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Inge Vierth – VTI
Heike Schleussner – VTI
Svante Mandell – VTI & KTH

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Keywords: Road freight transport; road charges; policy comparison

Centre for Transport Studies
SE-100 44 Stockholm
Sweden
www.cts.kth.se

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Inge Vierth[a]
Heike Schleussner[b]
Svante Mandell[c]

[a] – VTI, Stockholm, CTS Stockholm, *inge.vierth@vti.se*

[b] – VTI, Stockholm, CTS Stockholm

[c] – VTI, Stockholm, CTS Stockholm & KTH, Royal Institute of Technology; *svante.mandell@vti.se*

Abstract

We compare policy implications from time-based charges on road freight transports, represented by the case of Sweden, to those from distance-based charges, represented by the case of Germany. The analyses based on official statistics from 2005-2014 indicate that the German road freight policy has resulted in substantially larger revenues and a cleaner truck fleet and mileage. Some support is found for that the German policy causes spill-overs to the neighbouring countries. It can be shown that the Swedish hauliers use cleaner trucks for international than for national transports. In general, the firms have incentives to use the cleanest trucks in the countries that have introduced distance-based tolls. As an estimate of the consequences of this in Sweden, the difference in environmental impact is estimated between the case with the actual composition of trucks using the Swedish network and the hypothetical case where the composition is the same as on the German toll roads. The socio-economic costs are estimated to be around € 16 million per year. This puts pressure on countries as Sweden to implement stronger policies to counter the spill-over effect. The time based charges, e.g., the Eurovignette, seem to be outdated.

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1 Introduction

The road freight transport market within the EU is nearly completely deregulated. Firms holding a licence to perform road freight transport in one EU-country are allowed to perform transportation to, from and through other EU-countries as well, except for some restrictions for cabotage transports. Even though the EU-market is deregulated, the policies towards road freight transport are to a large extent up to individual EU-countries to decide upon, as long as they do not violate the limits imposed by the EU.

The present paper studies the impact from different road freight policies. We mainly compare Sweden and Germany. Size, economy and transport system differ between these two countries. Even so, the comparison is of interest as Sweden and Germany have had a similar economic development during the last ten years but employ very different policy measures. In particular, they differ regarding infrastructure charging systems for trucks. Sweden applies the time-based Eurovignette to charge for the use of the roads. Germany introduced distance-based and Euro class differentiated tolls on the motorways and major roads in 2005 and has subsidised the purchase of clean trucks between 2007 and 2013. Also, Sweden allows trucks over 40 tonnes for domestic road transports, while Germany does not. We focus on how road freight policy has influenced the state budget, the composition of the truck fleet, the mileage (number of vehicle-kilometres) performed and the environmental impact over the last decade.

Our results indicate that the German road freight policy has resulted in substantially larger revenues and a cleaner truck fleet. Furthermore, we argue and find some support for that Swedish hauliers use their cleaner trucks in Germany and the less clean ones in Sweden. That is, the German policy causes spill-overs that affect the neighbouring countries. As an estimate of the consequences of this in Sweden, we estimate the difference in environmental impact between the case with the actual composition of trucks using the Swedish network and the hypothetical case where the composition is the same as on the German toll roads. The socio-economic costs are estimated to be around € 16 million per year.

The paper is organized as follows. The next section provides some background and a brief review of the literature. Section 3 summarizes the relevant policies in Sweden and Germany. Section 4, representing the main part of the paper, compares how the policies influence state budget, truck fleet, mileage and emissions. The analysis is based on official statistics, toll data from the Federal Office for Goods Transport *(BAG)* and the Federal Motor Transport Authority *(KBA)* in Germany as well as data from the Swedish Transport Administrations' emission forecasts. As far as possible, given limitations of the data, the period 2005-2014 is covered. The paper ends with summarising conclusions in section 5.

2 Background and literature review

The Eurovignette directive sets common rules for infrastructure charges for heavy trucks (Dir. 1993/89/EWG). Initially it allowed to charge trucks over 12 tonnes; in 2006 this was extended to include trucks over 3.5 tonnes. The maximum level of the charges is capped by the infrastructure costs. Time-based and distance-based charges are not allowed at the same time. As can be seen from Figure 1, especially countries with a high share of transit transports like Germany, Austria and Poland have introduced distance-based road tolls. Sweden, Denmark and the Benelux-countries apply the time-based Eurovignette[1, 2].

