The effect on CO_2 emissions of taxing truck distance in retail transports

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Abstract

To finance transportation infrastructure and to address social and environmental negative externalities of road transports, several countries have recently introduced or consider a distance based tax on trucks. In competitive retail and transportation markets, such tax can be expected to lower the demand and thereby reduce CO_2 emissions of road transports. However, as we show in this paper, such tax might also slow down the transition towards e-tailing. Considering that previous research indicates that a consumer switching from brick-and-mortar shopping to e-tailing reduces her CO_2 emissions substantially, the direction and magnitude of the environmental net effect of the tax is unclear. In this paper, we assess the net effect in a Swedish regional retail market where the tax not yet is in place. We predict the net effect on CO_2 emissions to be positive, but off-set by about 50% because of a slower transition to e-tailing.

Keywords: Spatial distribution of e-tailing and consumers; CO_2 emissions measurement; online retailing; environmental taxes; carbon footprint; road network.

JEL codes: D22, L13, L81, R12

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1. Introduction

A negative externality arises from road transports due to fossil fueled vehicles emitting CO_2. To internalize the external costs of CO_2 emissions in general, the cap and trade system termed EU Emissions Trading System has emerged in Europe. However, the transport sector is left out of the system even if the road transports are affected by the fuel taxes that frequently are environmentally motivated. Moreover, in some countries such as Switzeerland (in 2001), Austria (in 2004), Germany (in 2005), Czech republic (in 2007), Slovakia (in 2010) and Poland (in 2011) a Vehicle Miles Travelled tax (VMT-tax or kilometer tax) has been imposed on (primarily) trucks. The foremost rationale for a VMT-tax is the financing of transportation infrastructure, but also to address social and environmental negative externalities of road transports (e.g. Calthrop et al 2007; Sorensen and Taylor 2008; Hammar et al 2011; Brännlund 2013; Stelling 2014; Jenn et al 2015). Several governments are contemplating the VMT-tax including the newly installed Swedish government. The scheme of the Swedish version of a VMT-tax is to charge a fixed value per kilometer on trucks. Hammar et al (2011) studied how the Swedish manufacturing industry would be affected in terms of their competiveness by the introduction of a VMT-tax on trucks, and their results show that the tax would decrease transport demand while increasing the demand for labor.

Transports are essential for retailing, which in turn is a core activity in most economies. Products are usually distributed by trucks to market places to which consumers travel with cars. Retailing is however gradually shifting towards e-tailing, i.e. the consumer orders the product online rather than buy it in a brick-and-mortar (BM) store, and has it transported by a professional carrier to (in Sweden, uncommonly) the home or to a delivery point in the vicinity of the consumer’s home. Carling et al. (2015a) found empirically that e-tailing implies a more efficient transportation of the product thereby leading to substantially less CO_2 emissions (the reduction in CO_2 emissions in the standard model was estimated to be 84%).

A VMT-tax in a competitive retail market can be expected to increase the retail price due to increased transportation costs and thereby lowering the demand such that transports and its CO_2 emissions related to retailing decreases. However, the relative price for the consumer of shopping online compared to in a BM-store would increase at the same time. Hence, it is to be expected that a VMT-tax will slow down the transition towards e-tailing, thereby counter-acting the anticipated reduction in CO_2 emissions resulting from more e-tailing in the future (cf Culthrop et al 2007).

Calthrop et al. (2007) considered the case when an externality is jointly produced by the use of intermediate inputs by firms and the consumption of final goods by households and referred to partial taxing if only one of the agents incurred the tax. They specifically discussed VMT-tax on trucks while private transports are exempted from it. Their theoretical modelling led them to the conclusion that a partial tax to internalize the externality may actually have negative welfare effects.

The aim of this paper is to estimate the net effect of a VMT-tax on CO_2 emissions related to transportations in the retail sector. Hence, the contribution of this paper is to complement the theoretical analysis of Calthrop et al. (2007) by assessing the effect of a partial tax. The effect is studied in a representative regional retail market in Sweden focusing on consumer electronics. Consumer electronics is the category of products most purchased online and believed to lead the way to e-tailing of other categories of retail products.

This paper is organized as follows. In section 2 we outline a simple microeconomic model for consumers' transition to e-tailing. This model is used for projecting the transition towards e-tailing in the region under study in the cases with and without a VMT-tax. In section 3 the data of the regional retail market is presented and the method for measuring CO_2 emissions, in various scenarios, related to a consumer's shopping is outlined. Section 4 presents results on how the VMT-tax affects CO_2 emissions induced by shopping related transports. In section 5 we discuss the sensitivity of the results to the assumptions made and make a concluding discussion.

