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Energy and Exports in China

Fritz Kahrl

David Roland-Holst

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CENTER FOR ENERGY, RESOURCES, AND ECONOMIC SUSTAINABILTY
338 GIANNINI HALL
UNIVERSITY OF CALOFORNIA
BERKELEY, CA 94707
PHONE: (1) 510-643-6362

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Energy and Exports in China

***Fredrich Kahrl and David Roland-Holst*[1]**

UC Berkeley

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Abstract

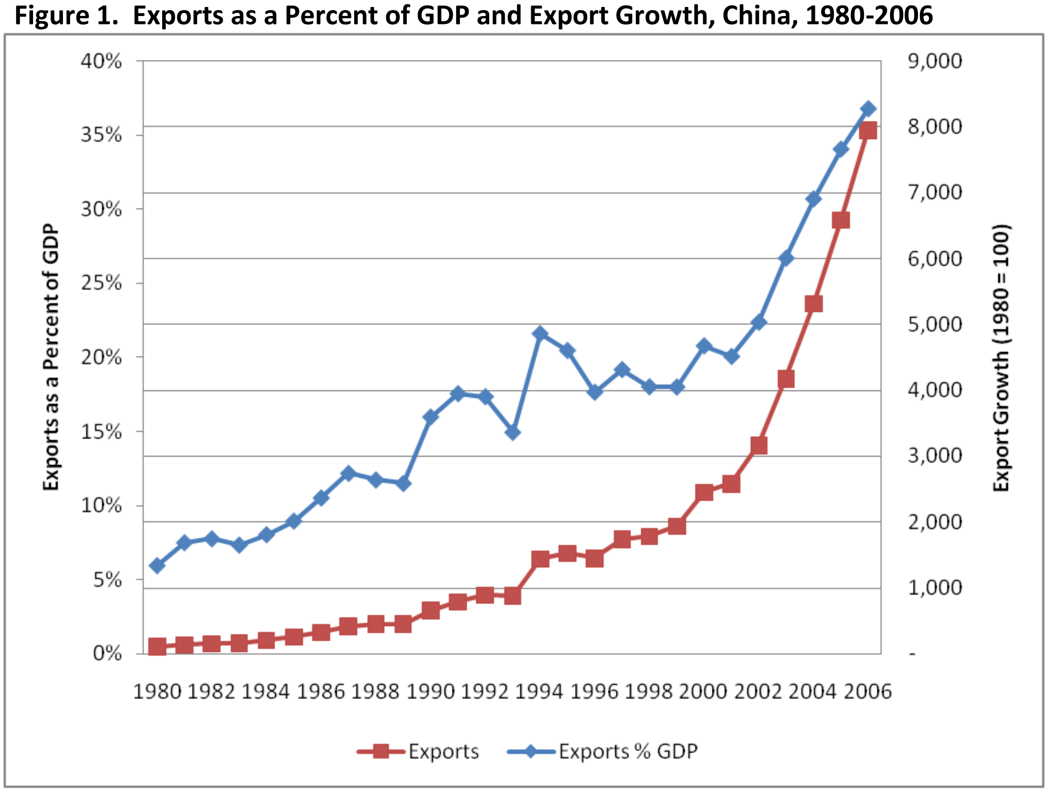
Rapid growth in China's exports following the country's accession to the World Trade Organization in December 2001 has led to changes in patterns of domestic energy use, with a significant increase in energy requirements along export supply chains. In this paper, we use detailed Chinese economic and energy data to examine energy flows along these supply chains, both at an aggregate and detailed sectoral level. More specifically, we analyze the implications of export-induced energy use for national strategies to reduce the Chinese economy's energy intensity and energy requirements, and as well as the potential repercussions of continued rapid growth in exports for international energy markets, and, by extension, on China's export competitiveness.

[1] Energy and Resources Group and Department of Agricultural and Resource Economics, respectively. Correspondence: dwrh@are.berkeley.edu.

1. Introduction

China's entry into the World Trade Organization (WTO) in December 2001 set forth a series of structural adjustments across its domestic economy. At the same time, China's rapidly expanding participation in global supply chains has occasioned adjustments in other countries, including domestic shifts in both demand and supply composition. Changing global trade patterns have included a dramatic rise in China's exports, both in absolute terms and as a share of its own GDP, since 2002 (Figure 1). In turn, growth in exports has altered the growth and structure of China's domestic energy use. Over the period 2002-2004, primary energy demand growth in China (15.3 EJ) far exceeded primary energy demand growth for the entire decade of 1990-2000 (5.5 EJ) (NBS, 2006), and the energy embodied in exports accounted for about 40 percent of this growth (Kahrl and Roland-Holst, 2007). With rapid export growth, the shares of local (households) and foreign (exports) use of China's domestically consumed energy have rapidly converged since 2002 (Kahrl and Roland-Holst, 2007).

Figure 1. Exports as a Percent of GDP and Export Growth, China, 1980-2006



Source: NBS, various years.