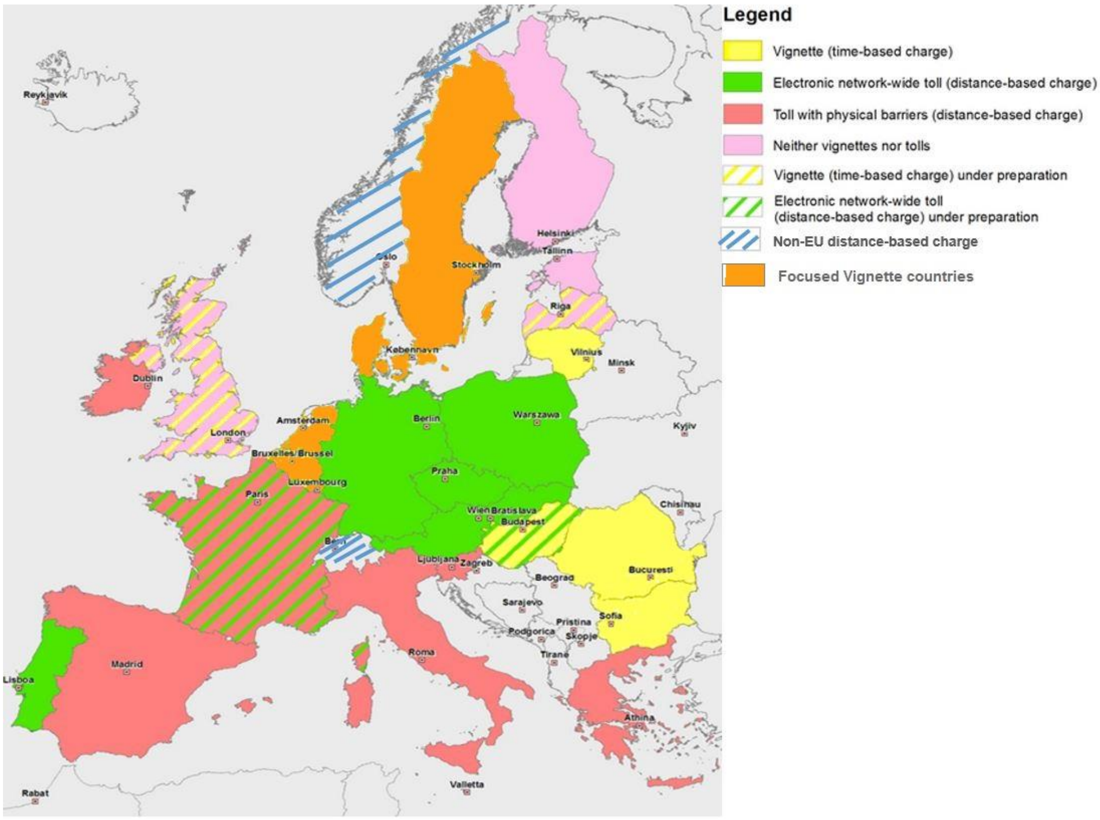

Figure 1: Charging of heavy trucks in Europe, based on European Commission (2012)

Common for nearly all charging systems for heavy trucks is that they apply some differentiation by number of axels and emission class (Euro class). After a Euro class becomes compulsory all new registered vehicles have to accomplish it. New Euro classes are usually on the market one or more years before they become compulsory. Dir. 91/542/EWG defined Euro 1 and Euro 2 that were compulsory from 10/1993 and 10/1996, respectively. Starting from 10/2001 Euro 3 and from 10/2006 Euro 4 became compulsory, regulated by 1999/96/EWG updated by 2001/27/EWG. Three years later, Euro 5 was required, described in dir. 2006/81/EWG and modified in 2008/74/EWG. Euro 6 became compulsory in 01/2014.

Dir. 8/77/EWG regulates the emissions of carbon oxide (CO), hydrocarbon (HC), nitrogen oxide (NOx), particulate matters (PM) and smoke. The requirements, expressed in g/kWh are illustrated in Figure 2 except smoke[3]. From Euro 1 to Euro 6, CO-emissions have been reduced by 67%, HC-emissions by 88%, NOx-emissions by 95% and PM-emissions by 97%.

[1] The original map (European Commission, 2012) was updated by the two non-EU-countries Switzerland and Norway (StatensVegvesen, 2014).

[2] For further information about the network wide road charges in other countries see (Hylén, Kauppila, & Chong, 2013).

[3] Smoke is expressed in m^{-1} and cannot be compared to the other emissions. There are requirements for Euro 3 (0,8 m^{-1}) and Euro 4 and 5 (0,55 m^{-1})

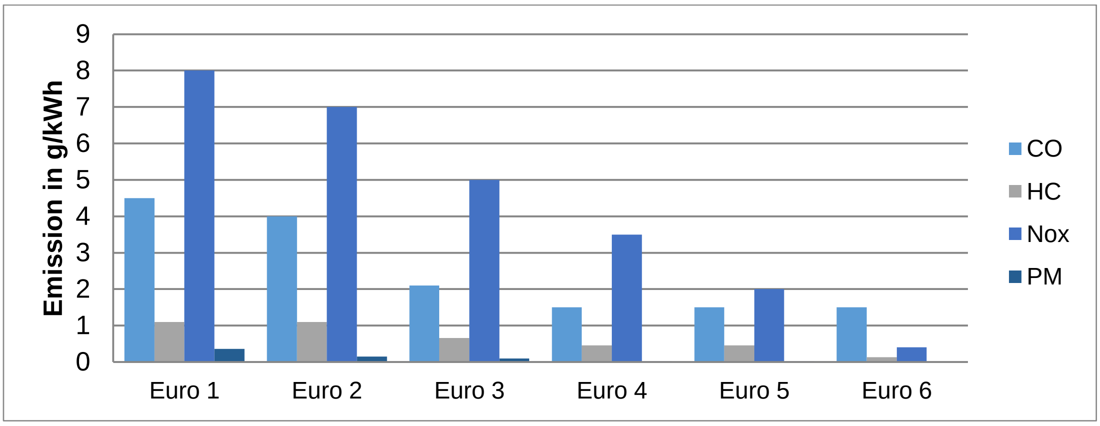

Figure 2: Emission standards by Euro class (DieselNet, 2009)[4]

The current state of research on the impacts of different road freight transport policies is becoming dated. The latest work the authors were able to find on the subject is from around 2010. This lack of attention from the research community is somewhat surprising as, since then, several countries have implemented road infrastructure charges and policies i.e. to reduce emissions etc. and other countries are planning this type of measures. Topics examined in the literature frequently relate to the environment and climate as in Stern (2006), Galilea & Ortuzar (2005), external costs as in Bak et al. (2006), Delucci & McCubbin (2010), judicial reviews concerning the directives as in Bickel et al. (2006), congestion charging in cities, e.g. Prud'homme & Bocarejo (2005), or the impacts of implemented charging system in a given country, e.g. Balmer (2003) who studies Switzerland.

In Sweden several government commissions have been carried out to study the potential impacts of distance-based tolls for heavy trucks. The most current study, SIKA (2007) comprises three steps.

1. Distance-based tolls are calculated based on the short term marginal costs differentiated by the trucks' weight and emission class and urban/rural driving.
2. The relative change in transport costs for different types of goods to and from different regions are calculated with the help of the national freight model. The transport costs are estimated to increase by about 3% on average due to the toll. The share of transport costs on the total production costs is estimated based on official statistics and information from industry representatives. The impact analysis focuses on timber, food and high value products. These are the commodities with a high share of transport costs and a comparatively high cost increase due to the toll. The increase of the transport costs is generally higher in the North of Sweden than in the South of Sweden.
3. The impacts on production and employment are estimated with help of a factor demand model. A Salter analysis is conducted to estimate risks for negative profits caused by the toll. Generally, the expected effects on industries and regions are small, and not clearly negative. The effects of the regions depend on the regional economic structure. Measures to mitigate potential negative effects of the toll are discussed.

[4] The last classification, not shown in the figure, is described by 'EEV' which is a term used in the European emission standards for "clean vehicles" over 3.5 tonnes – concerning Euro 5 and 6.

