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Energy-saving implications from supply chain improvement: An exploratory study on China's consumer goods retail system

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ABSTRACT

Despite significant public attentions to green supply chain management, few studies have explicitly addressed the energy implications of consumer-goods supply surplus, especially in developing countries like China. This study explored the energy-saving potential from improving supply chain efficiencies and reducing excess inventory in China's retail system from a life-cycle perspective. Through embodied energy analysis, we found that energy invested pre-manufacture contributed 80–95% of the total energy embodied in consumer products. Although embodied energy intensities had declined by 60–90% since the mid-1990s, the lessened marginal improvements implied that "low hanging fruits" have largely been captured, and the search for new opportunities for energy-saving is in demand. Positive correlations between total economic inputs and embodied energy in consumer goods indicated possible synergy effect between cost-reduction and energy-saving in supply system management. And structural path analysis identified sector-specific energy management priorities for each retail-related sector. This study suggested that improving supply chain efficiencies provides a promising supplement to China's current industrial energy-efficient projects which target reducing direct energy use *per se* as an intra-firm cost-saving measure. From the life-cycle perspective, the definition of "green sector" might have to be reconsidered in China towards a more energy-efficient economy and society.

1. Introduction

Worldwide public concerns have increasingly grown in recent years over climate change (Moss et al., 2010), energy scarcity (Chow et al., 2003), and global or local environmental issues (Kolbert, 2015). According to EIA (2013), energy use in the private sector accounts for more than 50% of the world's total energy consumption, surpassing that of any other end-use sectors. Industrial energy management is worth particular attention in developing countries like China, where the industrial sector attributes up to 70% of the nation's total energy use (Ke et al., 2012). With a large number of small and medium-sized enterprises (SMEs) whose operations management is rudimental, China may have significant energy-saving potentials from improving operational efficiencies in SMEs. Conventionally, China's governmental programs have largely focused on implementing hardware upgrade to improve energy efficiency in the industrial sector; and energy technologies are often promoted as an intra-firm cost-saving measure. During the past 30 years, as the importance of supply chain management has become more recognized (e.g., Lambert and Cooper, 2000; Mentzer et al., 2001), additional energy-saving and emission-mitigation opportunities have been emphasized for inter-firm systems, i.e., supply chain/system (e.g., Carter and Rogers, 2008; Sundarakani et al., 2010; Du et al., 2015). Green supply chain management (GSCM), therefore, has received rising attentions from both academics and practitioners (e.g., Seuring and Müller., 2008; Srivastava, 2007; Fahimnia et al., 2015) as an alternative means to promote energy-efficient and environmental-friendly business practices. Current GSCM literatures have explored the environmental influences of consumer preferences (e.g., Lenzen, 1998; Weber and Matthews, 2008), transportation systems (e.g., Cowell and Parkinson., 2003), packaging requirements (e.g., Matthews et al., 2002), business formats (e.g. Matthews et al., 2002; Xu et al., 2009), and supply chain configurations (Guillén-Gosálbez and Grossmann., 2010). However, the subject of energy consequences of inefficient supply chain management, especially the resulting excess inventory and societal production, has not been addressed adequately.

Supply chain management (SCM) is an integrated discipline embraced by a broad spectrum of practitioners, including manufacturers,

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distributors, and retailers, to achieve greater efficiency and enhance business advantage. Supply chain is a crucial functional unit in the societal circulation system of finished products. Firms along a supply chain make numerous decisions that not only influence their operational costs but also have substantial implications for energy use. They forecast demand, set prices, select the batch size of orders, choose transportation methods, build warehouse capacity, and decide when and how to liquidate excess inventory. However, because of the complexity and uncertainty of these decisions, firms do not always have the resources or capabilities to determine the efficiency-maximizing set of choices, and instead settle for "muddling through". The suboptimal operations of firms can cause system-wide inefficiencies through the "bullwhip effect", which refers to the amplified demand distortions that propagate upstream in a supply chain as a result of uncertain demand forecasting, order batching, time delays, risk aversion, and other forces (Lee et al., 1997).

A common consequence of supply chain inefficiencies is excess inventory, which is a widespread phenomenon in the markets of consumer products. Excess consumer goods inventory in the U.S. and worldwide markets were estimated to be $60 billion and $120 billion respectively in 2000 (Crandall and Crandall, 2003). Keifer (2011) found the value of excess inventory to represent 7% of annual revenues in the U.S. apparel sector. In late 2015, major retail brands in the U.S. showed significant higher inventory increase than sales increase (Kapner, 2015). Food overproduction and waste is a more severe issue in many countries; for example, England, Wales, and Scotland generated 4.6 million tons of food waste in 2005 (EAEW, 2005; Scottish EPA, 2005; EAEW, 2005), and the overproduction waste of ready-made meals supplied by convenience stores could account for more than 50% of a company's total outputs (Defra, 2007). Our interview with a representative from a major snacking food distributor in Tianjin City, China, revealed that an international-branded food manufacturer suffered a loss of 17 million CNY (equivalent to more than 2 million USD) in China because of the overstocks caused by a failed sales promotion plan in 2008. Overproduction not only entails the waste of resources already invested, but also requires significant further effort of technology, capital, and energy inputs for the end-of-life treatment (Stuart, 2009).