Recognizing the negative economic and environmental externalities of rapid growth in energy demand, as part of its 11th Five-Year Plan (2006-2010) China's central government set a binding goal of reducing economy-wide energy intensity by 20 percent. Given the importance of exports as a driver of domestic energy consumption in China, changes in energy demand along export supply chains will be a key factor in determining whether this goal will can be met. Over the medium and longer term, a combination of China's growth reliance on exports and the reliance of exports on energy may make the country especially vulnerable to energy prices. The latter can undermine China's export competitiveness, and with that its growth prospects, including a slowing of its transition from a low value added, manufacturing-oriented economy toward a high value added, service-oriented economy.

Internationally, China's emergence as a major exporter of embodied energy suggests the need to reconsider the conventional, supply-oriented framework for thinking about global energy use and how responsibility for its impacts is apportioned. As we discuss below, many of the negative externalities associated with rapid growth in energy demand in China — including commodity inflationary pass through, global energy price volatility, and rapid growth in greenhouse gas emissions — are driven in significant measure by foreign consumption patterns.

Based on a structural analysis of China's 2002 input-output and energy input tables, we examine three characteristics of emergent export-energy linkages in China:

1. scale and intensity in energy exports;
2. indirect and direct energy use in exports; and
3. exports and international energy markets.

The next section describes the methods used in this paper. Section two presents empirical findings in each of the above areas in greater detail. The final section offers concluding remarks.

2. Methods: Structural Patterns of Energy Use and Energy Prices

Energy is one of the most pervasive elements in modern industrial production systems. Energy services are embodied in all goods and services through both direct and indirect energy consumption. Indirect energy services extend along supply chains through the energy embodied in intermediate goods and via transport and distribution services. Elucidating these complex interactions requires detailed information about inter-industry linkages and careful accounting for energy's contribution at every stage of production from resource extraction to final consumption. In this section, we provide an overview of the inter-industry structural analysis used here to shed light on the complex pathways by which energy services flow through the Chinese economy.

Structural Patterns of Energy Use

To summarize the structural approach (see Kahrl and Roland-Holst, 2007, for a more detailed description), consider an economy with n production activities, represented by the linear input-output model

$$y_1 = A_{11}y_1 + A_{12}y_2 \qquad (1)$$

or

$$y_1 = (i - A_{11})^{-1} A_{12}y_2 = Mx \qquad (2)$$

where the activity coefficient matrix A is partitioned as

$$\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \quad (3)$$

for industry (1) and other (2) accounts, $M_{11} = (I\text{-}A_{11})^{-1}$ is the inter-industry Leontief inverse and x is a vector of exogenous income levels. Since the last expression implies $\Delta Y_1 = M\ \Delta x$, matrix M is also termed the multiplier matrix. Column i of M shows the global effects on all endogenous activity levels induced by an exogenous unit inflow accruing to sector i, after allowing for all interdependent feedbacks to run their course. Each coefficient in the multiplier matrix reflects the total demand induced in sector a_{ij} by a one unit change in final demand for sector j. Multipliers thus capture induced supply chain linkages throughout the economy.

We use sectoral primary energy intensities to capture induced energy demand in energy units, which assumes proportionality between transactions in the I/O table and sectoral energy inputs. In other words, if an increase in the demand for processed food increases the demand for agriculture by 0.4 units, the demand for energy in the economy increases by a proportional amount that is determined by the primary energy intensity (e.g., in joules/unit) of agriculture. The primary energy intensity (α) of each sector is that sector's total primary energy input (E_i) divided by its total output, or, in matrix notation

$$\alpha = E\hat{x}^{-1} \quad (4)$$

where $\hat{x}^{-1}$ is the diagonalized matrix of sector outputs. The total embodied energy in each sector is the transpose of α multiplied by the multiplier matrix, or

$$\varepsilon' = \alpha'(I - A)^{-1} \quad (5)$$

where ε is an embodied energy intensity row vector that reflects the embodied energy induced from sector j by a unit change in final demand. The energy embodied in final demand can be calculated by multiplying ε by the components of final demand, which here include household consumption (C), capital investment (I), government spending (G), and exports (EX)

$$\varepsilon \times (C + I + G + \quad (6)$$

Imports are not included in equation 6 because they do not consume domestic energy. We account for the effects of imports in the input-output table through sectoral energy intensities. Sectors with high imports will have lower sectoral primary energy intensities. In addition, imports do not have broader linkages in the domestic economy and thus do not induce indirect energy use through, for instance, purchases of electricity.

We use this general approach below to examine the embodied energy distribution and intensity of China's exports in 2002 at a 122-sector resolution. At this level of detail, we are able to provide a nuanced picture of which export sectors are driving energy demand growth throughout the economy, as well as their exposure to energy prices.