2. The switch towards e-tailing

The introduction of a VMT-tax for trucks will affect the demand for retail products in two distinct ways. First, assuming that both the retail and the transport markets are competitive[1], the tax will increase the price, including the cost of transports to the BM-store or the online delivery point and thereafter to the consumer residence, of the product[2]. This part of the tax is anticipated to reduce CO_2 emissions as the demand for products and their transportation

[1] In the Swedish case the consumer electronics market is under a fierce competition. Carling et al (2015) discussed the consumer electronics market in Sweden and pointed at the substantial number of vendors filing for bankruptcy. The Swedish transport sector is also subject to tough competition as a consequence of the recent surge in cabotage within EU.

[2] A consumer may purchase one product or a package of products at the time. The transportation is primarily related to the occasion of purchase, not to the number of products. We will therefore use product and parcel of products interchangeably.

decreases, and where the magnitude of the reduction will be dependent on the price elasticity of the products.

The second effect, largely overlooked in the Swedish debate, of the tax is that it will change the relative price of e-tailing versus traditional BM-store shopping, and this change in relative price will also have an effect on CO_2 emissions. To focus on how the tax will affect the on-going transition towards e-tailing, and this in turn affects emissions, we assume that the total market demand for the products under study is perfectly inelastic with respect to prices, and focus only on how the share of e-tailing is determined by the relative prices.

To make this idea operational in a simple way, suppose that the consumer faces a utility gain if the choice of e-tailing decreases the price of the product including transportation. A similar model was used by Aronsson et al. (2001) when analyzing how relative price differences between brand name and generic pharmaceuticals affected brand name market shares. Let Δu_t be the total discounted change in expected utility of the consumer if changing from a BM-store to an online retailer in period t. We simplify further by assuming that Δu_t depends only on the observed price of the product at the BM-store relative to the e-tailing price, including transportation cost in both cases. That is:

$$\Delta u_t = \frac{n}{(1-\delta)}\left(\frac{p_t^{bm}}{p_t^o} - 1\right) \qquad (1)$$

where n is the number of purchases of the consumer product during the period under study and δ is a discount factor. This formulation means that the utility change is positive (negative) if the price including transportation in the store exceeds (falls short of) the e-tailing price. To be specific on the cost of transportation we take:

$$p_t^{bm} = \bar{p}_t + \alpha_t^C d^{bm} + \alpha_t^T \bar{d}^{bm} \qquad (2)$$

$$p_t^o = \bar{p}_t + \alpha_t^C d^o + \alpha_t^T \bar{d}^o \qquad (3)$$

where $\bar{p}_t$ is the price of the product excluding the transportation costs assumed identical for the two shopping alternatives, α_t^C and α_t^T the kilometer cost for the consumer's car and the truck respectively. Moreover, d^{bm} and d^o are the consumer's distance to the BM-store as well as the online delivery point and $\bar{d}^{bm}$ are $\bar{d}^{o}$ the corresponding for the truck transporting the product from the entry point into the region and to the BM-store or online delivery point.[3]

Today most consumers still patronize BM-stores in spite of a relative price in favor of e-tailing when also including transportation costs, i.e. $p_t^o < p_t^{bm}$. We therefore also assume that the consumer is attached to brick-and-mortar shopping. As such, the consumer incurs a switching cost (cf Aronsson et al 2001), s_t (in utility terms), if she changes to e-tailing, and the cost differs between consumers depending on the attachment to BM shopping. Given that a consumer patronized the BM-store in period $t-1$, she will switch to e-tailing in period t if:

$$\Delta u_t - s_t > 0 \qquad (4)$$

i.e. if

$$\gamma(\frac{p_t^{bm}}{p_t^o} - 1) - s_t > 0 \qquad (5)$$

where γ = n / (1-δ). To be able to relate equation (5) to the transition to e-tailing, let the switching cost be uniformly distributed in all periods and thus independent of time. That is, in every period, a new switching cost is drawn from a uniform distribution, i.e. $s_t \sim U(0, b)$. This means that the consumer either will switch in the first period or have a positive chance of switching in the second period where the likelihood of having switched increases monotonically by time. Eventually, all consumers will have switched to e-tailing since the consumers may not re-switch and non-switchers always have a positive probability of switching in the next period. However, it will take a long time for the last consumer to having switched since the probability of not having switched only approaches zero asymptotically.

The upper limit, b, of the uniform distribution will determine the speed of transition towards e-tailing where a low, positive value of the parameter implies a fast transition and a high value a slow transition. An empirical estimate of b will thus be instrumental if we are to be able to empirically measure the second effect of the tax, and a standard approach to estimate the parameter is discussed in Section 3.