Supply chain inefficiencies cause not only economic losses, but also environmental and energy impacts. Financially, excess inventory pileups from failing to fulfill customer demands efficiently entail local carrying charges and rent. Environmentally, excess inventory embodies energy and natural resources which have been invested at each upstream stage of a product's life cycle. However, current academic attentions and business concerns mainly focus on the economic impacts (e.g. Crandall and Crandall, 2003; Singhal, 2005; Chen et al., 2005). Few studies have explicitly evaluated the energy impacts of supply chain inefficiencies which commonly results in excess inventory. Moreover, existing SCM practices are mainly concentrated on reducing excess inventory of raw materials and work-in-process (WIP) components, rather than that of finished goods (Chen et al., 2005). Excess inventory of finished goods, when being put into industrial use or retailing distribution networks, not only indicates extra direct energy consumption in warehousing and transportation, but also implies the indirect energy inputs embedded in the products being lost for opportunity uses. Although sometimes new production delay could help balance a firm's inventory pileup from making supply chain decisions inefficiently under uncertainties, this is only a short-term solution such as for one order cycle and for certain non-perishable products let alone that even a delayed use of the embodied energy implies that it might have missed better opportunity uses. From the long-term viewpoint, because of the uncertainties involved in SCM decisions, overproduction and excess inventory usually does not stop at a certain time point because firms realize its existence, but often worsens as firms move upwards a supply chain (Lee et al., 1997). In this study, we do not argue that discounted or discarded overstocks have no economic values or completely lose their energy contents. Instead, through better supply system planning, the cash and energy tied up in overstocked products could be invested in more profitable, efficient, and/or socially desirable alternative uses; for example, by producing more needed products, by efficiently scheduling the production plan, by optimizing the logistics arrangement for target consumer groups, and so forth.

Grounded on the life-cycle perspective, this paper aims to supplement current GSCM studies by explicitly exploring energy-saving implications from supply chain management, especially reducing supply surplus. This study examines the embodied energy of retail-related sectors (i.e. consumer goods production, packaging/transport/storage/retail services) in China for the past two decades. The objective is to explain why taming supply chain inefficiencies, and reducing excess inventory and overproduction in China's retail system could provide dramatic energy-saving potentials for this developing nation. The retail-related sectors are selected because of their fast growth throughout the country in recent years and their worsening surplus with growing economy. A Thomson Reuter analysis based on 350 Chinese companies revealed obvious inventory stockpiles appeared in China's consumer goods business in 2012 (Kowk, 2012). Retail system includes major consumer-goods manufacturing, packaging-materials production, transportation and storage services, and point-of-sale (i.e., wholesale and retailing). According to China's industrial classification system, this study specifically focuses on the following industrial sectors: (1) food production sectors; (2) apparels manufacture; (3) appliances manufacture; (4) electronics manufacture; (5) paper products manufacture; (6) plastics products manufacture; (7) transportation sectors; (8) storage services; and (9) wholesale and retail trade.

2. Methodology

2.1. Direct energy and embodied energy

Direct energy refers to the energy directly consumed in a certain business process and/or facility, and is often revealed on a product/service provider's energy bill, e.g. energy used for manufacturing equipment operations, building heating and cooling, and product transportation. Indirect energy is the energy used to produce, package, store, and transport the materials/components/service provided by a firm's suppliers; and is usually not counted as the firm's energy use. However, indirect energy is embedded in final products regardless of who pays for it. Embodied energy is the sum of direct and indirect energy associated with all of the production and distribution processes in a supply system, and embedded in a specific product at a particular stage of its lifecycle. For example, clothes produced in an appeal factory embodies not only the energy use within the factory, but also the energy embedded in the cotton which was used to make the final products; meanwhile, clothes displayed in a retail store for sale further embodies the energy used to transport and store them from the factory to the store, and possibly distribution centers in between. Embodied energy includes energy requirements for extracting raw materials, producing components, manufacturing finished products, and processing and transporting. One major method to quantify embodied energy is the Input-Output Embodied Energy Analysis; Bullard and Herendeen (1975), Costanza (1980), Treloar (1998), Liu et al. (2012), and Yang et al. (2014) are a few examples.