The toll is anticipated to lead to different types of adaptations for an economically efficient use of the infrastructure and welfare gains in terms of reduced external effects. The differentiation by emission class is expected to lead to a faster replacement of the fleet, though this effect is expected to decrease as the fleet becomes cleaner. The toll revenues are estimated to be about ten times the Eurovignette revenues, but the fuel tax revenues are anticipated to decrease due to decreased road freight traffic. The system's investment and operation costs must be weighed against the welfare benefits. It is stressed that the costs are difficult to estimate and highly dependent on the system that is chosen. A comprehensive system that enables the distinction between different areas and type of roads is very costly. Therefore there is reason to study simpler solutions that may be motivated from a socio-economic point of view and an idea on how a simplified system can be designed is presented in SIKA (2007). In April 2015, The Swedish government commissioned an investigation on distance-based tolls for heavy trucks that will be finalized in December 2016, (Regeringen, 2015).

McKinnon (2006) reviews various charging systems for trucks (Switzerland, Austria, Germany and a proposal in the UK) and reveals differences in their objectives, coverage, technology and toll levels. Possible effects on mode choice, route choice and truck utilization etc. are assessed and it is shown how the logistical impacts depend on the nature of the tolling scheme and level of charges. McKinnon (2006) estimated that the transport costs in Germany would increase by about 5-7 % and that most carriers would be able to pass this increase on to their clients. In 2006, a marginal reduction of the empty transports had been registered. A modal shift of 6 % from the road to rail was expected. Other studies state that there is neither enough capacity to perform more transports by rail (TransCare AG (2006)) nor the intention to shift to rail since the demand for 'road transport' is inelastic (Evangelinos (2009)). The concern that trucks would choose non-charged roads turned out to be unfounded in most cases since the costs for the lost time would be higher than actually paying the toll, (Deiters et al., 2006).

Furthermore, the *BAG* published reports about the impact of the toll on the German transport industry. The latest version from 2006 found an increase in new registered trucks between 10 – 12 tonnes that are not charged a toll. In 2005, 1.85 times more new trucks in this category were registered as compared to 2002. This is interesting as regional hauliers arguably would prefer to invest in lighter non-charged trucks. However, the share of these trucks is comparatively small, (BAG (2006)). The pattern is not entirely clear. For instance, Kossak (2006) found that there has been no traceable increase of transport costs and no significant impact on the structure of the trucking industry. Besides, there seems to be no verifiable impact on consumer prices, which stands in contrast to (McKinnon, 2006) observation about carriers being able to pass on charges to end-consumers, but a significant tendency towards a higher average load factor. Concerning the former it might be a consequence of the toll constituting a relatively small amount of the transport costs.

Experiences from Austria between 2004 and 2008 have shown that even though the mileage (number of vehicle-kilometres) has changed, the emissions per vehicle-kilometre did not become cleaner, TRT (2008). This is not surprising as the Austrian tolls during this period were not differentiated by emission class.

3 Policies in Sweden and Germany

In 1994, Germany, Denmark and the Benelux states started the Eurovignette cooperation and introduced the time-based Eurovignette. Sweden joined the cooperation in 1998 and Germany left the cooperation in 2003. The policies in Sweden (section 3.1) and Germany (3.2) are described in more detail below.

3.1 Sweden

Swedish trucks over 12 tonnes are charged annually while the trucks registered in other countries can choose to pay the Eurovignette annually, monthly, weekly or daily. The foreign trucks have to pay when they use the about 4,000 kilometres long Eurovignette network that comprises all Swedish motorways and certain other routes, Skatteverket (2010). The tariff is differentiated by number of axles (1-3, 4 or more) and Euro class (0, 1, 2-6). Table 1 shows the annual tariffs in 2015. The tariffs have not changed since 2008.

Table 1: Annual Eurovignette tariff, 2015 (Eurovignette AGES (2015))

Euro class	1- 3 axles	4 or more axles
Euro 0	€ 960	€ 1 550
Euro 1	€ 850	€ 1 400
Euro 2-6	€ 750	€ 1 250

The maximum monthly and weekly tariffs are in proportion to the duration of the use made of the infrastructure. The daily user charge is equal for all truck categories and amounts to € 8. As the daily charge is not differentiated, it does not provide incentives to use cleaner trucks. About 20% of the revenues are from daily paid Eurovignette fees.

3.2 Germany

In August 2003, Germany left the Eurovignette cooperation to introduce distance-based road tolls for trucks over 12 tonnes on the German motorways and some major roads. In 2012, the toll road network comprised 13,039 kilometres which is 5.6 % of all German roads. In June 2015, further 1,100 kilometres were included, Verkehrsrundschau (2015). Due to technical problems at the beginning the introduction of the toll was postponed from the end of 2003 to 1st January 2005. This caused a loss of revenues of about € 2.9 billion, VCD (2009), which is almost the same amount as the toll revenues in 2006.

The German toll is differentiated by number of axels and Euro class. Since 2005 the level of the toll has been raised several times. However, from January 2015 the level decreased since the latest federal transport infrastructure report calculated that the tolls exceed the infrastructure costs, Alfen et al. (2014). The main reason for this was an interest rate below what was expected, Tagesschau (2014). See Table 2.

Table 2: Development of the average toll rate (BGL, 2012) (TollCollect, 2015)[5]

	01.01.2005-30.09.2006	***01.10.2006-30.08.2007***	***01.09.2007-31.12.2008***	***01.01.2009-31.12.2014***	***since 1.01.2015***
Euro 6					0.128 €
Euro 5	0.095 €	0.095 €	0.105 €	0.148 €	0.149 €
Euro 4	0.095 €	0.115 €	0.125 €	0.176 €	0.160 €
Euro 3	0.115 €	0.115 €	0.125 €	0.197 €	0.191 €
Euro 2	0.115 €	0.135 €	0.150 €	0.231 €	0.201 €
Euro 0+1	0.135 €	0.135 €	0.150 €	0.281 €	0.211 €

The German government planned to compensate German firms for the toll by reducing the fuel tax, BMVBS 2012(a). This was rejected by the EU commission since foreign firms would be discriminated. In 2003, the German government agreed on compensation arrangements of in total € 600 million per year, (BMVBS(b), 2012):

1. reduction of motor vehicle tax for heavy trucks to the lowest legal volume (amounts to around € 150 million per year)
2. assistance programs (amounts to € 150 million per year) for
   (a) creation of incentives to purchase cleaner trucks (up to € 100 million per year),
   (b) support for security and environment (up to € 450 million per year)
   (c) program for training and skills (up to € 90 million),

The European commission allowed the subsidies to achieve cleaner trucks as they are assumed to be small enough not to distort competition, BAG (2009), VIFG (2015). Between September 2007 and September 2009 the purchase of Euro 5 trucks was subsidised. The subsidy of € 2,250 - € 4,250 per truck (depending on size of the firm) corresponds to about 50% of the price difference between Euro 4 and Euro 5, (Ekwall, 2012). Euro 6 was subsidised between 2010 and July 2011 (€ 1,400 - € 2,200 per truck)[6] and between February 2012 and September 2013 (€ 3,850 - € 6,050). At the moment there are no subsidies as Euro 6 became compulsory in January 2014 and Euro 7 is not yet available.