[3] The VMT-tax will increase the price and therefore it is expected to lower demand for consumer products, but it will also change the relative price between BM-store and e-tailing leading to a substitution from e-tailing. However, in principle it may also effect α_t^T as well as lead to a re-location of BM-stores and online delivery points thereby altering the shipping distances. Considering that re-location is costly in relation to the size of the VMT-tax, it seems far-fetched that a VMT-tax will provoke re-locations. As for the kilometer cost of trucks, α_t^T, one could imagine that the freight companies would adapt by, e.g., increasing capacity usage. In this case the reduction in demand and the substitution from e-tailing would be somewhat hampered.

From the work of Carling et al (2015a), we know that much more of the transportation is done by trucks in the case a product is being bought online than in a BM-store. As such, the two effects of the introduction of the VMT-tax can be identified. First, there will be a direct demand effect as transportation cost increases. Second, from Carling et al (2015a) and equation (5), we also know that the switch to e-tailing, ceteris paribus, will be countered by the tax. This is so because more of the transportation work is done by trucks in e-tailing compared with brick-and-mortar retailing, and the tax is imposed solely on trucks, thereby increasing the price of the product disproportionally more for online retailers, thus changing the relative price in favor of brick-and-mortar retailing.[4]

The second effect of a VMT-tax cannot readily be abstracted from as a consequence of the on-going transition towards e-tailing. Figure 1 shows the evolution of e-tailing of consumer electronics in the years 2003-2014 (solid line) in Sweden.[5] It is expected that the transition towards e-tailing will continue, although the future transition rate is of course hard to foresee (HUI research 2012, 2014). We estimated[6] the parameter *b* based on the historical data and produced two scenarios for the years 2015-2025 of the evolution of e-tailing in Dalarna, which is the region under study in the empirical analysis. The first scenario is the short dashed line in Figure 1 suggesting that about 34 % of consumer electronics will be bought online by the year 2025 in the region. This scenario implies that e-tailing of consumer electronics has matured and that the growth rate in the years to come is decreasing. We also consider a second scenario (long dashed line) where today's transition rate is maintained for the coming years resulting in e-tailing of about 42 percent by 2025.

We follow Carling et al (2015a) in focusing on consumer electronics, as these consumer products constitute the largest e-tailing category in Sweden (HUI Research 2014) and presumably leads the way to online shopping for other consumer products in the future. In this case, we will demonstrate that knowing the current share of e-tailing and how the introduction of the VMT-tax affects the relative price between the brick-and-mortar and online shopping is, after imposing some additional assumptions, sufficient for calculating the effect of the tax

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[4] An intriguing and complicating issue in e-tailing, not considered here, related to the assessment of the net effect of VMT-tax is the choice offered to the consumers of choosing the time-length of deliverance. By accepting a higher price, the consumer is offered speedier deliverance. The speedy deliverance is presumably less efficient and consequently less environmentally friendly. We speculate that the relative price of speedy deliverance would increase with a VMT-tax, leading more consumers to choose the slower and more environmentally friendly choice.

[5] There is uncertainty in the values of the years prior to 2010 and the time series should be considered indicative of the evolution of e-tailing. Source: HUI Research (2009).

[6] Details on the estimation in Section 3.

reform on the CO_2 emissions from consumer electronics retailing in Dalarna, Sweden. We will calculate the change in CO_2 emissions from retailing due to the introduction of the tax, and this change will be decomposed into the first direct effect on the demand of transports (hereafter denoted demand-effect) and the second effect on the transition towards e-tailing (hereafter denoted LOE-effect, loss of e-tailing effect) as discussed above.