Structural Patterns of Energy Price Transmission

To examine the relationship between energy prices and exports in greater detail we use an approach that is dual to that of the last section and elucidates energy price vulnerability across export activities. In particular, consider the same classification of endogenous and exogenous accounts and identical notational conventions as above, reading down column 1 of the SAM gives us:

$$p_1' = p_1' A_{11} + p_2' A_{21} \quad (7)$$

which yields

$$p_1' = (1 - A_{11})^{-1} p_2' A_{21} \quad (8)$$

Let $p = (p_1)$ be the vector of prices for the endogenous sectors of the SAM, and set the vector of exogenous costs (taxes, import costs) as $v = p_2 A_{(2)}$, where $A_{(2)}$ is the submatrix of the SAM composed by column adjoining A_{21} and A_{22}. In matrix notation

$$p = p A + v = v (I\text{-}A)^{-1} = v M \quad (9)$$

where M is the multiplier matrix.

Using this technique it is possible to estimate an energy cost elasticity of demand for each economic sector and each source of final demand. The input elasticity measures the total change in primary energy (i.e., coal and oil) costs — and, by extension, total energy use — throughout the economy with a unit increase in final demand. Given that these elasticities are based on cross-sectional data, it is important to interpret them with caution in a more longitudinal context. However, as indicators of dynamics within the Chinese economy they provide insight onto the relative contribution of different sources of final demand on energy demand.

In calculating these cost elasticities, we focus on coal and oil. Due to China's relatively minor natural gas consumption (2.6 percent of total primary energy consumption in 2002), we include natural gas in our oil calculations. China's 122-sector I/O table combines oil and gas extraction, and disaggregating the two sectors is not straightforward. In converting between value and physical units this aggregation likely produces a small underestimate.

Data Sources

For the majority of this analysis we use the National Bureau of Statistics' (NBS') 122-sector, 2002 input-output (I/O) table and 2002 energy input table. China's national I/O tables are published every five years, and the 2002 table is the most recent official table. More recent unofficial, updated versions of the national I/O table are available based on the underlying structure of the 2002 table, but none have the sectoral detail contained in the 122-sector 2002 table. When necessary we use the 2004 I/O table to discuss structural changes that occurred in the Chinese economy after 2002.

NBS energy input tables are published on an annual basis in the *China Statistical Yearbook* series. The tables describe primary and secondary energy inputs for 40 sectors. Moving from 40 to 122 sectors requires significant disaggregation, which we do by assuming that primary energy prices within industry clusters (e.g., services) are equivalent, and disaggregating the 40-sector energy input table to 122 sectors via sectoral price distributions in the I/O table. For instance, "Crop Cultivation" (I/O table) is aggregated in "Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy" (energy input table); among the 5 sectors in the 122-sector table that would fall under Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy, Crop Cultivation accounts for 61 percent of the 5 sectors' total payments to coal, and thus accounts for 61 percent of physical coal consumption by Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy.

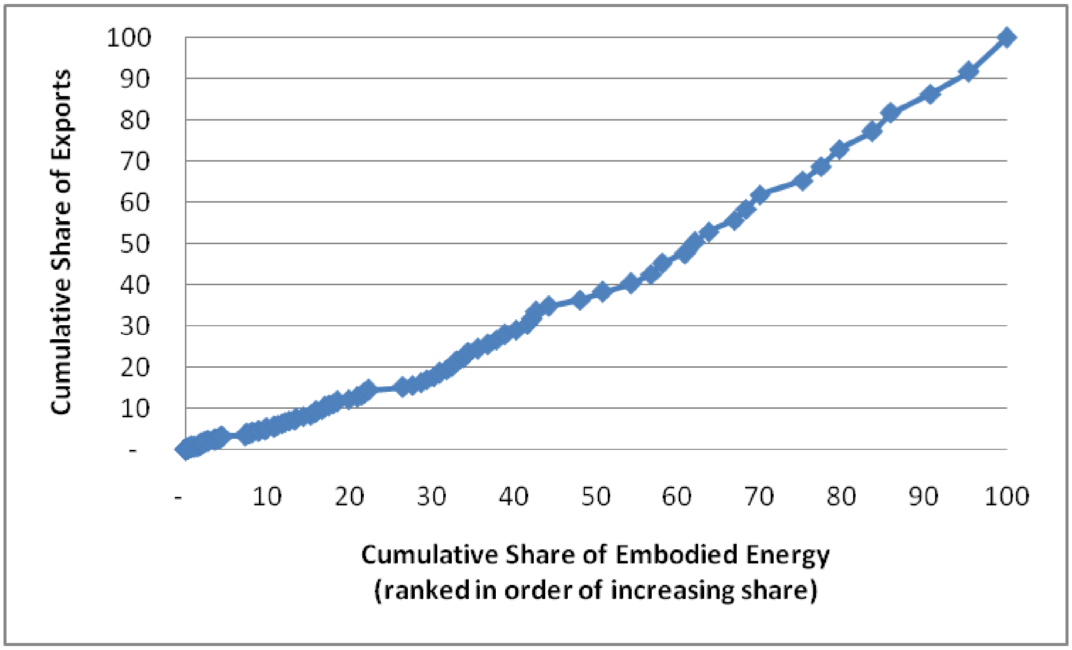
3. Results: Emergent Export-Energy Linkages