In total, the German government provided financial assistance of about € 199 million to modernize the German truck fleet between 2007 and 2013, BMVI (2015). Unfortunately we only have access to yearly figures from 2009 to 2013, so we estimated the distribution for the first two years based on the missing subsidies of € 50 million assuming more financial assistance in the first year.

[5] Table 2 does not distinguish between different by axles rates as these differences are very small. Euro 5 and EEV got clustered to simplify the analysis and because they pay the same toll rate.
[6] EEV was subsidised with € 1.050 - € 1.650 per truck, the total amount of subsidies in table 3 contains the merged data.

Table 3 Subsidies for cleaner trucks in Germany 2007-2013 (KfW, 2014)[7]

	Euro 5			Euro 6				Total
	2007	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	
€ million	30	20	12	39	69	17	12	199

It seems likely that the subsidies mainly influence the composition of the fleet. The design of the infrastructure charges, however, most likely influences both the fleet and the mileage. Below we study this based on the data that we have access to.

4 Comparison

4.1 State budget

We start by comparing the impact on the state budget in the two countries studied. Table 4 shows the Eurovignette revenues in Sweden from 2006 to 2014. The total revenues varied between € 80 and 90 million with a clear decrease in the years after the recession. The data distinguishes between revenues from Swedish trucks and revenues from foreign trucks. From comparing these two groups it is evident that the revenues from Swedish trucks are more stable. This is probably related to the fact that the number of trucks over 12 tonnes was quite constant and all trucks have to pay the Eurovignette. In contrast, the revenues from foreign trucks decreased almost by half after the recession.

Table 4: Eurovignette revenues in Sweden 2006-2014 (in million €)[8]

Revenues (in million €)	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***
Swedish trucks	63,2	64,2	62,0	58,4	64,9	67,5	69,6	63,7	61,2
Foreign trucks	23,2	26,3	31,7	25,3	16,5	18,7	19,0	23,0	21,5
Total	**86,4**	**90,6**	**93,8**	**83,7**	**81,4**	**86,1**	**88,6**	**86,7**	**82,8**

Table 5 shows the Swedish revenues, both in total and per vehicle-kilometre. The table also shows the revenues from the higher, more differentiated, toll for trucks over 12 tonnes in Germany. Between 2006 to 2008 the toll revenues in Germany increased on the average by about 5% per year. After the 44% increase of the toll rate in 2009 the revenue grew almost about one third compared to 2008.

[7] Euro 6 and EEV are clustered.

[8] Exchange rates for the respective year, x-rates (2015)

Table 5: Revenues in million, Mileage in million vehicle-kilometres and Revenue per vehicle-kilometre in Sweden[9] and Germany[10] 2006* - 2014

		2006	2007	2008	2009	2010	2011	2012	2013	2014
Sweden	Revenues in million €	86.4	90.6	93.8	83.7	81.4	86.1	88.6	86.7	82.8
	€/vehicle-kilometre	**0.020**	**0.020**	**0.021**	**0.020**	**0.019**	**0.019**	**0.020**	**0.020**	**0.019**
Germany	Revenues in million €	3078	3359	3466	4410	4484	4499	4364	4390	4440
	€/vehicle-kilometre	**n.a.**	**0.123**	**0.126**	**0.181**	**0.174**	**0.169**	**0.164**	**0.161**	**0.158**

Unfortunately, there are no official data in Germany for the revenues divided by foreign and German trucks. However, based on the mileage, 39 % of the revenues was received by foreign hauliers in 2014. This share has increased by three percent-units since 2007, (BAG, 2014). Compared to the toll revenues of about € 29 billion earned during the period 2006-2013 (see Table 5) the total amount of subsidies of € 199 million (see Table 3) is about 0.7%.

A comparison of the revenues per vehicle-kilometre for the two countries reveals that the German toll system generates revenues that on average are eight times higher than the Swedish revenues (before the increase of the toll rate in 2009 about six times and after almost nine times higher). Furthermore, the revenues per vehicle-kilometre in Sweden are stable. In Germany the increased toll rate in 2009 had large impact on the revenues per vehicle-kilometre.

Since 2009 the revenues per vehicle-kilometre in Germany decreased even though there was no reduction of the toll. This points towards that the composition of mileage by Euro class has changed, i.e., that there has been a switch towards cleaner vehicles used for longer distances. This is an expected response to the change in toll rates 2009 which increased the tolls for less clean trucks proportionally more than for cleaner trucks. For instance, the toll for Euro 3 vehicles increased by 58% (from € 0.125 to 0.197), while for Euro 5 the increase was 41% (from € 0.105 to 0.148, see Table 2).

4.2 Fleet

Below, we focus on the impacts on the composition of the truck fleet by Euro class. To standardise the data we merge Euro 0–2 to one group as well as trucks that were registered before 1993. Earlier, Sweden used its own classification system for trucks (Miljöklass MK). To make it comparable to the Euro class system, we transform it as follows; Euro 0–2: MK1, 2 and 3, Euro 3: MK 2000, Euro 4: MK 2005, Euro 5: MK 2008 + Hybrid + EEV. Given this, Figure 3 breaks down the trucks by Euro class for the weight categories 3.5-12 tonnes, 12–40 tonnes and over 40 tonnes in Sweden. The Figure exhibits the shares for 2005-2014 as well as the average share for each weight category.