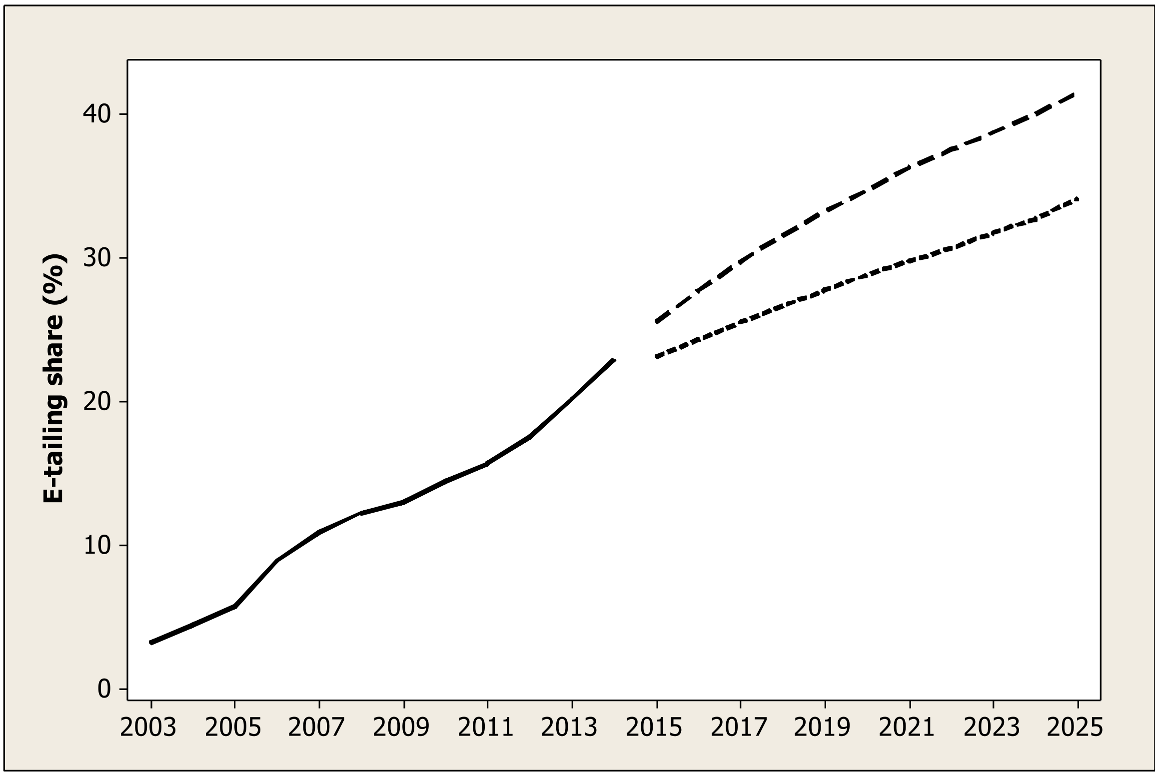

Figure 1: The share of e-tailing for consumer electronics in per cent. The solid line is the trend in Sweden. The short and long dashed lines are projections for the coming years in the region of Dalarna under different assumptions, both derived without the tax being introduced.

3. Data and evaluation method

Consumer electronics are in the vast majority of cases imported into Sweden, 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 BM-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's delivery points to the consumer's residence. Part of the route is covered by professional carriers' trucks, such as Swedish Post, and other parts of the route are covered by the consumer and her car. We focus on the CO_2 emissions of the complete route from regional entry point to consumer residence.

Following Carling et al (2013, 2015a), the study concerns the Dalarna 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 shares many geographical, economic, and demographic characteristics with, for example, Vermont in the USA. The routes of the trucks as well as the consumers in the empirical analysis to either the BM-store or the delivery point are optimized to provide the shortest distance.[7] To do so we follow Dijkstra (1959).

Dalarna is also representative of Sweden as it comes to e-tailing behavior (HUI research 2012). Swedish Post delivers most e-tail parcels in rural areas in northern Sweden, where over ten parcels per year and household are delivered in many northern municipalities. The three municipalities with the most parcels delivered are Storuman, Jokkmokk, and Gällivare, all located in the sparsely populated interior part of northern Sweden and all averaging 11.4–12.0 parcels delivered per year and household. In contrast, in most municipalities in southern Sweden, particularly the three largest cities, fewer than seven parcels are delivered per year and household. In the municipalities of Malmö, Gothenburg, and Stockholm, 5.9–6.1 parcels are delivered per year and household. The Dalarna region lies between the extremes of Sweden with seven to nine parcels delivered per year and household by Swedish Post, with two exceptions: in the municipalities of Malung and Sälen, in the remote north of the region, over ten parcels are delivered per year and household, while in Borlänge, in the center of the region and with a well-developed retail trade, fewer than seven parcels are delivered per year and household (HUI Research 2013).

E-tailing as shopping in BM-stores may entail shopping one or several products at the same occasion. Detailed information on multi-product shopping is hard to come by, and we will therefore consider a typical purchase (possibly consisting of several of products). In year 2012 it was reported (HUI Research 2012) that 20 million online bought parcels were delivered at a total value of SEK 30 billion. We will therefore consider a typical package to contain one or several products of an accumulated value of SEK 1,500. Furthermore for the aspect of

[7] We follow Carling et al (2015b) in the use of the region's road network and refer the reader to their work for details.

shipping, the package is assumed to be 0.25 cubic meters so it fits the trunk of an ordinary car.[8]

The truck carrying the package to either the BM-store or the delivery point is operated by a professional carrier using a Scania truck and a trailer with a standard loading volume of 100 m^3 respecting the Swedish restriction of 24 tons of load per vehicle. The Scania truck runs on diesel, emits 1.08 kg per km of CO_2 (according to the producer; see www.scania.com), and is assumed to be loaded to 60% of its capacity with identical packages, such that the consumer's package constitutes one of 240 in the load and is responsible for approximately 0.005 kg per km of CO_2. For the cost of transportation with the truck we follow Hammar et al (2011) in their study of the VMT-tax and its effect on manufacturing in Sweden and assume a cost per kilometer of 13.50 SEK.