In the three subsections below, we explore three major emergent themes from the energy-export nexus in China. *Scale and Intensity in China's Energy Exports* examines the distribution of embodied energy in China's export sectors, focusing on the relationship between sectoral shares of export value and shares of embodied energy intensity. *Direct and Indirect Energy Use in China's Export Sectors* quantifies the magnitude of direct and indirect energy use in export sectors. *China's Exports and International Energy Markets* investigates the interface between rapid export growth in China and international energy markets.

Scale and Intensity in China's Energy Exports

At an aggregate level, energy use is characterized by two effects: scale and intensity. When scale effects dominate, high rates of economic growth in sectors with low energy intensities can lead to large increases in total energy requirements. When intensity effects dominate, low rates of economic growth in sectors with high energy intensities can lead to large increases in energy demand. As a per capita resource constrained economy, China does not have an obvious comparative advantage in producing exports that consume a significant amount of domestic energy resources. Understanding how scale and intensity effects interact in export sectors is thus of considerable relevance to long-term energy and economic policy in China.

Figure 2. Cumulative Shares of Exports and Embodied Energy, China, 2002



Both scale and intensity effects are important in China's energy-export regime. Most of China's energy-intensive goods and services comprise a small share of exports. Figure 2 illustrates this point graphically. Of the 111 sectors that had non-zero exports in 2002, the smallest 95 export sectors accounted for 40 percent of exports by value, but 54 percent of the energy embodied in exports; the largest 16 sectors accounted for 60 percent of exports by value but only 46 percent of the energy embodied in exports. Sixty-three sectors had embodied energy intensities above the economy-wide average, comprising 62 percent of total energy use and 40 percent of export value. The curve in Figure 2 separates visually into 3-4 segments, with the lowest 15 percent of exports including the most energy intense segment (i.e., having the flattest slope). Nevertheless, at 46 percent of energy embodied in exports (3.8 EJ), China's 16 largest export sectors were responsible for 10 percent of the country's total domestic energy consumption (39.6 EJ)[2] in 2002 (NBS, 2006).

[2] As noted later in the text, we do not include transformation losses in primary electricity in our calculations here, which leads to a 3.8 EJ discrepancy between this calculation of total primary energy consumption and the NBS calculation.

Figure 3. Sectoral Shares of Export Value and Export-embodied Energy, China, 2002