[9] Based on data from the Swedish tax authority, (Skatteverket 2012, 2015)
[10] The revenues in 2005 in Germany was about € 2 866, the numbers for 2014 has to be estimated by the numbers until June, the estimated revenue for 2015 is about € 4 340
See: (BAG, Jahresbericht 2005-2013, 2006-2014); (VIFG, 2015)

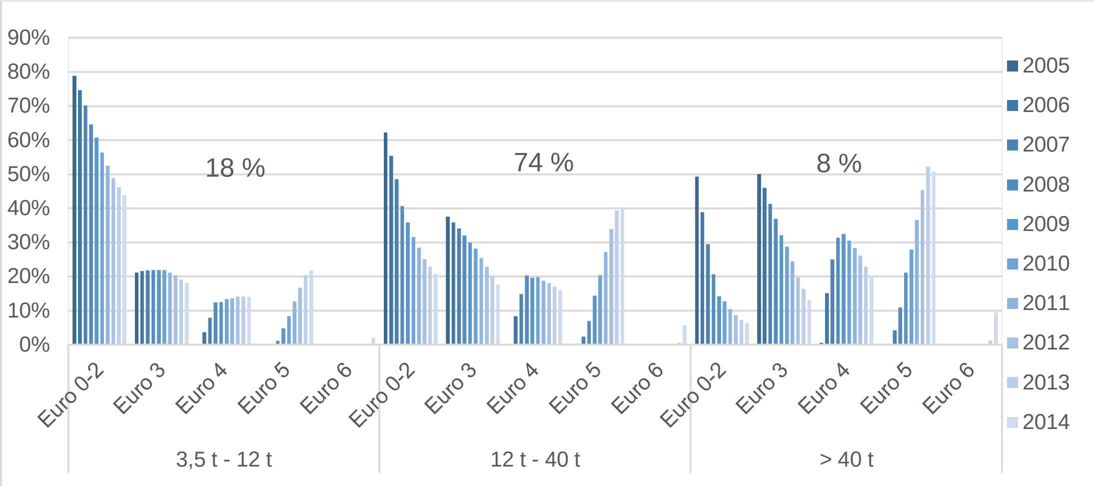

Figure 3: Composition of the Swedish truck fleet by weight and Euro class, 2005–2014 (Yahya M.-R. , 2015)

Trucks between 3.5 and 12 tonnes have the highest share in Euro 0-2 supporting the presumption of not having incentives to invest in cleaner trucks as these trucks are not obliged to pay the Eurovignette. Both the figures for Sweden and Germany show that the modernization is slowest for the trucks under 12 tonnes that are typically used for short distance transports in urban areas. This is where the external costs related to the emissions are highest. Other policies than those for long distance transports, that are discussed in this paper, are needed to speed up the modernization of trucks used in urban areas, Adolf et al. (2012).

It is clear from Figure 3 that the heavier are the trucks, the larger is the share of Euro 5 and Euro 6. The same is found when looking at new registrations of Swedish trucks over 12 tonnes. Since Euro 6 became compulsory the number of new registered Euro 5 trucks decreased by the same amount as the Euro 6 class grew (8 %), Myhr (2015). In total, the number of trucks can be described as stable but the trucks over 40 tonnes increased by 34 % while the trucks under 12 tonnes decreased. It is also informative to look at the age of the fleet in Sweden. Trucks heavier than 3.5 tonnes were on average 10.8 years old in 2014, the average age has increased by about 7 % since 2006, Myhr (2015).

In Figure 4 the composition of the German fleet by weight and Euro class is shown from 2010–2014. Longer or more detailed time series were not available. The share of trucks between 3.5 and 12 tonnes is higher in Germany than in Sweden, which is among others due to different economic and infrastructure conditions. The trucks are generally heavier in Sweden. This is true even when disregarding that Sweden allows trucks over 40 tonnes. Only looking at 3.5-12 tonnes compared to 12-40 tonnes, there is a much higher share of trucks in the 12-40 tonnes category in Sweden (80 %) as compared to in Germany (38 %).

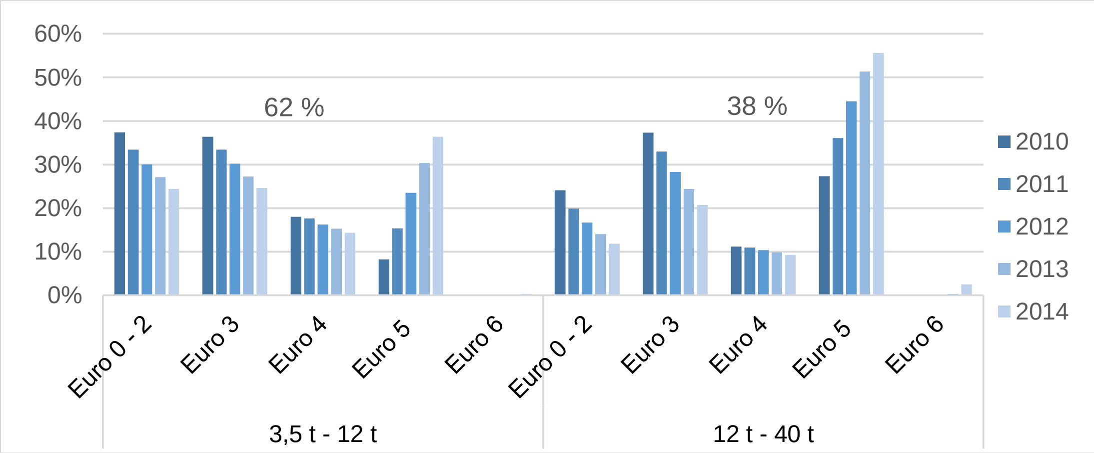

Figure 4: Composition of the German truck fleet by weight and Euro class, 2010–2014[11]

Comparing the trucks over 12 tonnes that pay the toll, the German fleet has a higher share of "cleaner trucks" than the Swedish fleet. The relatively low share for Euro 4 for the trucks over 12 tonnes in Germany could be explained by the subsidies of Euro 5 between 2007 and 2009. There was a quite small price difference between Euro 4 and 5 and thean almost simultaneous start of the production of the Euro 4 and Euro 5 engines, BGL (2007). According to KBA (2015), the average age of the trucks between 3.5 and 40 tonnes[12] is three years less for the German fleet (7.7 years) than for the Swedish fleet (10.8 years). The average age decreased from 2006 to 2014 about 2.5 %. The subsidies of clean vehicles and more differentiated tolls in Germany are likely to contribute to this, but more data would be needed to fully explain the differences in the age of the fleet.