To calculate the marginal cost and the CO_2 emissions of the consumer's transportation of the package from the BM-store or the delivery point we assume the following. First, the consumer drives a gasoline-powered Toyota Avensis 1.8 with CO_2 emissions of 0.15 kg per km[9], making the trip to pick up the package and return to her residence. The Toyota is five years old and is driven 10,000 km per year, its second hand value is SEK 103,000, and the consumer has a yearly cost for insurance, service, and other costs amounting to SEK 11,850 annually. The resulting cost per kilometer is SEK 3.20.

Emissions when on- and offloading the products and when moving it indoors are neglected, and emissions from transporting the products to the region's boundary from the manufacturer are assumed to be the same irrespective of its being purchased online or in a store and are thus set to zero in the calculations. Moreover, we stipulate that each person in Dalarna is equally likely to purchase the package, i.e., that there is no geographical variation in the likelihood of a purchase although there may be geographical variation in shopping at a BM-store or online.

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[8] Though road distance is not the same as CO_2 emissions, we nevertheless assume a perfect correlation between the two. We do this despite being aware that other factors, such as speed, time, acceleration, deceleration, road and weather conditions, and driver and vehicle types, are being ignored. Stead (1999), based on data from the 1989–1991 National Travel Survey, suggested using road distance as a proxy for vehicle emissions because of the ease of collecting and computing it. Previous work in Dalarna indicates that, while intersections and arterial roads imply higher emissions, emissions crucially depend on road distance (Carling, Håkansson, and Jia, 2013b; Jia, Carling, and Håkansson 2013). It is an approximation to replace CO_2 emissions with road distance, though it is a fairly good one, as also demonstrated in a sensitivity analysis by Carling et al (2015a).

[9] This emissions rate is according to the EU norm for testing car emissions and refers to driving on a mixture of urban and non-urban roads. In 2012, newly registered cars in Sweden emitted 0.14 kg per km of CO_2, whereas the existing car fleet in Sweden emitted somewhat more CO_2.

Maximum likelihood was used to estimate the value of b as in equation (5) and it was found to be 4.7. In estimating this parameter we proceeded as follows. We assumed 2001 to be the first year of e-tailing and defined the random variable T to be the number of years (starting the counter in 2000) until a switch from BM shopping to e-tailing. Further, we assumed that the variables in equation (5) are time-constant implying that T is geometrically distributed governed by a parameter p. p in turn relates to the sought parameter b as $p = \gamma(\frac{p^{bm}}{p^{o}} - 1)/b$ where we took the average of the relative price including transports between BM and e-tailing for all consumers in Dalarna to get b. In the ML-estimation of p one needs to consider that the data is incomplete (left and right censored) in that the observed e-tailing consumers by 2003 may have switched in any of the years between the start and 2003 and that the majority had not been observed to have switched by 2014. Hence, the likelihood contribution of a consumer, requiring t years to switch to e-tailing, is

$$L(t/b) = I[t \leq 3](1-(1-p)^{3}) + I[3 < t \leq 14]p(1-p)^{t-1} + I[t > 14](1-p)^{14} \quad (6)$$

where the indicator function $I[\cdot]$ takes on one if true and zero otherwise. The maximum of the likelihood function is found by a simple grid search.

At the outset all consumers in the region are labelled as having or having not switched to e-tailing in 2014 by applying equation (5) and assuming 2001 to be the first year of e-tailing in the region. Figure 2 illustrates how the share of e-tailing consumers varies spatially in the region according to the model. In the figure, the locations of the seven BM-stores as well as the online delivery points are also highlighted. As expected from the formulation of the theoretical model and in accordance with data available from surveys (HUI research 2012), consumers further away from the BM-stores (e.g. in the north of the region) are more likely to having switched to e-tailing by 2014.

