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主　論　文　の　要　旨

論文題目　An Empirical Study on Energy Use, Carbon Emissions and Economic Growth in China

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論　文　内　容　の　要　旨

Energy consumption, energy–related CO2 emission and economic growth are three interrelated issues at the forefront of public attention. This dissertation aims to investigate the driving forces of China's energy use and carbon emissions, to analyze their roles in economic growth and to provide policy implications for energy conservation and carbon emissions abatement in China.

Chapter one discusses the research background, research objective and questions, and the organization of this study.

Chapter two provided a brief overview of energy use in history. Energy flow charts were provided to describe China's energy supply and use system and its changes, and to make a comparison of the international energy systems among the main economies in the world.

Energy is always an important factor to the improvement of social and economic welfare in human history. The transitions of power source divide human history into four distinct energy eras: biomass fuels, draft animals, waterwheels and windmills, fossil fuels and electricity. The energy transition from animal power and biomass fuels to engines and fossil fuels has driven productivity growth significantly. In the long term, technological innovation, which is the new capital stock in economics jargon, is the primary source of productivity growth.

The demand for energy is a derived demand from the utilization of capital stocks. Coal and petroleum used as fuels, for example, started with the diffusion of steam engines in textile manufacture from the mid-1700s and the diffusion of internal combustion engines in transportation from the late 1800s. From the 1800s to the 1910s, the share of coal in the global total primary energy supply (TPES) climbed from single digits to 50%. From the 1900s to the 1970s, the share of hydrocarbon fuels (crude oil and natural gas) increased from almost zero to approximately 60% within seven decades. Meanwhile, coal dropped to only 25% from 50%. After the oil crisis in the 1970s, the world energy structure has been largely stable throughout the last forty years. In this period, hydrocarbon fuels have accounted for approximately 55% of the world's TPES, coal for around 25%, biofuels for around 10% and primary electricity (hydro- and nuclear-) for the last 10%.

During the past few decades, the most significant changes in China's energy system include the following three points. First, China's energy supply still mainly relies on coal, but currently more than half of its petroleum supply is imported on the international market. Second, the direct use of coal in final demand has been significantly substituted by electricity, decreased from more than one-half to one-quarter. Third and most important, though China's energy intensity decreased two-thirds from 1978 and resembles an inverted U-shape across per capita income, its total energy consumption has accelerated since the early 2000s and it became the largest energy consumer in the world in 2010. It is critical to understand the driving forces of China's energy use for the design of energy policy on both national and global scales.

Chapter three conducts a structural decomposition analysis (SDA) based on hybrid input–output tables, and discusses the driving forces of total energy use in China from 1992 to 2010. As shown in the results, China's energy uses are embodied in the three final demand categories — gross fixed capital formation, household consumption expenditures and exports. The impacts of these factors on total energy use shifted with the development of the economy. In the 1990s, China's energy use was still mainly driven by household consumption, which accounted for about two-fifths of the total energy use, but its contribution to the energy use change decreased from 31 percent (1992–1997) to 20 percent (1997–2002). In contrast, the contribution of exports to the changes in energy use increased from 30 percent (1992–1997) to 39 percent (1997–2002). In other words, China was shifting toward becoming an export–oriented economy in the 1990s.

However, gross fixed capital formation (investment) has been a major factor driving China's economic growth in the past decade. The energy use embodied in gross fixed capital formation increased from approximately 30 percent of total energy use before 2002 to 39 percent in 2010, and its contribution to the change of energy use swelled to three-quarters during 2007–2010. This investment–led economic growth is unsustainable because the heavy dependence on investment not only created energy and environmental problems but also increased systematic risk, including surging local government debt. It is urgent for China to switch its economy from export– and investment–based growth to domestic consumption–oriented growth.

With exports and investment driving economic growth, the income of Chinese households has reached the level at which energy–intensive goods are affordable. Household consumption has contributed 30 percent of the total energy use and to one-quarter of its change in 2010. Given China's population and accelerating urbanization, the commercial and transportation sectors should expect to surpass the industrial sector as the main energy demand drivers in the future.

