their figure is at the lowest end of the literature surveyed in the previous section, while ours here is towards the high end. One reason for the discrepancy could be the different consumption categories that we assess, particularly as we divide consumption into more than 20 categories compared with Wei et al.'s eight. Another clear difference is that in Wei et al. (2007), the 'residence' category dominates urban indirect energy demand, accounting for more than 60 per cent of it. Included in this category are the production and supply of electric power, steam, hot water and gas, all of which are assumed to be direct energy demand in our analysis.

- 14 In addition, given that richer households spend a higher proportion of their income on services than poorer households, and these are largely excluded from our story here, the share of energy and emissions that can be attributed to indirect sources is likely to be understated more for rich than for poor. Our sample households spend, on average, 2,243 yuan per capita on services, which accounts for 27 per cent of per capita current-period consumption. For the poorest group, service expenditure is 727 yuan per capita, accounting for 23 per cent of the total current-period consumption, while for the richest group this figure is 5,592 yuan, accounting for 30 per cent of the current-period consumption (see columns 3 and 6 in Appendix Table A16.1).
- 15 See Appendix Table A16.3 for details.
- 16 When, however, only non-coal direct energies are included, the effect of the household head's education switches sign and becomes positive and statistically significant. These contradictory results are puzzling, but are perhaps related to high correlations between per capita income and education levels in combination with the high coal content of poorer households' direct energy consumption.

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Table A16.1 Breakdown of per capita expenditure

	Total per capita expenditure	Current period per capita consumption	Per capita service cost	Per capita consumption excluding services	Per capita current period consumption as % of per capita expenditure	Per capita service cost as % of per capita current period consumption	Per capita current period consumption excluding services as % of per capita total expenditure
	(1)	(2)	(3)	(4)	(5) = (2)/(1)	(6) = (3)/(2)	(7) = (4)/(1)
Decile 1	3,655	3,095	727	2,369	0.85	0.23	0.65
Decile 2	5,200	4,323	1,039	3,284	0.83	0.24	0.63
Decile 3	6,438	5,211	1,285	3,926	0.81	0.25	0.61
Decile 4	7,402	5,934	1,513	4,421	0.80	0.25	0.60
Decile 5	8,694	6,872	1,790	5,082	0.79	0.26	0.58
Decile 6	9,973	7,687	2,021	5,666	0.77	0.26	0.57
Decile 7	11,639	8,843	2,421	6,422	0.76	0.27	0.55
Decile 8	13,562	10,015	2,723	7,292	0.74	0.27	0.54
Decile 9	16,390	11,827	3,316	8,511	0.72	0.28	0.52
Decile 10	27,303	18,845	5,592	13,252	0.69	0.30	0.49
Average	11,026	8,265	2,243	6,022	0.75	0.27	0.55

Table A16.2 **Aggregation of survey sectors into Table 16.4 sectors**

Table 16.4 sector	Survey sectors included
Processing of food from agricultural products	Grain, starch, meat, poultry, eggs, seafood, vegetables, fruits
Manufacture of foods	Manufacture of grain, beans, meat, poultry, eggs, seafood, sugar, vegetables, fruits, milk, cake, canned food and semi-cooked food plus one-third of eating-out expenses
Manufacture of beverages	Alcohol and drinks
Manufacture of tobacco	Tobacco
Manufacture of textiles	Clothing materials
Manufacture of textile apparel, footwear and caps	Clothes, shoes, bedclothes, textile decoration
Processing of timber and wood products	Furniture materials
Manufacture of furniture	Furniture
Manufacture of paper and paper products	Paper and stationery
Printing, reproduction of recording media	Newspapers, magazines, books, textbooks, education software
Manufacture of articles for culture, education and sports	Sports equipment, electronic dictionaries, audio and video products, culture decorations
Manufacture of raw chemical materials and chemical products	Detergent and cosmetic goods for hairdressing and bathing
Manufacture of medicines	Medicine, nutriments
Manufacture of metal products	Lighting, cutlery, tea sets, small tools
Manufacture of transport equipment	Cars, bikes, motors and their components
Manufacture of electrical machinery and equipment	Electrical, medical and health equipment
Manufacture of measuring instruments and office machinery	Pianos, other musical instruments, body-building equipment, watches
Manufacture of artwork and other manufacturing	Jewellery and other miscellaneous items
Production and distribution of water	Water
Construction	Housing decoration and building materials
Services	Services: sewing, housekeeping, medical treatment, communication fees, recreation fees, education fees, rent, imputed rent, housing management fees; transportation fees * 0.75; eating-out expenditure * 0.67

Table A16.3 **Emission shares of consumption goods by income decile**

	Share of total emissions		Share of indirect emissions	
	First	Tenth	First	Tenth
Indirect emissions				
Processing of food from agricultural products	0.045	0.046	0.223	0.117
Manufacture of foods	0.104	0.123	0.513	0.312
One-third of eating out	0.003	0.019	0.015	0.048
Manufacture of beverages	0.004	0.011	0.021	0.027
Manufacture of tobacco	0.002	0.003	0.008	0.007
Manufacture of textiles	0.000	0.001	0.002	0.002
Manufacture of textile apparel, footwear, caps	0.007	0.026	0.036	0.065
Processing of wood products	0.000	0.000	0.000	0.001
Manufacture of furniture	0.000	0.004	0.001	0.009
Manufacture of paper and paper products	0.002	0.002	0.009	0.006
Printing and recording media	0.002	0.003	0.008	0.009
Manufacture of articles for culture, education and sports	0.000	0.003	0.002	0.009
Manufacture of raw chemical materials and products	0.011	0.041	0.052	0.103
Manufacture of medicines	0.001	0.014	0.005	0.036
Manufacture of metal products	0.001	0.003	0.003	0.008
Manufacture of transport equipment	0.001	0.023	0.002	0.059
Manufacture of electrical machinery and equipment	0.001	0.005	0.002	0.012
Manufacture of communication, computers and electronics	0.000	0.004	0.001	0.011
Manufacture of instruments, cultural and office machinery	0.000	0.001	0.000	0.002
Manufacture of artwork and other manufacturing	0.009	0.038	0.045	0.097
Production and distribution of water	0.010	0.015	0.050	0.039
Construction	0.001	0.009	0.003	0.024
Direct emissions			Share of direct emissions	
Coal	0.459	0.040	0.576	0.065
Petrol	0.029	0.144	0.036	0.237
Gas	0.222	0.295	0.279	0.487
Electricity	0.087	0.128	0.109	0.211
Share of direct emissions in total	0.797	0.606		