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Impacts of trade related sustainability strategies on freight transportation: Modelling framework and application for France

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ABSTRACT

The circular and functional economies are being presented in the literature as potential strategies for future sustainable societies. In terms of the consequences for supply chains, they will promote a much more dispersed and diversified, local and network based usage of goods than the current economy, which is comparatively linear, concentrated, long distance oriented and scale economy based. A gap in the literature is the assessment of the effects of these systems on freight transport flows. In our paper, we present a first attempt at estimating this impact using freight transport scenario building and quantitative modelling. In order to translate the main parameters that characterize these systems into factors determining freight transportation volumes, we develop a framework based on a typology of goods categories describing functional and spatial proximity between producers and consumers. In order to simulate changes in the economy, we develop scenarios for the shifting of goods from one category to another and, additionally, include internalization policies that should guide their realization. We calculate the impacts on freight flows using a new interregional transport model for France that includes distribution chains and produces estimates of external costs of transport. Our results show that circular and functional economies could lead to a 2–5% reduction of air pollutant emissions and up to a 14–26% reduction if combined with the internalization of external costs. The scenario with ongoing mass production for differentiated demand is found to lead to a 5% increase of environmental impacts compared to the baseline.

1. Introduction

Since 1989 and the Brundtland report, sustainable development has been defined as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In this view, sustainability is organized around three pillars – economy, social, and environment – of which the efficient management should lead to the arrival of a sustainable society. The characteristics of such management have been the core of the debate among economists, sociologists and ecologists. Examples of debates include the substitutability of natural capital (Pelenc et al., 2015), the use of gross domestic product (GDP) as a measurement of social welfare (Fleurbaey, 2009) and the relevance of the concept of social and environmental externalities (McAfee, 1999). In this paper, we choose the position of a relative definition for sustainability, in which one situation is said more sustainable than the other if the former situation leads to less environmental impact

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than the latter one. Our aim is to study the impact of approaches or strategies that are said to bring about a world which is more easily sustainable than the current one: the functional and the circular economy.

Much progress in research towards reducing the environmental impacts of our societies has come from the field of Industrial Ecology. The core idea is the ecological metaphor, by which the linearity of our production–consumption system is criticized, comparing it to the circularity of flows within ecosystems. The resulting strategy is named circular economy (CE). It aims at copying the functioning of ecosystems by transforming wastes into resources, establishing a closed material cycle through minimization of dissipative emissions, dematerializing products and economic activities, and decarbonizing energy (Erkman, 1998). The circular economy has been recognized as a core sustainability strategy by State and International organizations (European Parliament, 2015; UNEP, 2015; Heck, 2006). The CE's main objective is thus environmental sustainability.

The same can be said from another strategy called functional economy (FE) recognized as a promising sustainable strategy by international and State bodies (UNEP, 2002; European Commission, 2004). Originally introduced by Giarini and Stahel (1989), the FE's core principle is the selling of the service provided by goods instead of goods themselves. This principle has also been denoted as product-service systems (Beuren et al., 2013). Concretely, it means that the company remains the owner of the goods constituting the inputs to the customers' required services. Therefore, the maximization of the goods' use instead of their productions becomes a core feature of companies' objectives. This latter point received interests from industrial ecologists as the number of goods produced may decrease as their use is optimized, resulting in a reduced environmental burden for society. In the past decade, the insight has been growing that FE can be an important condition for the CE (Maxwell et al., 2006; Vezzoli et al., 2015). The CE builds on FE in the sense that functions of used products, components and materials must be redefined beyond the physical appearance and the original use of the product, and characterized in terms of its functional properties. An important debate is still open, on the extent to which the FE will cause an acceleration of consumption and related increase in emissions, because of the improved fit with consumer needs that new product-service systems can offer (Bisiaux et al., 2014).

It is thus widely accepted that the strategies of FE and CE will have a profound effect on the economy and notably the manufacturing activities and their organization. An interesting gap in the literature is the assessment of the potential impact of these strategies on the transportation and logistics sector's activities. Currently, the assumed sustainability of CE and FE is based on the expectation of the reduction of material flows within the economy, but little is known on the logistic reorganization of flows induced by such reduction. Corresponding to the integrated management of all the activities required to move products through the supply chain, i.e. freight transport, storage, inventory management, materials handling and all the related information processing, logistics is a central issue in the relationships between producers and customers. In the case of CE and FE, an increasing density of linkages between manufacturing firms, replacing transport of waste and new inputs may cause lower freight transport volumes and lower transport distances. At the same time, the value of products per unit weight may increase, due to an increase of the value added in the supply chain when waste is recycled. Besides, freight transportation is also an important contributor to the environmental issues of climate change and local air pollution. It accounts for over a fifth of energy related global greenhouse gas emissions (IEA, 2010) and it produces as much as 36% of 2012 carbon dioxide (CO_2) French emissions (CITEPA, 2011). Other harmful car exhaust emissions include sulfur dioxide (SO_2), particular matter (PM10), nitrogen oxides (NOx), non-methyl volatile organic compounds (NNMOV) and carbon monoxide (CO). It is thus important to understand if the changes induced by FE and CE on the organization of manufacturing activities and trade will lead to reduction or an increase of freight and logistic related environmental impacts. Sustainable logistics studies have traditionally focused on emission reduction from freight transport, for example through the improvement of exhaust and engine efficiencies, modal shift, or the increase of vehicle capacity and filling ratio (McKinnon et al., 2015). So far, assessments of sustainability strategies in freight transportation have focused on measures initiated by the sector itself (see e.g. Wong et al., 2016, for a recent review), policies aiming at specific company decisions such as the choice of mode of transport (McKinnon et al., 2015) and generic policies intending to internalize the external costs of transport (see e.g. Piecyk and McKinnon, 2007; Tavasszy et al., 2016). Recent literature has started to broaden the usual content of sustainable logistics to include the recent theories of CE and FE. Here, we will not expand on the theoretical links between CE, FE and sustainable supply chains. Our focus is on an empirical framework to assess the macro level impacts of CE and FE through freight transportation. We refer the interested reader to the following texts: the principles of CE and links to sustainable SCM are explained in Genovese et al. (2015) and Ghisellini et al. (2016). Tukker (2015) explains the roles and expected impact mechanisms of CE and FE on sustainability. Gallaud and Laperche (2016), departing from the French tradition of spatial analysis, make the important link to spatial and functional proximity as a central characteristic of CE. Brandenburg et al. (2014) review quantitative models for SSCM but do not focus on models that predict impacts of CE and FE on freight transportation volumes at macro (i.e. national or regional area) level.

Our research objective, therefore, is to explore the possible impacts of CE and FE on freight transportation and its emissions. Our main contributions to the literature are threefold. Firstly, to our knowledge, an assessment of the effects of CE and FE strategies on freight transportation volumes has not been attempted before. While CE and FE strategies are usually studied from the production or consumption viewpoint, i.e. from the manufacturer or customer viewpoint, for our purposes we need to operationalize them from the viewpoint of the relation between these, focusing in particular on the notion of spatial and functional proximity between producer and consumer. This operationalization of the CE and FE strategies for logistics and freight transportation scenarios is to our knowledge original. Secondly, the impacts of these strategies are assessed in a quantitative, empirical way using an exploratory freight transportation model for France. We explain how the scenarios

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