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Transport-related CO_2 effects of online and brick-and-mortar shopping: A comparison and sensitivity analysis of clothing retailing

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ABSTRACT

This paper compares transport-related CO_2 emissions of online and brick-and-mortar shopping based on supply, delivery, order and travel data related to one multi-channel clothing retailer. A sensitivity analysis sheds more light on how situational factors, such as the customers' travel distances, returns, the use of public transport modes and information behavior via different channels influence the outcome of this comparison. The results show that online retailing causes lower CO_2 emissions under many conditions. Nevertheless, the brick-and-mortar channel is more environmentally friendly when travel distances are small. The radius for which brick-and-mortar shopping has an advantage increases when returns, shifts in the use of public transport and information behavior are also considered.

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1. Problem delimitation

Managers of parcel services and online retailers may have concerns that customers question the environmental impacts of their delivery processes. People "perceive delivery vehicles in residential areas as noisy, dirty and a safety risk to vulnerable road users" (Cairns, 2005). Furthermore, people may believe that the delivery process in online retailing causes significant CO_2 emissions and thus that brick-and-mortar retailing is more environmentally friendly.[1]

While many studies of CO_2 effects focus on book distribution or consumer electronics, here we analyze CO_2 effects in clothing retailing; after electronics and books, this is the third most important category in online retail (Datamonitor, 2011). In clothing retailing, customers may be willing to travel longer distances to their preferred brick-and-mortar store and return rates in online shopping are high. Sensitivity analyses shed light on the conditions under which brick-and-mortar retailing might cause fewer CO_2 emissions than online shopping. The analysis considers travel distances to the store, return rates, public transport use and information behavior. The comparison and sensitivity analysis is based on shopping data from a German multi-channel clothing retailer.

2. Method

The clothing retailer has stores in several big cities and an online shop, focusing on a specific market segment in which it has a strong retail brand. Its stores are well known for their unique atmosphere, also attracting customers from longer distances. The online shop offers the same assortment of merchandise as the brick-and-mortar-stores. The majority of

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[1] This concern is supported by a small survey of customers at two retail stores to rate the environmental friendliness of both channels: 53.7% thought brick-and-mortar shopping to be less environmentally damaging, 32.4% believed the opposite and 13.9% were unsure.

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parcels are delivered by a European parcel service. Generally, the selected store and the online system are both typical for multi-channel clothing retailers with strong retail brands, mostly running large stores in major cities.

The analysis starts at the retailer's central warehouse, which is the initial point for the stores' supplies and the delivery of online orders. The first part of the supply chain is the same for both channels and the central warehouse is "the point at which there is no difference between store and e-shopping" (Mokhtarian, 2004).

Both channels are compared in terms of their CO_2 emissions. We keep the focus on the impact of transportation. In doing so, we exclude the energy use of running the stores and the customers' shopping on the Internet. We assume that the shopping locations, i.e. traditional stores and the internet shop, run anyway, aiming to evaluate the effects caused by the customers' shopping behavior only. In this way, we focus on the medium-term rather than the long-term perspective. The latter would include more complex decisions like changing the energy supply to a more environmentally-friendly supplier or closing down stores.

2.1. CO_2 emissions for the brick-and-mortar supply chain

Starting from the central warehouse, the brick-and-mortar supply chain consists of two processes: transport from the central warehouse to the stores and the customers' trips to the stores. The retailer provided information about the store supply, such as distances, vehicles used and frequencies for two stores. Store 1 is located in the center of a major city. Store 2 is situated a little outside the center in another city, close to the retailer's central warehouse. We chose differently located stores to compare various situations. The supply of store 1 entails a tour of 437.0 km, while that of store 2 only involves 10.7 km. Store 1 is served six times per week, store 2 five times. The average load per tour is 3000 parcels for store 1, and 2200 for store 2. To calculate the CO_2 emissions caused by transporting the goods to the stores, initially the fuel consumption of the vehicle used is calculated in terms of its load factor and then the fuel consumption is multiplied by the CO_2 factor of the fuel. For the combustion of diesel, this factor is 2.629 kg of CO_2 per liter (Kranke, 2009).

Customer journeys are analyzed based on a customer survey conducted in the stores examined. Both stores can be reached by public transport, car and bicycle or on foot. The questionnaire surveyed the trip to the store, such as the transport mode used, trip chaining, the customer's postal code and the products bought. The survey was conducted behind the cash desk of the two stores. Consequently, only people who bought something were interviewed. A sample of 702 questionnaires was used, of which 327 were collected in store 1 and 375 in store 2.

To calculate the CO_2 emissions for the shopping trip caused by the customers' journeys, we used recent information on the CO_2 emissions per passenger-kilometer for the different transport modes: 144 g of CO_2 for cars, 73.5 g of CO_2 for public transport (Statistisches Bundesamt, 2008) and 139.5 g of CO_2 for a motorbike (Schächtele and Hertle, 2007). Besides, a decision had to be made as to how to deal with customers walking or cycling to the stores. These trips do not generate any CO_2 emissions but are relevant shopping trips. Therefore, these datasets were included in the analysis. To determine the CO_2 emissions of each customer trip, the double distance between the customer's home (postal code) and the store was multiplied by the CO_2 emissions of the transport mode used. The CO_2 emissions of each purchase were then calculated by adding the emissions caused by the store supply and customer travel. To simplify the analyses, it is necessary to make a major assumption; only emissions for trips in which shopping at the retailer was the main reason for the trip are taken into account. No CO_2 emissions are assumed for datasets where shopping at the retailer was not the main reason for traveling.

2.2. CO_2 emissions for the online supply chain

We calculated the CO_2 emissions for the processes along the online channel based on information provided by the retailer about the orders from the online shop, i.e. the parcels' destinations and articles ordered. A dataset of 40,000 orders delivered over four weeks was used. The parcel service provided detailed information about the parcel delivery process, such as distances, the vehicles used and their load. The online supply chain consists of three processes, also starting from the central warehouse. The parcels are transported to the outbound-depot close to the central warehouse (outbound-process), then allocated to the inbound-depots close to the customers' destinations (line-haul) and, finally, delivered to the customers (inbound-process). Contrary to Weber et al. (2009) and Matthews et al. (2001) and others, no airfreight is used along this supply chain due to the small distances involved.

The three processes in the online supply chain are of different lengths. The outbound process is quite short, involving 13.0 km (doubled for the calculation because the distance is driven only for the parcel delivery). The line-haul has an average length of 388.8 km. With an average of 1.3 km driven per parcel, the inbound-process covers the shortest distance and is calculated by the 200 km of a delivery trip divided by 150, the average number of parcels transported. For calculating CO_2 emissions from the online supply chain, we use the same approach as for brick-and-mortar retail.

3. Results

3.1. General comparison

To calculate the emissions of brick-and-mortar shopping, the store supply process and the travel behavior of customers have to be analyzed. The supply of store 1 requires transport over a distance of 437.0 km. For store 2, the distance is only

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