Looking more closely on the mix of the Euro classes for the trucks 12–40 tonnes in the two countries in 2014, it becomes obvious that Germany has a cleaner fleet than Sweden (see Figure 5). The much higher share of Euro 5 trucks in Germany (55%) compared to Sweden (40%) is both due to the subsidies of Euro 5 trucks 2007-2009 and the level and design of the distance-based toll. One explanation of the slightly higher share of Euro 6 trucks in Sweden can be that the Swedish firms did not have the same incentives to buy Euro 5 and needed to modernize their fleet in 2014.

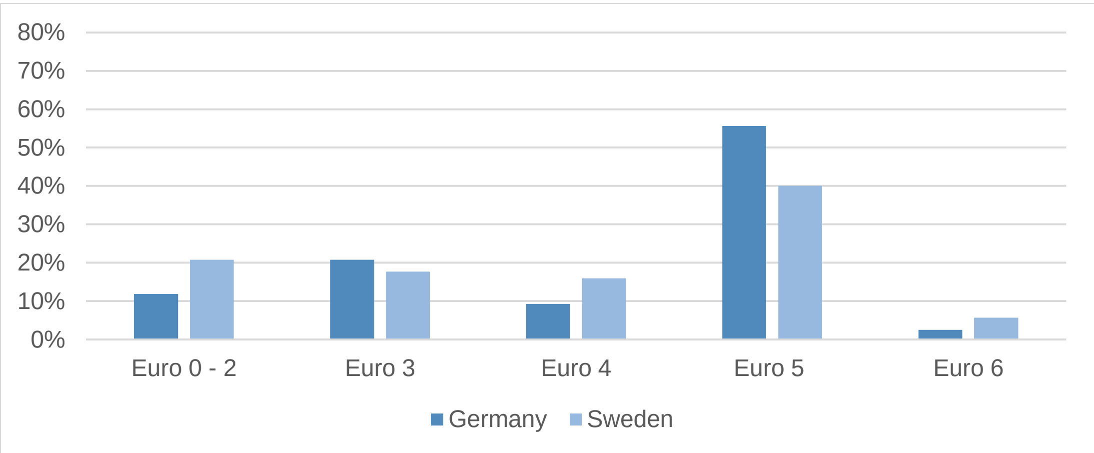

Figure 5: Comparison: Fleet in Germany and Sweden by Euro class in 2014, 12 – 40 t

[11] (KBA, Fahrzeugzulassungen (FZ 13), 2010 - 2014)

[12] Even though the focus should be pointed on trucks heavier than 12 tonnes be had to use trucks > 3.5 tonnes for Germany and Sweden because of lack of more specified data.

The difference in average age of the fleets indicates that firms made use of the financial incentives, which are greater in Germany than in Sweden, to modernize their fleet. One has to have in mind that the owners of cleaner trucks also have the advantage of paying lower distance-based tolls (see Table 2). Below, we turn our focus towards the impact of the infrastructure charges by analysing the mileage on the (toll) roads.

4.3 Mileage

In total 4,597 million vehicle-kilometres were performed by trucks over 3.5 tonnes on Swedish roads in 2014 (4,358 million kilometres by trucks over 12 tonnes). According to Yahya (2015) about 14% of the mileage is supposed to be carried out by foreign trucks. There are no data about the Euro classes of the foreign trucks in Sweden. As in Yahya (2015) we assume that Swedish and foreign trucks have the same Euro class distribution. The total vehicle-kilometres between 2005 and 2014 by Euro and weight class as well as the average shares for the weight classes can be seen in Figure 6. In total the mileage can be described as stable but the vehicle-kilometres carried out by trucks of 3.5 to 12 tonnes decreased from 2005 to 2014 by about 35 % while the vehicle-kilometres carried out by trucks over 40 tonnes increased by about 10%. The vehicle-kilometres performed by trucks in the class 12-40 tonnes were quite stable.

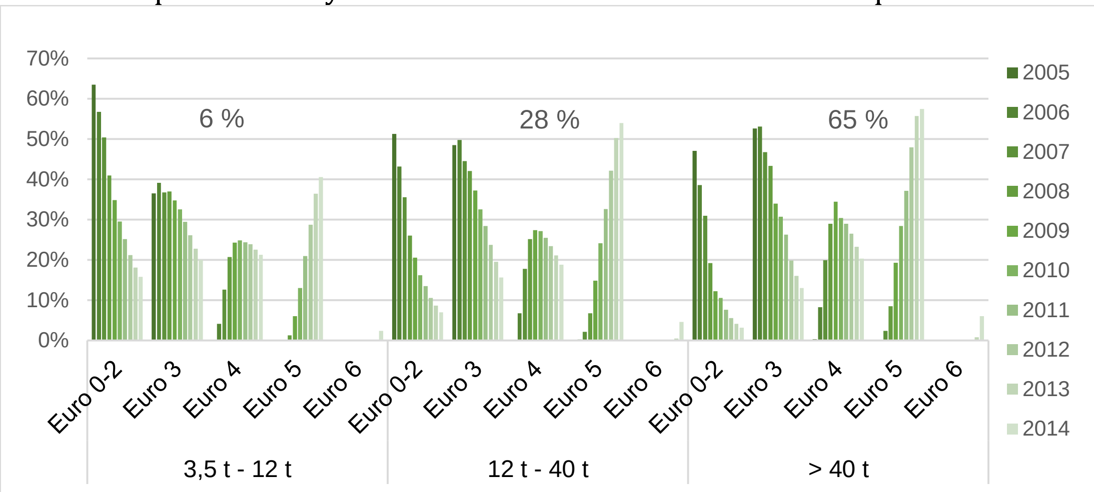

Figure 6: Mileage (vehicle-kilometres) in Sweden with Swedish and foreign heavy duty vehicles 3.5- 12 tonnes and 12- 40 tonnes[13], 40- 60 tonnes (Yahya M.-R. , 2015)

The Euro class composition of the mileage (Figure 7) "is cleaner" than the composition of the fleet (Figure 3). As expected, the mileage in 2014 was carried out by cleaner trucks than in 2005. In 2006, more than 90% of the mileage was performed by Euro 3 trucks or worse. By 2011, this share had decreased to 80 %. Generally, the mileage was cleaner for the heavier trucks seeing this in the higher share of Euro 5 and Euro 6-trips. Compared to the share in the fleet (9 %) a remarkable part of the mileage is performed by trucks over 40 tonnes (65 %). Trucks between 12 and 40 tonnes with a share of almost three quarters in the fleet perform less than a third of the vehicle-kilometres. This shows that the heaviest trucks are used for the longest trips.