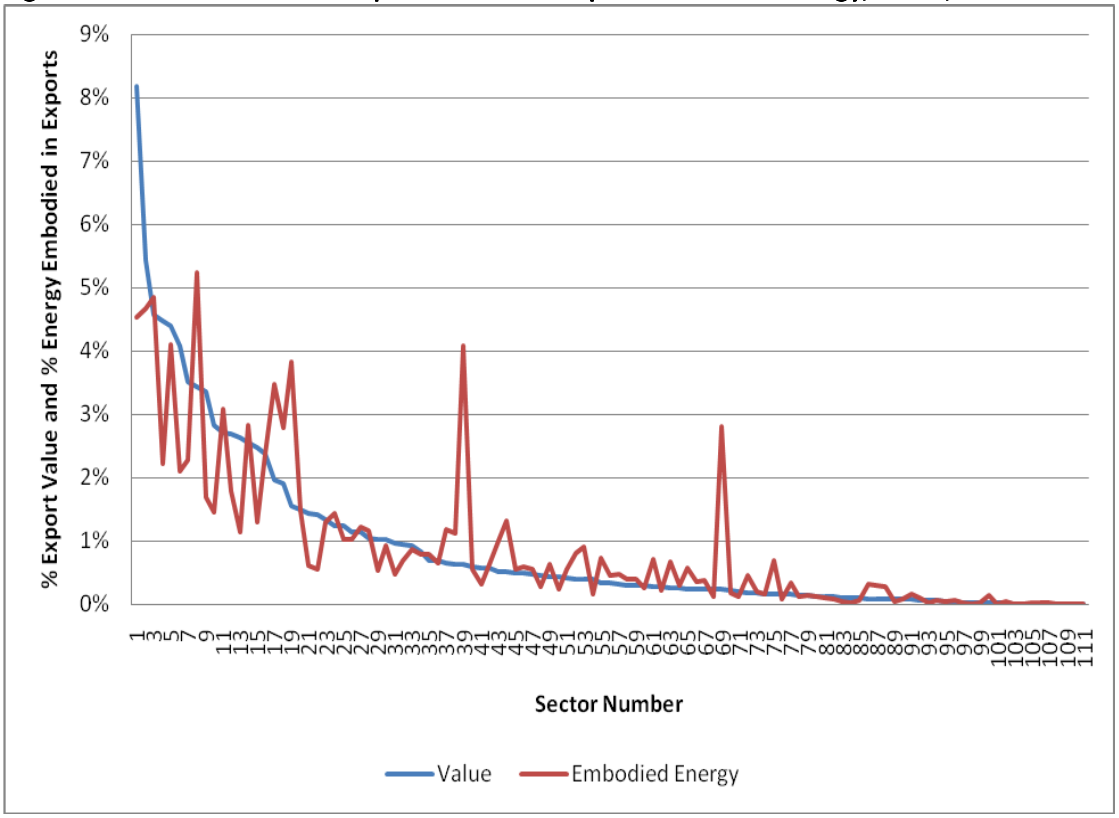


Figure 3 extends this notion. For sectors where embodied energy intensities are higher than the economy-wide average, embodied energy share exceeds export value share (i.e., the red line is above the blue line). While there is significantly more energy variance around the export value mean in the top 30 export sectors, most of the positive variation is in sectors that comprise 1 percent or less of total export value. In other words, the majority of China's most energy-intensive export sectors individually produce less than one percent of the country's export value.

The six major spikes in Figure 3 include (from left to right): Metal Products, Basic Chemicals, Plastics, Water Transport, Petroleum Refining and Nuclear Processing, and Coking. Table 1 shows the energy intensity, share of total exports, and share of the total energy embodied in exports for China's top 20 export sectors by value in 2002. Interestingly, the embodied energy intensity of several subsectors that are typically considered to be less environmentally destructive, such as the textiles subsector, is above the economy-wide average. However, it is also important to note that the apparently low embodied energy of the electronics subsectors in Table 1 is misleading because we only consider domestically consumed energy and China's electronics sector is import intensive. In a number of supply chains China is the last stop for assembly and re-export of finished goods. Instead, Table 1 may suggest that most of the energy requirements for, for instance, textile production are met inside China, while a significant portion of the energy required for electronic goods is consumed abroad and embodied in imported components.

Table 1. Share of Exports, Share of Embodied Energy, and Embodied Energy Intensity of China's Largest (by value) 20 Export Sectors, 2002

	Share of Total Exports (%)	Share of Total Embodied Energy (%)	Embodied Energy Intensity (MJ/RMB)
Wholesale and retail trade services	8.2	4.5	1.5
Wearing apparel	5.4	4.7	2.3
Knitted and crocheted fabrics and articles	4.6	4.9	2.9
Other computer peripheral equipment	4.5	2.2	1.3
Other electric machinery and equipment	4.4	4.1	2.5
Radio, television and communication equipment and apparatus	4.1	2.1	1.4
Leather, fur, down and related products	3.5	2.3	1.7
Metal products	3.4	5.2	4.1
Cultural and office equipment	3.4	1.7	1.4
Business services	2.8	1.4	1.4
Other general industrial machinery	2.7	3.1	3.1
Resident and other personal services	2.7	1.8	1.8
Electronic element and device	2.6	1.1	1.2
Cotton textiles	2.6	2.8	3.0
Telecommunication equipment	2.5	1.3	1.4
Toys, sporting and athletic and recreation products	2.4	2.4	2.7
Water transport	2.0	3.5	4.8
Plastic products	1.9	2.8	4.0
Basic chemicals	1.5	3.8	6.7
Household electric appliances	1.5	1.5	2.7
Total Above	66.7	57.2	2.3
Total Exports	--	--	2.7

There are three primary options for reducing the embodied energy intensity of China's exports at an aggregate level:

1) reduce exports of goods and services with the highest embodied energy intensity;

2) increase exports of goods and services with lower embodied energy intensity; and

3) improve energy efficiency at the sectoral level.

Based on Figures 2 and 3 above, we argue that pursuing option 1 will require detailed targeting but should be undertaken as a matter of course, given the country's per capita resource constraints and the fact that energy-intensive exports, both individually and collectively, account for a small share of total export value. Table 2 shows that compositional shifts as part of option 2 would include a shift away from heavy industry and toward light industry and services. However, as Table 1 illustrates, light industry is a broad aggregation, many sub-sectors of which have relatively high embodied energy intensities. In addition, with continued high rates of export growth, China's energy demand will continue to rapidly increase, even with a shift toward sectors with lower embodied energy intensity, simply because of scale effects. Option 3 requires further elucidation because our focus is on embodied energy rather than energy consumed directly by exporting sectors. These concepts are discussed in greater detail in the next section.

Table 2. Share of Exports, Share of Embodied Energy, and Embodied Energy Intensity, Aggregated Export Sectors, 2002

	Share of Total Exports (%)	Share of Total Embodied Energy (%)	Embodied Energy Intensity (MJ/RMB)
Agriculture	**1.5**	**1.2**	**2.1**
Mining	**1.4**	**2.9**	**5.4**
Light Industry	**26.0**	**23.8**	**2.1**
Heavy Industry	**20.3**	**30.5**	**4.1**
Energy Services	**0.9**	**5.0**	**15.5**
Construction	**0.3**	**1.0**	**3.7**
Transportation	**4.5**	**6.6**	**3.9**
Services	**16.7**	**9.8**	**1.6**
Average	**--**	**--**	**2.7**

Notes: Heavy industry here includes equipment manufacturing.

