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Measuring transport related CO_2 emissions induced by online and brick-and-mortar retailing

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ABSTRACT

We develop a method for empirically measuring the difference in transport related carbon footprint between traditional and online retailing ("e-tailing") from entry point to a geographical area to consumer residence. The method only requires data on the locations of brick-and-mortar stores, online delivery points, and residences of the region's population, and on the goods transportation networks in the studied region. Such data are readily available in most countries. The method has been evaluated using data from the Dalecarlia region in Sweden, and is shown to be robust to all assumptions made. In our empirical example, the results indicate that the average distance from consumer residence to a brick-and-mortar retailer is 48.54 km in the studied region, while the average distance to an online delivery point is 6.7 km. The results also indicate that e-tailing increases the average distance traveled from the regional entry point to the delivery point from 47.15 km for a brick-and-mortar store to 122.75 km for the online delivery points. However, as professional carriers transport the products in bulk to stores or online delivery points, which is more efficient than consumers' transporting the products to their residences, the results indicate that consumers switching from traditional to e-tailing on average reduce their transport CO_2 footprints by 84% when buying standard consumer electronics products.

Introduction

Environmental considerations are at the center of the agenda for politicians in many countries and much research is devoted to meet the challenges of climate change, sustainability, and related environmental issues. The environmental impact of retailing on CO_2 emissions should not be underestimated. In Great Britain, the average consumer over 16 years old made 219 shopping trips and traveled a total of 926 miles for shopping in 2006 (DfT, 2006). Considering that most of these trips were reportedly made by car, and that transport vehicle miles traveled is the main variable determining CO_2 emissions, ways to reduce car use for shopping are sought (Cullinane, 2009).

In a Swedish setting, Carling et al. (2013a) studied the environmental optimality of retail locations, finding that current retail store locations were suboptimal. The suboptimal location of retailers generated on average 22% more CO_2 emissions than did a case in which they were optimally located. Furthermore, in a related study, Carling et al. (2013b) used GPS data to track 250 Swedish consumers for two months. In that study, the authors compared downtown, edge-of-town, and

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out-of-town shopping in terms of the CO_2 emissions caused by shopping trips. They concluded that downtown and edge-of-town shopping were comparable in transport CO_2 emissions, but that out-of-town shopping produced approximately 60% more emissions from transportation.

As traditional brick-and-mortar shopping entails substantial environmental impact, it would be pertinent to compare the CO_2 emissions from transportation induced by brick-and-mortar shopping with those of online shopping that needs a physical distribution. Few recent empirical studies (e.g., Edwards et al., 2010; Wiese et al., 2012) analyze the impact of online shopping on the environment. Wiese et al. (2012) studied the CO_2 effects of online versus brick-and-mortar shopping for clothing in Germany; their main finding is that, although online shopping usually induces lower CO_2 emissions, the opposite is true when the distances involved are moderate. In a study of the carbon footprint of the "last-mile" deliveries of conventionally versus online-purchased goods, Edwards et al. (2010) found that neither home delivery of online purchases nor conventional shopping trips had an absolute CO_2 advantage, though home delivery of online-bought goods likely entailed lower CO_2 emissions unless the conventional shopping trips were made by bus.

In this paper, we address the issue of emissions along the entire supply chain from entry point to the studied region to consumer residence for all major suppliers of the product under study.

Our study aims primarily to develop an empirical method for measuring the transportation CO_2 footprint of brick-and-mortar versus e-tailing that call for a physical distribution from entry point to a region or country to consumer residence.[1] This method will then be used to calculate and compare the environmental impact of buying a standard electronics product online with buying the same product in a brick-and-mortar store in the Dalecarlia region in Sweden. In addition, the actual locations of brick-and-mortar stores and online delivery points in the region will be compared with the locations that would minimize CO_2 emissions.

Our paper contributes to the literature in the following way. First, contrary to previous studies, the method developed makes it possible study all transport related emissions from entry into a region of interest and to the consumer residence in it. Previous studies have either been analyzing the transport related emissions within one retail chain (Wiese et al., 2012) or been focusing on the carbon footprint of the "last-mile" deliveries of conventionally versus online-purchased products (Edwards et al., 2010). Second, our method allow for simulations of how different locations of both brick-and-mortar stores and online delivery points, as well as different logistic solutions for the distribution of the goods, affects emissions. As such, our method could also be used when constructing environmentally friendly retail networks that minimize consumer travel. Third, the method also allow for simulations of changes in how attractive a consumer finds a brick-and-mortar store relative to online shopping, and the consumer's willingness to travel to shop for the product under study.

We will focus on consumer electronics, as these consumer products constitute the largest e-tailing category in Sweden (HUI Research, 2014), presumably leading the way to online shopping for other consumer products in the future. Consumer electronics are in the vast majority of cases imported into Sweden,[2] and pre-shipping via an entry port is required before a product reaches a consumer's residence, regardless of whether the product is bought online or in a store. Consequently, the product's route on the Swedish transportation network to the consumer's residence can be identified. In brick-and-mortar shopping, the route extends from the entry port via the store to the consumer's residence, while in online shopping, it extends from the entry port via the Swedish Post distribution points to the residence. Part of the route is covered by professional carriers, such as Swedish Post, and other parts of the route are covered by the consumer. We focus on the CO_2 emissions of the complete route from regional entry point to consumer residence.

The study concerns the Dalecarlia region in central Sweden containing approximately 277,000 consumers, whose residences are geo-coded. The region contains seven brick-and-mortar consumer electronic stores and 71 delivery points for online purchases. Consumers reach the stores or delivery points via a road network totaling 39,500 km. Mountains in the west and north of the region restrict the number of gateways into the region to three from the south and east, limiting the routing choices of professional carriers. The region is representative of Sweden as a whole in terms of the use of e-tailing and shares many geographical, economic, and demographic characteristics with, for example, Vermont in the USA.

This paper is organized as follows. Section 2 'Online and brick-and-mortar retailing of consumer electronics in Sweden' thoroughly describes online shopping in Sweden in 2012 and 2013. Section 3 'Data and method' gives details of the data and the heuristic algorithm used in finding optimal locations. Section 4 'Empirical analysis of CO2 emissions induced by consumers shopping' presents the empirical analysis, which starts by calculating the environmental damage induced by buying a standard consumer electronics product online versus in a local brick-and-mortar store. The results are also aggregated to the whole of Sweden for e-tailing in general as well as for consumer electronics products. Section 5 'Robustness of the measurement method' presents a sensitivity analysis incorporating all assumptions imposed, to arrive at the results presented in section 4 'Empirical analysis of CO2 emissions induced by consumers shopping'. Finally, section 6 'Discussion' concludes the paper.

[1] Note also that this implies that the development of theory or a conceptual framework is outside the scope of this paper. The interested reader is referred to Cullinane (2009) for the outline of a conceptual framework regarding how e-tailing affects the environment.

[2] There are a few producers of consumer electronics that still manufacture their products in Sweden, but in most cases R&D and design are made in Sweden while production is located in low wage countries like China. Also, consumer electronics is the industry that has had the most rapid outsourcing of production in the Swedish economy, with textile manufacturing and rubber manufacturing as the only industries with nearly as much of the production being outsourced to low wage countries (Lennartsson and Lindholm, 2004).