The same pattern can be seen from examining the Swedish mileage within Sweden and to/from other countries (see Figure 7). It is striking that in 2013 more vehicle-

[13] 12-40t: includes amongst others Rigid Truck between 12 tonnes, more than 32 tonnes as well as TT/AT >20-34t

kilometres were performed by Euro 0-2 trucks again and the international road performance became less clean. We have not found any explanation for this. Possibly, it is due to an increased difference in tolls that made the use of less clean trucks relatively less costly in Sweden. However, sending the cleaner trucks abroad is not necessarily only a result of high and Euro class differentiated infrastructure charges in other countries. Newer/cleaner trucks are also generally used for longer trips.

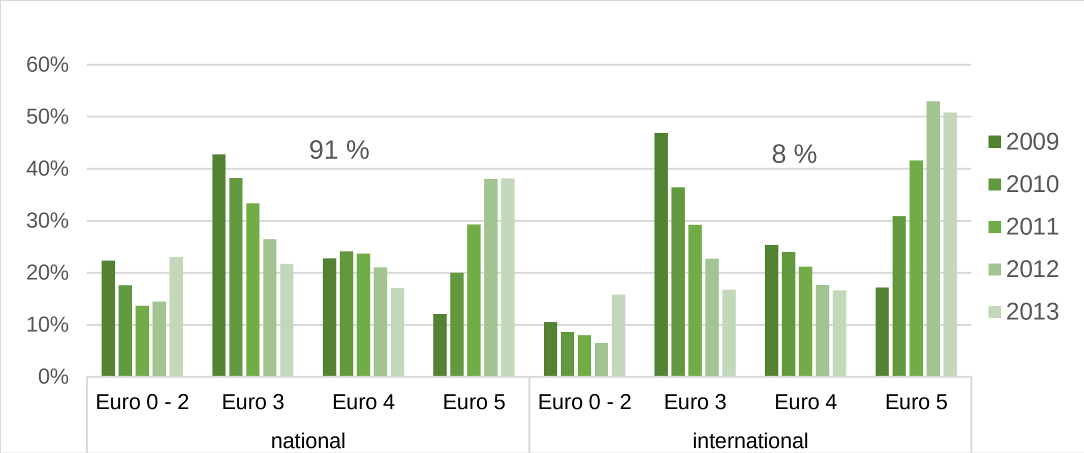

Figure 7: National and international mileage of Swedish trucks >3.5 tonnes, 2009- 2013; Share of the average mileage (Trafikanalys, 2009-2013)[14]

Similar findings are made for Germany looking at the mileage (see Figure 8). As expected, the longer the trip the cleaner are the trucks used. Time series show that, while the vehicle-kilometres on the entire German road network appeared to be stable at around 29 billion vehicle-kilometres annually, the share on the German motorways increased from 83 % (2009) to 93 % (2013)[15]. This indicates that the tolls have not made trucks choose other roads to avoid the toll roads to any major extent. This is in line with Deiters et al. (2006).

As in the Swedish case, the composition of the mileage (in Figure 8) is cleaner than the composition of the fleet (Figure 4). Comparing the mileage on German toll roads and uncharged roads reveals that the cleaner trucks are used more often on toll roads. For example it can be stated that in 2013 almost 90% of the trucks equipped with Euro 5 drove on toll roads whereas the share of trucks with the same Euro class driving on non-toll roads was 80 %[15]. The percentage of the vehicle-kilometres performed by Euro 0-2 trucks is negligibly small. Euro 4 does not have a great share in the German mileage; the share was quite constant at around 10% but has decreased since 2011. Since 2014, the share of Euro 6 got larger. Regarding to the Euro class mix, no difference between German and international trucks can be found.

[14] No data for earlier years available

[15] (BAG, Jahresbericht 2005-2013, 2006-2014); (KBA, *Verkehrsaufkommen (VD1)*, 2013)

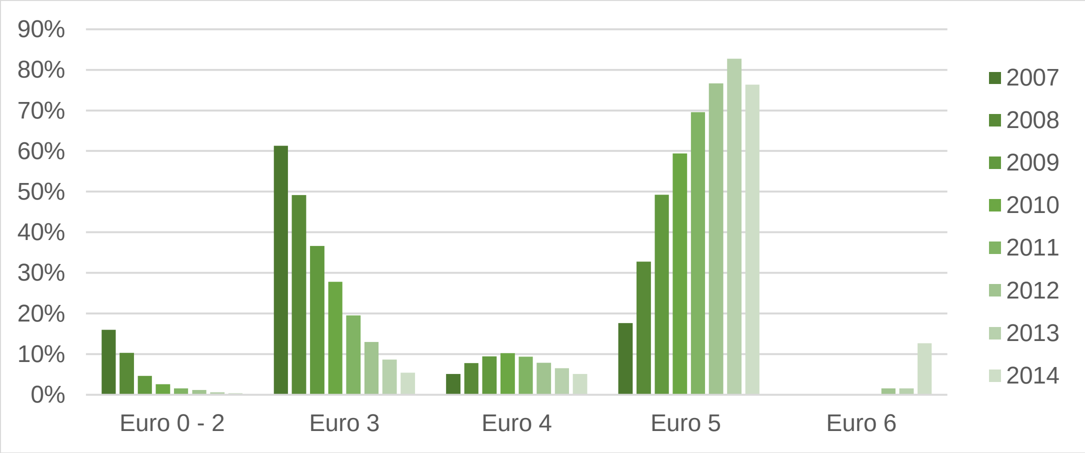

Figure 8: Total mileage in Germany performed by German and international trucks >12 tonnes on toll roads[16]

Figure 9 shows the mileage by Euro class in Germany and Sweden in 2014. Not surprisingly, the composition of the mileage (Figure 9) is in both countries cleaner than the composition of the fleet (Figure 5). This follows from the cleaner trucks are used to a larger extent for long trips. The vehicle-kilometres performed by Euro 5 is about 75% in Germany and about 65% in Sweden. As the share of Euro 6 in the fleet is larger in Sweden than in Germany, it is interesting to note that for mileage the share Euro 6 is higher in Germany. Arguably, this may be a consequence of the larger Euro class differentiation in the German tolls.

