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Title **CO2-emissions from transportation induced by online and brick-and-mortar retailing**

Track General Papers

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Abstract Environmental aspects are on the top of the political agenda and much research is devoted to meet the challenges of climate change and sustainability. The impact of the retail industry on CO2-emissionsshould not be underestimated. In for instance Great Britain, the average consumer over 16 years of age made more than 200 trips to shop in 2006, and the total travel distance to shopping was more than 900 miles (DfT, 2006). Since most of these trips are reported to be done by car, and since vehicle miles travelled is the main variable determining the CO2-emissions,methods to reduce car usage in shopping is being sought in Great Britain(Cullinane, 2009).In an empirical study in Sweden, Carling et al. (2013a) scrutinized the optimality of retail locations from an eco-friendly point of view. They found that current location of retail stores is not optimal. It was calculated that the sub-optimal location of retail stores generates 22% more CO2-emissions from excess travel compared with a case where they were optimally located. In two related studies, Jia et al (2013) and Carling et al. (2013b) GPS-data were used to track travel behavior of 250 Swedish consumers in the city of Borlänge during two months. In Jia etal (2013) it was found that consumers normally traveled the shortest route to fromthe home to the shopping establishment. In Carling et al (2013b) the focus was to compare downtown, edge-of-town and out-of-town shopping with regard to theCO2-emissions caused by shopping trips with car. They concluded that out-of-town shopping resulted in approximately 60% more CO2-emissions compared to downtown and edge-of-town shopping which were comparable. Since traditional brick-and-mortar shopping implies a substantial environmental impact, it is of interest to compare the CO2-emissions induced by brick-and-mortar stores with those of online shopping. There is a limited empirical literature (e.g. Wiese et al., 2012; Edwards et al., 2010) analyzing the impact of online shopping on the environment. Wiese et al. (2012) studies the CO2-effectsof online and brick-and-mortar shopping for clothing in Germany. The core finding of their paper is that, although online shopping in most cases induces lower CO2-emissions, the opposite is true in situations where distances to the stores are modest. In a study focusing on the carbon foot printof the “last mile” deliveries of brick-and-mortar and online bought goods, Edwards et al. (2010) found that neither home delivery of goods bought online nor shopping trips to brick-and-mortar stores had an absolute CO2advantage though home delivery of online bought goods was likely to imply lowerCO2-emissions unless the shopping trips to brick-and-mortar store were made by bus. It can be concluded from the current literature of online shopping and the CO2-emissions that previous studies has ignored all transport work but the last mile. It has also ignored the long term general equilibrium effects associated with increased online retailing. In this paper we address both the issue of emissions all along the supply chain from point of entry into Sweden[1]to the residence of the consumer, as well as the potential impact of long term general equilibrium effects of increased online retailing. The primary aim of our study is to calculate and compare the environmental impact of buying a standard electronic product online with buying the same product in a brick-and-mortar

store. To do so we focus on consumer electronics as this category of consumer products is the largest category in online retailing in Sweden and probably is leading the way for online shopping of other consumer products in the future. All consumer electronic goods are imported to the country and pre-shipping via some entry-port is therefore required before reaching the consumer's home regardless if the product is bought online or in a consumer electronics store. Consequently, the route of the product on the Swedish road network to the consumer's home can be identified. Either, in the case of brick-and-mortar shopping, it will be from the port via the store to the consumer's residence or, in the case of online shopping, from the port via the Swedish Post's distribution points to the home. Part of the route will be covered by professional carriers such as the Swedish Post or the other ones employed by retailing firm. Another part of the route will be covered by the consumer. We focus on the CO2-emissionsdue to travelling the complete route. The geographical setting of the study is the region Dalecarlia in the mid of Sweden containing some 277,000 consumers with their homes precisely geo-coded. In the region, there are currently 7brick-and-mortar consumer electronic stores and 71 delivery points of products bought online. The consumers reach the stores or the delivery points via a road network amounting to 39,500 km. Natural barriers restricts the number of gateways into the region to three from the south and east, making the routing choice for the professional carriers limited. The current location of stores and postal delivery point could be suboptimal. We use the p-median model (Hakimi 1965) to find the best possible location from transportation point of view in order to evaluate the full potential of reduction in CO2-emission. Since the p-median problem is NP-hard we use a heuristic algorithm, Simulated Annealing, to find good solutions of locations.The empirical results show that a purchase of a stationary computer on line instead of in a brick and mortar store on average give about 84% lower CO2-emisions. Scaled up to national level and the total sales of consumer electronic packages, the growth of e-commerce retailing has led to a yearly reduction of CO2-emissions from transportation of about 28 million kg in Sweden. In addition, potential long term general equilibrium effects of increased online retailing such as the exit and/or relocation of mortar-and-brick stores and potential effects on consumer demography are also analyzed. The results are stable for most assumptions, except in the case where consumers first visit the brick-and-mortar store and thereafter order it online. References DfT (2006) National Transport Survey: 2006 (London, TSO).Cullinane, S. (2009) From bricks to clicks: The impact of online retailing on transport and the environment. Transport Reviews, 29, 759-776.Carling, K., Håkansson, J. and N.Rudholm (2013a) "Optimal retail location and CO2-emissions". Applied Economic Letters, 20:14,1357-1361.Carling, K, Håkansson, J, and Jia, T (2013b) Out-of-town shopping and its induced CO2-emissions, Journal of Retailing and Consumer Services,20:4, 382-388.Edwards, J.B., McKinnon, A.C. and S.L. Cullinane (2010) Comparative analysis of the carbon footprints of conventional and online retailing: A "last mile" perspective. International Journal of Physical Distribution & Logistics Management, 40, 103-123Wiese, A., Toporowski, W. and S.Zielke. (2012) Transport-related CO2 effects of online and mortar-and-brick shopping: A comparison and sensitivity analysis of clothing retailing. Transportation Research A, 17, 473-477. Jia, T, Carling, K, and Håkansson,J, (2013) Trips and their CO2 emissions induced by a shopping center, Journal of Transport Geography, 33,135-145. Hakimi, S.L., (1965) Optimum distribution of switching

centers in a communications network and some related graph theoretic problems. Operations Research 13, 462-475.Hakimi, S.L., (1964) Optimum locations of switching centers and the absolute centers and medians of graph. Operations Research 12:3, 450-459.[1] More precisely, to the point of entry of the region in Sweden which is used in the empirical analysis.