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China's metabolic patterns and their potential problems

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ABSTRACT

In this paper we deal only with the demographic and energy issues associated with China's metabolic patterns and present several serious problems that China would face in the future. For this purpose we use our general multi-scale methodology, Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM for short). The second section briefly presents the basic ideas behind this methodology. MuSIASEM is shown to be a combination of (i) Georgescu-Roegen's flow-fund production theory in economics; (ii) hierarchy theory in ecology and (iii) hypercycle theory in chemical reaction cycles. The third section deals with China's population size and its structural problems associated with the metabolic patterns of the country and presents a few potential problems. A shortage of labor hours would be a serious threat to China's economic prospectus unless labor productivity per hour increases dramatically. It is shown that the hourly monetary return in 2050 must be 24.5 US dollar (for 1800 yearly working hours) and 27.6 US dollar (for 1600 yearly working hours), to maintain China's GDP levels predicted for 2050. The fourth section first presents the metabolic patterns of China by four of four quadrants-four angles figure for the secondary and tertiary sectors. This section also discusses a prospect of China's oil import depending on three plausible scenarios. Oil import "guestimates" are 1290, 2010, and 2730 (million tonnes) in the year 2050 based on the three scenarios. Since the world total oil production in 2010 is 3945 million tonnes, the import oil burden for China will be alarming in the near future. The fifth section concludes the paper.

1. Introduction

China has achieved rapid economic growth since Deng Xiao Ping launched economic reforms in 1978. This economic development can be seen as a transition from a centrally planned economy toward a market based economy, while keeping the communist regime. This transition entails another important transition from an agricultural society toward an urban industrial society. During the period of 1999–2003, for example, real GDP grew on average by 8% per year, three times the world average growth rate (Liu and Diamond, 2005). China has achieved the highest GDP growth rate, around 12% in the year 2011 and is still growing at 7% GDP growth rate up to 2014 (Trading Economics, 2014). The Chinese government is determined to get another quadrupling in GDP size by 2020 (Aldhous, 2005). However, to accomplish such a goal China could face formidable problems in relation to demographic dynamics (e.g., Vaupel and Yi, 1991; Adamchak, 2001; Cai and Wang, 2006), energy demand and supply (e.g., Adams and Shachmurove, 2008; Ito et al., 2010; Shan et al., 2012; Lin and Ouyang, 2014), and environmental problems (Chak et al., 2008; Kan et al., 2012).

Concerning demographic problems, there is a variety of potential problems that might hamper China's future economic development (Vaupel and Yi, 1991; Adamchak, 2001; Cai and Wang, 2006). China's population of more than 1.3 billion is still growing. It is a little less than one-fifth of the world's population (about 7.2 billion as of January 2014). Demographic transition has occurred more rapidly in China than in most developed countries. China's population is aging: the elderly may number 300 to 400 million by 2050. Efforts to reduce the population growth will increase the proportion of elderly. To increase the size of the work force, a substantial delay in the age of retirement may be necessary. To reduce the number of births, some judicious mix of delayed childbearing and lower fertility will be required. The population policy choices, such as the one-child policy made in China, will determine the future size, age

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composition, labor resources, the timing of retirement, and family patterns.

Concerning energy issues, looking at the recent history one can note that despite the huge energy demand for China's economic development, China had maintained itself as one of the largest oil exporters in Asia until early 1980s, due to China's consistent policy of promoting petroleum exports as a foreign exchange earner (Ebel, 2005). However, energy security has become an increasingly important concern for Chinese government since the mid-1990s as domestic energy production has failed to keep pace with demand. A rapid growth in the use of road transport has driven a considerable increase in demand for oil consumption. China became a net importer of oil in 1995 and in less than 10 years has become the second largest oil importer in the world after the United States (Andrews-Speed et al., 2002; Jian, 2005), even though China imports only 12% of the energy it consumes, as compared with 40% for the United States and 80% for Japan (Zweig and Fianbai, 2005). Due to its size, the Chinese market is a crucial element responsible for 40% of the global increase in oil demand since 2000 (Jian, 2005). Under these circumstances, China is planning an increase in its use of natural gas and nuclear power to limit the air-quality consequences and to meet demand for electricity (Ebel, 2005). By 2020, according to official projections, gas-fired stations could meet 15% of China's electricity needs, while nuclear power may be expanded to around 5% (Aldhous, 2005). However, since power supply must be doubled over the same period, it will also be absolutely necessary to secure a sufficient supply of oil together with a massive reliance on coal consumption. In a business as usual scenario, China's energy consumption will reach 6493.07 million tons of coal equivalent in 2030 (Lin and Ouyang, 2014). China will, indeed, require rapidly growing imports of oil, coal, and gas (Adams and Shachmurove, 2008). If the energy consumption per capita in low-consumption areas increases, the total consumption in China will also increase significantly (Ito et al., 2010).