Direct and Indirect Energy Use in China's Export Sectors

Direct and indirect energy use analysis reveals where energy consumption occurs along supply chains. The construction sector provides an illustrative example. The construction sector's direct consumption of energy — diesel fuel to run bulldozers, for instance — is comparatively small. However, the construction sector's indirect consumption of energy, including among others sources the energy required to produce cement and steel used in buildings, is considerable. As a result, the construction sector has the highest ratio of indirect to direct energy consumption (21.6) of all 122 sectors examined here.

Whether direct or indirect energy use is more prevalent in exports is an important consideration for effective policy design because it determines where along supply chains measures to manage export-induced energy demand growth should be located. If direct energy use is more prevalent, border measures are effective tools to limit increases in energy demand caused by export growth. Alternatively, if indirect energy use dominates, regulation must move further upstream to be more broadly effective. For instance, if exports of an energy-intensive product like steel are significantly larger than the steel used in producing other exports, lowering export credit rebates for steel exports would reduce the steel sector's contribution to export-induced energy demand growth by presumably reducing steel exports. If instead the amount of steel used in making exports is significantly greater, border measures would have less effect in reducing the energy requirements for steel production associated with exports.

In calculating direct energy use, we include secondary energy inputs (i.e., coke, petroleum products, and electricity), which we take directly from the NBS "total energy" heading. NBS total energy calculations include conversion losses for hydropower, nuclear, and wind, which we do not include in the sectoral energy intensities that feed into our embodied energy calculations. The difference is less than 10 percent of total domestic energy consumption, which thus leads us to a relatively small underestimate of the indirect-direct energy ratio. Additionally, the Coking and Petroleum and Nuclear Processing sectors have misleadingly high indirect-direct energy ratios because NBS total energy calculations do not include primary energy consumption. However, removing these two sectors lowers the average ratio by less than two percent.

The indirect-direct energy ratio is calculated as a simple ratio E_I/E_D, where indirect energy consumption (E_I) is a sector's direct energy consumption (E_D) subtracted from its total embodied energy consumption.

Table 3. Direct and Indirect Energy Consumption by Final Demand Sector

	Direct (E_D)	Indirect (E_I)	Ratio (E_I/E_D)
Exports	**2.3 EJ**	**6.1 EJ**	**2.7**
Households	**3.8 EJ**	**9.1 EJ**	**2.4**
Investment	**1.1 EJ**	**12.9 EJ**	**12.2**
Government	**0.9 EJ**	**2.1 EJ**	**2.3**
Total	**8.0 EJ**	**30.1 EJ**	**3.8**

Policy dialogue within China has focused on restraining intensive exports with low indirect-direct energy ratios, such as low value added processed metals. However, as Table 3 shows, on average indirect energy inputs are higher than direct energy inputs in China's exports by a factor of 2.7. In other words, nearly three times as much energy is consumed to produce inputs for exporting sectors than is used by the exporting sectors themselves. This is not to argue that border measures to reduce energy-intensive exports are misguided. Quite the contrary; reducing incentives for energy-intensive exports is an important strategy in China's procession up the value added ladder. Instead, the argument here is that, as a strategy to reduce export-induced energy demand growth, focusing on sectors with low indirect-direct energy ratios (i.e., heavy industry) will not significantly reduce energy demand because most of these sectors' output is embedded in other goods and services. Conversely, targeting sectors with high indirect energy requirements could achieve the government's goals more effectively on an export value basis.

The high indirect-direct energy ratio in investment is driven by the construction sector, which comprised 60 percent of gross capital formation in 2002. Again, the construction sector provides a useful point of departure for thinking through the implications of energy management across supply chains. Improving embodied energy efficiency in the construction sector might involve, for instance, reducing the energy used per input of cement production, or instead reducing the amount of cement used per unit of output in the construction sector. Similarly, the high indirect-direct ratio in exports suggests that focusing on energy and materials relationships along supply chains might produce more cost-effective results (i.e., in terms of foregone export revenue) than limiting regulatory efforts to the border.

China's Exports and International Energy Markets

While considerable research has gone into the effects of China's WTO accession on global labor markets and trade patterns, less attention has been given to the impact of China's WTO entry on global and regional energy markets. Part of the reason for this is that discussion of China's oil consumption is often framed in terms of vehicle ownership and household gasoline consumption, which does not accurately represent how oil functions in the Chinese economy. In China, the majority of domestically consumed petroleum products are used in the production and distribution of goods and services rather than as transportation fuels consumed by households. As the oil used in export supply chains accounted for a nearly equivalent share of the country's total oil consumption as the oil used in the production of goods and services consumed by households, the links between China's exports and oil consumption deserve greater attention.