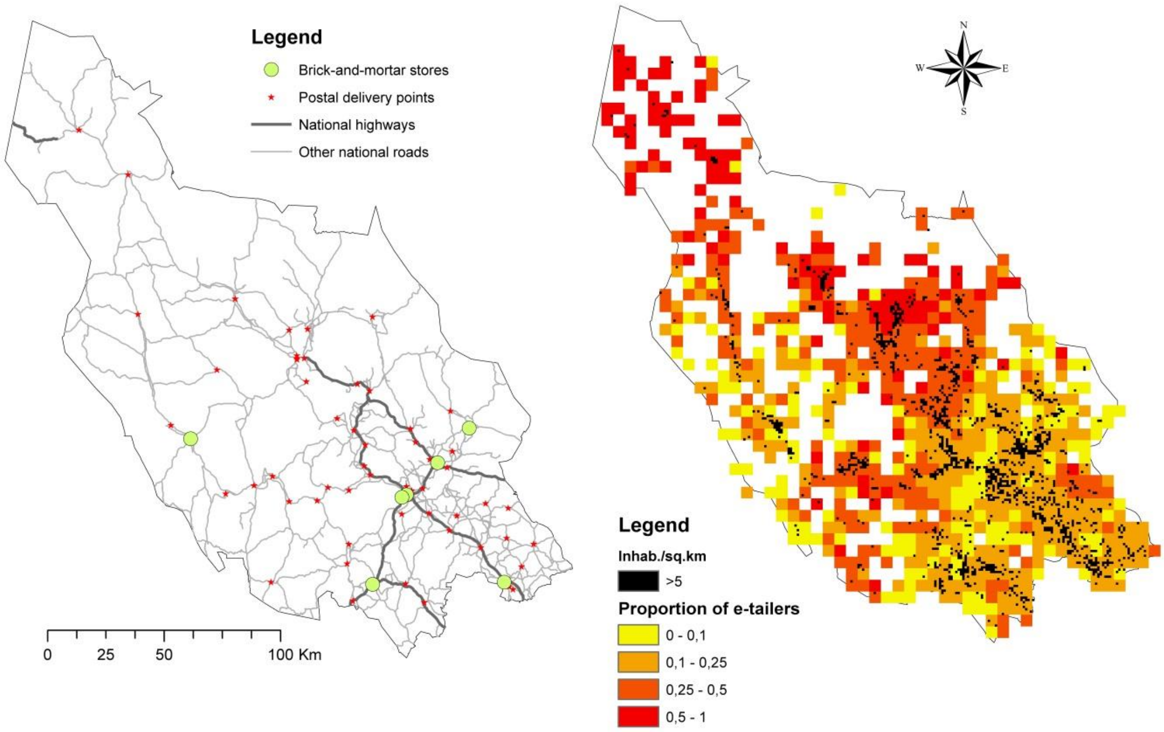

Figure 2: The model implied spatial distribution of e-tailing consumers in Dalarna as of 2014.

4. The estimated effects of the VMT-tax

The size of the VMT-tax has been debated, but not settled. Hammar et al (2011) assumed the VMT-tax to amount to SEK 3.67 per kilometer and we have considered the same value. Recalling that the kilometer cost for trucks was SEK 13.50, the tax implies a substantial increase in the marginal price of transportation. From the consumer's perspective, however, the transportation cost of the truck plays a marginal role on the price of the package. The average cost of truck transportation of the package was found to be less than SEK 25 to be compared with the total price SEK 1,500. Hence, it should not be expected that the VMT-tax will have strong behavioral effects on the consumers.

We examine how the VMT-tax affects the transition to e-tailing in the two scenarios depicted in relation to Figure 1 by assuming the tax to be introduced in the beginning of 2015. In Table 1a the projected proportion of switchers to e-tailing is given with and without the VMT-tax for the coming years under the first scenario of a moderate growth in e-tailing. In this scenario, the VMT-tax induces on average 0.43 percent less transition to e-tailing.

Table 1a: The effect of the VMT-tax on the e-tailing share and the CO_2 emissions related to a package of consumer electronics for the average consumer in Dalarna under four assumptions of the price elasticity for consumer electronics. First scenario.