Concerning the environmental problems, in particular air pollution problems, the total emission levels of CO_2, SO_2 and NO_x had already surpassed those of USA levels: CO_2 in 2005, SO_2 in 1993 and NO_x in 2005 (calculated by the authors from US Environmental Protection Agency, 2012 and 2013; Lu et al., 2011; U.S. Energy Information Administration (EIA), 2013; Zhang et al., 2007). The emergence of a number of mega cities since the 1990 is another serious aspect of the air pollution problems. Air pollution has become one of the top environmental concerns in China. Currently, Beijing, Shanghai, and the Pearl River Delta region including Guangzhou, Shenzhen and Hong Kong, and their immediate vicinities are the most polluted regions in China (Chak et al., 2008). This phenomena increased health risks observed among the Chinese population (Kan et al., 2012). Furthermore, there is a serious concern linked to global warming, which is due to the massive use of coal. In fact, between 75% and 80% of China's electricity is still generated by burning coal (Aldhous, 2005). The effects of acid rain are also spreading, and there are suggestions that soot is already disrupting the regional climate (Aldhous, 2005). Due to acid rain and the increasing demand for water in China, 90% of the rivers are polluted and two-thirds of the cities are short of fresh water.

In this paper we deal only with the demographic and energy issues associated with China's metabolic patterns and present several serious problems that China would face in the future. For this purpose we use our general multi-scale methodology, Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM for short). Section 2 presents briefly the basic ideas behind this methodology. This methodology is shown to be a combination of (i) Georgescu-Roegen's flow-fund production theory in economics; (ii) hierarchy theory in ecology and (iii) hypercycle theory in chemical reaction cycles. Section 3 deals with China's population size and its structural problems associated with the metabolic patterns of the country and presents a few potential problems. A shortage of labor hours would be a serious threat to China's economic prospectus unless labor productivity per hour increases dramatically. Section 4 first presents the metabolic patterns of China by four of four quadrants-four angles figure for the secondary and tertiary sectors. Section 4 also discusses a prospect of China's oil import depending on a few plausible scenarios followed by Section 5, the conclusion of this paper.

2. Brief introduction to MuSIASEM for studying China's metabolic patterns

Before making an assessment of the metabolic patterns of China, we indicate eight important changes within socioeconomic systems that occurred ever since the Industrial Revolution in the 1760s: (i) large scale and intensive use of fossil fuels that support "high metabolic speed" in the broadest sense of the term; (ii) establishing a global transportation network that is a basis of the motive power of civilization; (iii) dramatic increase in population size ("endosomatic humans") and in machines and capital equipment ("exosomatic humans"); (iv) structural changes in population and industries toward "inverted triangle"; (v) land use pattern change; (vi) human time allocation change; (vii) growth oriented behavior and attitude and their consequences that led to the income distribution problems; and (viii) institutional changes for reinforcing seven changes described above.

We have been trying to establish a general scheme (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism, MuSIASEM for short) that can adequately address these eight changes. This new scheme, MuSIASEM, is a theoretical development based on a combination of the three pioneering fields of works: (i) Georgescu-Roegen's flow–fund production theory in economics (Georgescu-Roegen, 1969, 1971); (ii) hierarchy theory in ecology (e.g., Allen and Starr, 1982; O'Neill et al., 1986; Salthe, 1985) and (iii) hypercycle theory in chemical reaction cycles (Eigen, 1971; Ulanowicz, 1986).

Lotka (1956) introduced the theoretical notion of human society consists of a double metabolism, one related to endosomatic organs inside the human body and another related to exosomatic organs created by humans such as tools and mechanical devices. This idea was further elaborated by Georgescu-Roegen (1971) in his efforts to integrate economic and biophysical processes in view of sustainability. To effectively address the double-metabolism and to indicate the need for an integrated approach to sustainability issues, Georgescu-Roegen introduced the flow–fund scheme, the first important element of MuSIASEM. Flow coordinates are elements that enter but do not exit the production process (e.g., onion for curry soup) or, conversely elements that exit without having entered the process (e.g., a new product). Flow elements include matter and energy in situ, controlled matter and energy (energy carriers in this paper), and dissipated matter and energy. Fund elements (capital, labor, and Ricardian land) are agents that enter and exit the process, transforming input flows into output flows. Fund elements can only be used at a specified rate and must be periodically renewed. Georgescu-Roegen's scheme can account for scale and time duration and addresses the question of whether or not a given technology is viable. A technology is viable if and only if an economic system it represents can operate steadily as long as flows of available energy and matter are forthcoming in necessary amounts in relation to the set of constraints determined by the characteristics of the fund elements. Georgescu-Roegen's scheme is based on an explicit acknowledgment of both multi-scale integrated analysis and the existence of biophysical constraints on the process of economic development (Georgescu-Roegen, 1971). Another crucial idea associated with