Chapter four adopts a hybrid environmental input–output model to investigate the energy–related CO2 emission embodied in Chinese final demand. China became the largest emitter in the world in 2006 and currently accounts for 27% of global annual carbon emissions in 2012. Its historical cumulative emissions climbed to 11% of global total emission in 2012, which is approximately 41% of the US. CO2 emissions are byproducts of energy consumption in economic activities.

The results show that the final demand category of consumption is responsible for 51% of Chinese CO2 emission in 1992 and decreased to 34% in 2010. The changes in consumption contributed around one-fourth (21% to 26%) to total CO2 emission growth during each period from 1992 to 2010. The growth of CO2 emissions embodied in the household consumption is typically determined by factors such as income level, consumption patterns, population and the household size. The household sizes, for example, declined from 3.96 in 1990 to 3.10 in 2010. The decreasing household size cuts the per capita energy use efficiency and pushes per capita emissions.

In contrast to the decreasing share of consumption, the investment activity related CO2 emission increased from 31% in 1992 to 42% in 2010. The growing final demand for investment amounted to 2,430 Mt CO2 between 1992 and 2010 (48% of total changes), of which 84% occurred between 2002 and 2010. In the period 2007–2010, especially, investment activity contributed 92% of total emission changes. Around 56% to 70% of emission embodied in investment between 1992 and 2010 are related to final demand for 'Construction', which is due to its energy–intensive input structure, such as cement manufacturing, iron and steel production and electricity demand.

Exports related emissions have grown most rapidly compared to all the other final demand categories. Emissions from the production of goods and services destined for exports increased from 494 Mt (17% of total emissions) in 1992 to 1,870 Mt (24% of total emissions) in 2010. The composition of exported goods and services is changing, which indicates a shifting role of China in the global economy from a producer of cheap, labor–intensive goods toward high–end and more capital intensive products.

The indirect energy use and carbon emissions indicate the length of the roundabout production chain, or the roundaboutness of production, which was one of three concepts used to describe the specialization of economics. The increasing of division and specialization of labor are associated with the growth of productivity and the capital deepening process. My calculation shows that the share of indirect carbon emissions rose from 73% in 1992 to 87% in 2010 since the growing of the roundabout production with the developing of Chinese economy.

Chapter three and four provide the demand side analysis of the energy and emissions in China by using a hybrid input–output model. Chapter five conducts a supply side analysis by constructing a three–factor translog production function with a stochastic frontier for Chinese economy. It is found that the output elasticity of energy input is approximately 0.4 in China since 1978, which means one percent growth in energy input would push about 0.4 percent of aggregate economic growth. The elasticity of substitution of capital–energy is about 0.23 before mid-1990s, and then dropped to only −0.26. The negative elasticity of substation reveals the perfect complementary between capital and energy input in China.

An inefficiency model is provided to explain the sources of economic inefficiency. I found that the provinces located in coastal regions and with a higher level of liberal economy have lower economic inefficiency, and the shares of fiscal expenditure in GDP and State Owned Enterprises (SOE) in industrial production are positively correlated with technical inefficiency. The calculated TFP index illustrates the sources of economic growth in China. Since the launch of the reform and opening policy in 1978, China's economic growth can be divided into three periods. First, TFP contributed about 22% to 44% of China's growth from 1978 to late-1980s. The contribution of productivity improvement to economic growth is a result of series reforms, such as the household–responsibility system and price reform. Second, China's economy supported by the devaluation of RMB, SOE and tax reform from early-1990s to late-1990s. Third, China's growth is mainly driven by investment activity from late-1990s, such as government spending on large–scale infrastructure projects, and both foreign and domestic investment in manufacture. Accompany the increasing investment, energy use surged in the last decade in China.

A provincial comparison on the total–factor energy efficiency reveals the difference between the actual energy use and the optimal energy input. I provide the energy–saving potential index among the provinces in China. It can be found that the higher developed provinces have higher energy efficiency. Scenario analysis is provided to describe the potential for energy conservation in China. Given the current technology and knowledge, China can reduce about 31 percent of its energy input if it operates as the same technical efficient as Guangdong province.

Finally, I have to emphasize that energy and environment issues are derivatives of economic and societal development. These systemic issues cannot be solved once and for all. Chinese policymakers should continue to deepen reform to build up a market–based economy and energy system. It should be the markets, but not governments that organize the use and distribution of energy resources and the environment.