A second reason is that the impact of a rapid rise in China's exports on global energy prices has been tempered by the predominance of coal as a source of energy in export supply chains. While oil dominates coal at an aggregate level in value terms, in energy units coal is roughly three times larger. International coal markets are smaller and less integrated than international oil markets, and national coal prices in Asia have historically not been synchronized in the way that world oil prices have been. While coal prices within China roughly doubled between 2002 and 2007 (Rosen and Hauser, 2007), more visible effects on regional coal markets were relatively subdued until China became a net coal importer in early 2007.

Table 4. Shares of Accumulated Coal and Oil Expenditures

	2002		2004	
	Coal	Oil	Coal	Oil
Households	35%	30%	33%	29%
Government	9%	9%	6%	5%
Investment	36%	36%	35%	37%
Exports	20%	25%	26%	29%
Total	100%	100%	100%	100%

Based on the method outlined in *Structural Patterns of Energy Prices*, Table 4 shows the shares of accumulated coal and oil expenditures among sources of final demand. An intuitive way to interpret the results in Table 4 is that 20 percent of China's total domestic coal expenditures (i.e., expenditures by all sectors in the economy) and 25 percent of its oil expenditures were used in the production and distribution of exports in 2002. If the sectors producing for household and foreign (export) consumption faced similar oil prices on average, the physical amount of China's domestically used oil embodied in the goods and services consumed by households and exports would have been nearly on par in 2002.

To examine changes in the shares of accumulated coal and oil expenditures since 2002, we use the same method with the NBS 2004 I/O table. Between 2002 and 2004, the shares of households and exports rapidly converged, following a pattern of physical energy consumption convergence described in greater detail in Kahrl and Roland-Holst (2007). By 2004, oil expenditures for the production of goods and services for household consumption were equivalent to those for foreign consumption (exports). Exports' share of accumulated coal expenditures grew even more rapidly than oil from 2002-2004. Household consumption of embodied coal expenditures here includes the coal used in residential electricity consumption, which makes the scale of convergence even more striking.

Table 5. Average Coal and Oil and Energy Cost Elasticities

	Basis Points		MJ/yuan	
	Coal	Oil	Coal	Oil
Households	**2.15**	**2.33**	**17.60**	**5.54**
Government	**1.58**	**1.82**	**12.94**	**4.33**
Investment	**2.53**	**3.19**	**20.67**	**7.61**
Exports	**2.09**	**3.25**	**17.13**	**7.75**

Note: Value to energy conversions are based on implied prices based on I/O table and energy input table data; for coal the implied price is 250.52 yuan/ton, for oil 1,788.90 yuan/ton (~US$29/barrel); based on IPCC (2006) figures we use lower heating values of 20.5 GJ/ton and 42.3 GJ/ton to convert coal and oil, respectively, to convert from physical to energy units.

As Table 5 shows, oil and coal cost elasticities (the two left-most columns) range from near equivalence, in the case of households, to significant divergence, in the case of exports. That coal and oil elasticities diverge by more than one basis point suggests that exports are significantly more cost vulnerable to oil prices than coal prices. In other words, a one percent increase in the price of oil has a much larger effect on export sector costs than a one percent price increase in the price of coal. From an energy perspective, however, all final demand sources are more coal than oil dependent (the two right-most columns). The latter is consistent with China's overall energy mix, where coal accounted for 66 percent and oil 23.4 percent of total primary energy consumption in 2002 (NBS, 2006).

An important insight from of Table 5 is that exports have higher oil cost elasticity than any other source of final demand. That is, a unit increase in the oil prices increases the cost of production for export more than for household consumption, government expenditure, or capital investment, and is more than one basis point higher than households. Much of the difference among final demand sectors in terms of oil cost elasticities derives from compositional differences in their cost structures. As Table 6 illustrates for households and exports, oil costs in household consumption are dominated by the oil used to produce food — in chemical fertilizers and diesel fuel to drive tractors, for instance. Oil costs in exports are instead dominated by the textile and shipping industries. It is important to reiterate here that the figures in Table 6 are costs rather than consumption per se. The water transport sector accounts for nine percent of the total value of oil inputs to production for exports and not necessarily nine percent of the oil used to produce exports.