	E-tailing share		Relative	CO_2 (kg)	Change (‰) in CO_2 with tax for elasticity of:			
Year	w/o tax	with tax	diff (‰)	w/o tax	0	0.2	0.5	1.0
2015	23.2	23.2	-2.6	4.953	1.6	-0.8	-4.4	-10.5
2016	24.4	24.3	-3.7	4.843	0.8	-1.7	-5.4	-11.8
2017	25.6	25.5	-4.3	4.721	2.5	0.0	-4	-10.6
2018	26.7	26.5	-6.7	4.623	1.1	-1.7	-5.8	-12.5
2019	27.8	27.7	-4.3	4.518	1.1	-1.5	-5.8	-12.8
2020	28.9	28.8	-4.2	4.420	1.4	-1.6	-5.9	-13.1
2021	29.8	29.8	-1.0	4.328	0.7	-2.3	-6.7	-14.3
2022	30.7	30.6	-3.3	4.254	1.6	-1.6	-6.1	-13.9
2023	31.8	31.7	-3.8	4.153	2.6	-0.5	-5.3	-13.2
2024	32.8	32.5	-10.1	4.017	4.5	1.2	-4.0	-12.4
2025	34.2	34.1	-3.2	3.893	2.6	-0.8	-6.2	-15.2
Average			-4.3		1.9	-1.0	-5.4	-12.8

We have computed the CO_2 emissions related to the transportation of a package of consumer electronics for the average consumer in Dalarna to be 7.59 kg if all shopping took place in BM-stores. In 2015 without a VMT-tax, the model suggests that 23.2 per cent of the shopping will be online thereby reducing the CO_2 emissions to 4.95 kg. With a growth in e-tailing to 34.2 per cent by 2025, the CO_2 emissions are further reduced to 3.89 kg. Introducing the VMT-tax in to the first scenario, the reduction in CO_2 emissions will be contingent on the price elasticity as illustrated in Table 1a. In the absence of a demand-effect, i.e. if the price elasticity is zero, the slower transition towards e-tailing due to the tax leads to 1.9 ‰ higher CO_2 emissions on average over the years to come. Making the reasonable assumption of a price elasticity of 0.5 (Clementz, 2008), the net effect of the tax is an additional reduction in CO_2 emissions with 5.4 ‰. Hence, it seems that the demand-effect of the tax on CO_2 emissions is countered to about 25 % (i.e. $(1.9/(1.9-(-5.4)))$ by the LOE-effect.

A similar analysis for the second scenario with a stronger growth in e-tailing is presented in Table 1b. In comparison with the first scenario, the faster growth in e-tailing implies a greater reduction in CO_2 emissions without the tax, whereas the demand-effect of the tax on CO_2 emissions is more pronouncedly countered by the LOE-effect. For the case of a price elasticity of 0.5, the LOE-effect seems to be about a half of the demand-effect (i.e. $(4.2/(4.2-(-3.9)))$.

In Section 2 and 3 we provided the rationale for the base-line settings of the parameters of equations 2 and 3, $\bar{p}_t, \alpha_t^C, \alpha_t^T$. It is obvious that the demand-effect is to some extent sensitive to the settings, however the LOE-effect in relation to the demand effect was found to be quite insensitive. We re-did the analysis after having changed the setting of $\bar{p}_t$ from SEK 1,500 to 500 as well as having increased the VMT-tax by 50% with respect to the base-line setting of SEK 3.69 per kilometer. The latter alteration could equally well be interpreted as a decrease is truck capacity utilization or a change in relative cost by truck versus private car transportation.

Table 1b: The effect of the VMT-tax on the e-tailing share and the CO_2 emissions related to a package of consumer electronics for the average consumer in Dalarna under four assumptions of price elasticity. Second scenario.

	E-tailing share		Relative	CO_2 (kg)	Change (‰) in CO_2 with tax for elasticity of			
Year	w/o tax	with tax	diff (‰)	w/o tax	0	0.2	0.5	1.0
2015	25.6	25.5	-6.1	4.718	2.8	0.2	-3.8	-10.4
2016	27.8	27.7	-3.6	4.515	2.2	-0.7	-4.9	-12.0
2017	29.8	29.6	-7.3	4.321	5.6	2.5	-1.9	-9.5
2018	31.7	31.4	-9.6	4.165	4.1	1.0	-3.8	-11.8
2019	33.3	33.2	-5.5	4.017	4.5	1.2	-4.0	-12.4
2020	34.8	34.7	-0.7	3.893	2.6	-0.8	-6.2	-15.2
2021	36.4	36.0	-9.4	3.765	7.7	4.0	-1.6	-10.9
2022	37.6	37.5	-3.8	3.668	4.1	0.0	-5.7	-15.5
2023	38.8	38.7	-3.6	3.566	5.9	2.0	-4.2	-14.3
2024	40.1	39.9	-6.0	3.459	2.9	2.0	-3.2	-7.2
2025	41.6	41.0	-12.8	3.351	4.2	0.6	-3.6	-14.9
Average			-6.2		4.2	1.1	-3.9	-12.2

5. Concluding discussion

The VMT-tax could provide a mean to fund roads when fuel tax revenues are in decline. Furthermore, it is commonly believed that it could also provide a mean to internalize some social and environmental negative externalities of road transports. We begin the concluding discussion by examining the VMT-tax as a mean for funding roads.