Table 6. Share of Accumulated Oil Costs, Exports and Households in China, 2002

Exports	Share of Accumulated Oil Costs (%)	Households	Share of Accumulated Oil Costs (%)
Petroleum and nuclear processing	12.2	Crop cultivation	8.3
Water transport	9.1	Petroleum and nuclear processing	7.0
Whole and retail trade services	5.0	Wholesale and retail trade services	4.9
Knitted and crocheted fabrics and articles	4.3	Livestock and livestock products	4.9
Wearing apparel	4.2	All other food manufacturing	4.8
Plastic products	3.5	Food serving services	4.3
Other electric machinery and equipment	3.5	Electricity, steam and hot water production and supply	4.2
Metal products	3.1	Water transport	4.1
Air passenger transport	2.8	Resident and other personal services	3.7
Toys, sporting and athletic and recreation products	2.4	Fishery	3.5

Tables 4 and 5 suggest two broad trends. First, exports account for, and are driving, a considerable portion of China's domestic oil and coal consumption. To a significant extent, then, China's impact on world energy markets is the result of, and being driven by, foreign consumption. At the same time, China's exports are more cost-vulnerable to oil prices than any other source of final demand. Export-induced energy demand growth, and the ensuing upward pressure on energy prices, is thus itself ultimately a threat to China's export competitiveness.

5. Conclusions

Exports have been a primary driver of China's economic growth since the country's accession to the WTO in late 2001. Export growth increased from 13 percent annually over 1990-2001 to 25 annually from 2002-2006; exports grew from 22 percent of GDP in 2002 to 37 percent in 2006 (NBS, various years). Rapid growth in China's exports was accompanied by a large increase in energy demand, much of it used to fuel export production, both directly and indirectly. At an aggregate level, China's energy demand growth from 2002-2004 significantly exceeded its energy demand growth during the previous decade. In earlier work we estimated that 40 percent of this growth in 2002-2004 energy demand was driven by exports.

In this paper, we discuss the effects of China's rapid export growth on the country's energy use patterns, both at an aggregate and detailed sectoral level. Using China's 122-sector, 2002 national input-output (I/O) table and energy input table, we examine the interaction between scale and intensity in China's embodied energy exports, the magnitude of direct and indirect energy consumption in export sectors, and the interface between China's exports of embodied energy and international energy markets.

At 122-sector resolution, 63 sectors had embodied energy intensities that exceeded the economy-wide average in 2002. While these 63 sectors contributed to 40 percent of China's export value, 50 of them accounted for less than 1 percent individually, and 13 percent collectively, of total export value. Despite their small contribution to total export value, these 50 sectors comprised 27 percent of the country's export-induced energy demand. Clearly, there is scope for reducing the embodied energy intensity of China's export sector without unduly influencing export value through policies that discourage exports in these sectors.

A second strategy for reducing the energy intensity of China's exports might entail a compositional shift from heavy industry to light industry and services in exports. However, as we describe above, within each of these sectoral aggregations is a range of embodied energy intensities, and aggregate sector promotion policies thus may not necessarily lead to intensity reductions. Additionally, because of the scale of China's exports, even policies that reduce energy intensity might still be consistent with significant new energy requirements. The largest 16 of China's export sectors accounted for 60 percent of the value but only 46 percent of the energy embodied in China's exports. Despite their comparatively low embodied energy intensity, export-induced energy consumption by these 16 sectors accounted for 10 percent of China's total domestic energy consumption in 2002.

The question of how to most effectively reduce the energy requirements for China's exports is intimately linked to the notion of direct versus indirect energy use. Direct energy use refers to the direct energy inputs into an export sector. Indirect energy refers to the energy inputs upstream of the export sector. This distinction is important for determining the targets and ultimate incidence of energy-related trade regulation. If direct energy is larger than indirect energy in export sectors, border measures to limit exports might be more effective in reducing the embodied energy intensity of exports. If indirect energy is larger, border measures will be less effective because production from the most energy intensive sectors is embedded in exports (e.g., steel in a car export). As we describe above, across China's export activities indirect energy use is larger than direct use by a factor of nearly three. In other words, three times as much energy is consumed upstream of export sectors than in export sectors themselves. While China's indirect-direct energy use ratio varies over individual export sectors, at an aggregate level its magnitude suggests that China's central government needs to take a more integrated approach to energy, resources, and trade policy.

Although a great deal of analysis has been dedicated to the impact of China's WTO accession on global labor markets and global trade patterns, less attention has been given to the impact on international energy markets. Two issues might explain this lapse. First, China's growing oil use is often framed in terms of the country's rising demand for personal transport, which is a misleading perspective. The majority of China's oil consumption fuels production and distribution of goods and services, not in final demand. For their part in this, exports play a significant role in driving China's oil use. Indeed, by 2004 domestic (household) and foreign (export) consumption accounted for roughly the same share of the embodied costs of Chinese oil consumption.

Second, reliance on inexpensive domestic coal has tempered the impacts of China's export-induced energy demand growth on international energy markets. China's role in Asian coal markets has indeed historically been as a source of supply rather than a source of demand because of the country's substantial coal reserves. With China's emergence as a net coal importer in early 2007, this situation may change. As we describe above, exports' share of embodied coal consumption has increased dramatically since 2002, and exports are now a major driving force in China's domestic consumption of both coal and oil. In both cases, the rapid rise in China's exports has left the country's export sector more vulnerable to international energy prices, which may ultimately affect its export competitiveness.

6. References

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