In Sweden as in many other countries, the road network is generally considered a public good and therefore financed by taxes (foremost as a tax on gas and other taxes related to car ownership, but recently to a greater extent also other taxes unrelated to transports). However from a theoretical perspective, a pure public good would optimally be funded by a lump-sum tax or from taxing any available stable tax-base. Hence, in this case it is not warranted a financing from the transport sector itself.

The common usage of a tax on gas to finance roads was however justified as a proxy to a user based fee, as the usages of the road network arguably is positively correlated with gas consumption (cf Sorensen and Taylor, 2006). A VMT-tax could possibly be a better proxy to road usages, particularly in a time when vehicles are run on more diverse sources of energy. The present limitation of VMT-tax to trucks is however making it far from optimal as the vast majority of the users of road networks are exempted from the VMT-tax.

As stated before, it is believed that a VMT-tax could reduce CO_2-emissions related to transports. Our results suggest that a VMT-tax would cause a trivial reduction on emissions in retail transports in the order of 0.5%. To put this reduction in perspective it is useful to consider the impact of the on-going shift towards e-tailing following from technological innovation in the distribution channel. The transportation of the package of products considered in this work was estimated to on average generate 7.59 kg of CO_2 emissions had it been purchased in a BM-store. Today the average is about 5 kg of CO_2 emissions as a consequence of 20% being e-tailed, and the projection by 2025 of 40% being e-tailed would lower the average to about 3.4 kg. The shift from BM-store shopping to e-tailing to 40% implies a reduction of about 50% CO_2 emissions in the transportation of the retail products.

We now return to the issue that taxing only trucks in the distribution of retail products implies a partial tax on the carriage of the product to the consumer's residence. From the theoretical work of Calthrop et al. (2007) it followed that the direction of the effect on CO_2 emissions of a partial taxing is unclear in spite of an obvious demand-effect. In the scenarios considered in this work, the demand-effect dominated the LOE-effect. However, we found that the LOE-effect was substantial (up to 50%) with regard to the demand-effect. Hence, in a cost-benefit analysis of VMT-taxing this work suggests that the indirect LOE-effect needs to be considered. Nevertheless, we think that it would be inappropriate to introduce a tax that would hamper the technological evolution of the distribution system in retailing. The reason is that the technological evolution according to our results will reduce the CO_2 emissions much more than a VMT-tax. It may also be noted that the optimal way to internalize the externalities of CO_2 emissions would be to tax the emissions directly.

The quantitative assessment of a VMT-tax presented in this paper is indicative, but of course contingent on the premises given in section 3. Carling et al (2015a) provided an elaborated sensitivity analysis with regard to the premises concerning demographic and geographical consumer behavior used in this paper. Further, they also examined different transportation modes and logistic solutions. The sensitivity analysis in Carling et al (2015a) suggested the results to be robust to changes in these premises and this will then also be the case in our setting.

Some of the premises underlying our analysis deserve a short discussion. We have for example assumed here that the consumer travels solely for the purpose of picking up the package of products. To the extent shopping is an on-the-flow or multi-purpose activity, it would be inappropriate to entirely attribute the CO_2 emissions of the travel to retailing. However, as noted earlier an in-depth study of consumer shopping trip behavior was conducted in Borlänge, a centrally located city in the region under study (Carling et al 2013b; Jia et al 2013), where some 250 volunteer car owners were tracked for two months using GPS, and the typical travel behavior for trips to a store selling durable goods such as consumer electronics was to drive the shortest route from the home to the store, and then back again. Consequently, we approximated shopping-related trips using the shortest route in our analysis.

In this paper we have examined the environmental impact of transportation related to the retailing of consumer electronics. Consumer electronics was chosen since this category of products is the one most purchased online and therefore the most mature category in e-tailing, and consumer electronics is believed to lead the way to e-tailing of other categories of retail products. As such, the market share of e-tailing is generally lower for other types of products. A comparison of the two scenarios of market share of e-tailing leads to the conclusion that the faster the growth in e-tailing, the larger the LOE-effect. Hence, it should be expected that an analysis conducted on other, less e-tailing matured products with a more rapid shift to e-tailing would yield an estimated LOE-effect greater than what we have found for consumer electronics.

Finally, the analysis abstract from the manufacturing of consumer electronics. It should be noted, however, that approximately 80% of the environmental impact of consumer electronics comes from manufacturing rather than transporting them (Weber et al. 2007). To properly internalize the social and environmental externalities of retail, manufacturing should be considered in addition to transports.

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