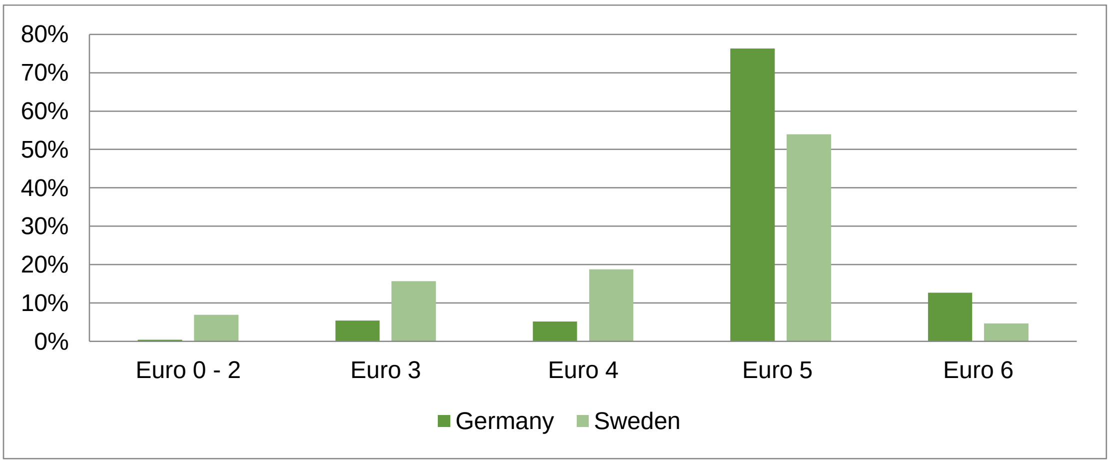

Figure 9: Mileage in Germany (German and foreign trucks) on toll roads and Sweden by Euro classes performed by trucks 12 - 40 tonnes in 2014

4.4 Emissions

The *BAG* calculates an "emission index" for the vehicle-kilometres performed by trucks from the different countries on the German toll roads. The index is expressed in g/kWh and comprises CO, HC, NOx and PM emissions. It is calculated by the sum of the total permissible amount of pollutant Euro classes S_i multiplied with the total vehicle-

[16] (BAG, 2006 - 2014)

kilometres with the respective vehicle Euro classes L_i and divided by the sum of the total vehicle-kilometres with the respective vehicle Euro classes. That is;

$$E_{BAG} = \frac{\sum_{i=1}^{n}(S_i \times L_i)}{\sum_{i=1}^{n} L_i} \quad [g/kWh]$$

Figure 10 shows the development between 2007 and 2014. The emission index for German trucks on the German toll roads is as expected lower than the index for the Swedish trucks on the German toll roads (and the average which is not shown but converges almost with the German index). This could be explained by the German fleet (Figure 4) and mileage (Figure 8) being cleaner than the Swedish fleet (Figure 3) and mileage (Figure 6). Furthermore, Figure 7 indicates that Swedish firms use "cleaner trucks" for international than for national trips. One explanation for this is that have to pay lower road tolls in Germany. While not shown in Figure 9, all countries have improved 'their' emission index since 2007 but the progress is slower for e.g. Sweden. In 2014, the trucks from Austria, Slovenia, Denmark and Hungary had the lowest emission index and Greece and Ireland the highest, BAG (2014).

The index in Figure 10 includes only the vehicle-kilometres on German toll roads. It is likely that the Swedish fleet that is used for national and international transports is less clean than the average European transports but this cannot be proven for sure.

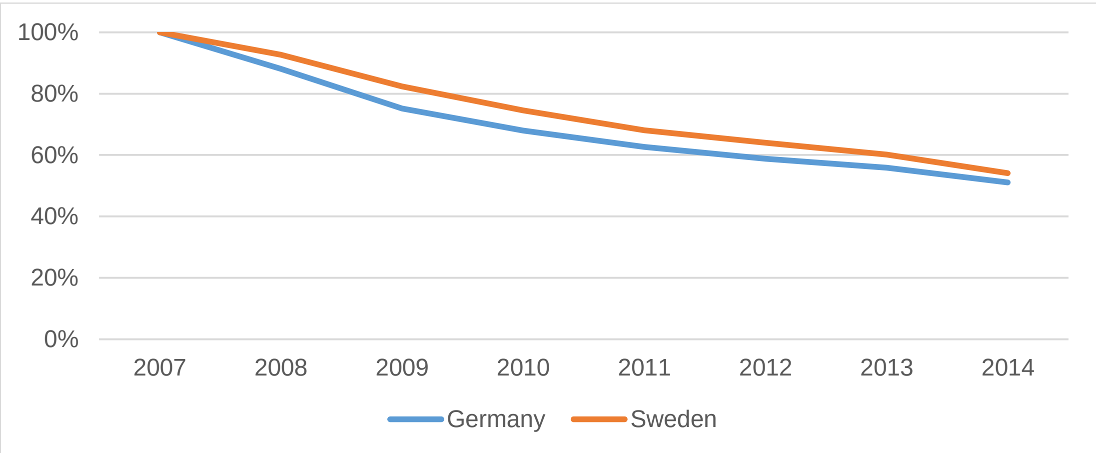

Figure 10: Development of the emission index on German toll roads for German and Swedish trucks based in year 2007[17]

Calculations performed by the Swedish Transport Administration show how the mileage carried out by trucks over 12 tonnes and their emissions developed in Sweden 2007 - 2014. Figure 11 illustrates that the mileage increased slightly but that the CO, HC, NOx and PM emissions (solid lines) decreased due to the modernization of the fleet.

However, as has been discussed above, the composition of the fleet in Sweden differs from that in Germany. To illustrate the consequences of this difference in fleet composition, we calculate what the emissions would have been given that the Swedish fleet would have the same Euro class composition as that on the German toll roads. The

[17] (BAG, 2010) (BAG, 2013) (BAG, 2014) (BAG, 2007) (BAG, 2008) (BAG, 2009) (BAG, 2011)

results are illustrated in Figure 11. The dashed lines show that the HC-emissions should decrease by 84% (instead of 72%), the NOx emissions by 63% (instead of 53%) and the PM emissions by 69% (instead of 60%). The CO-emissions are calculated to decrease by 18% (instead of 12%).[18]

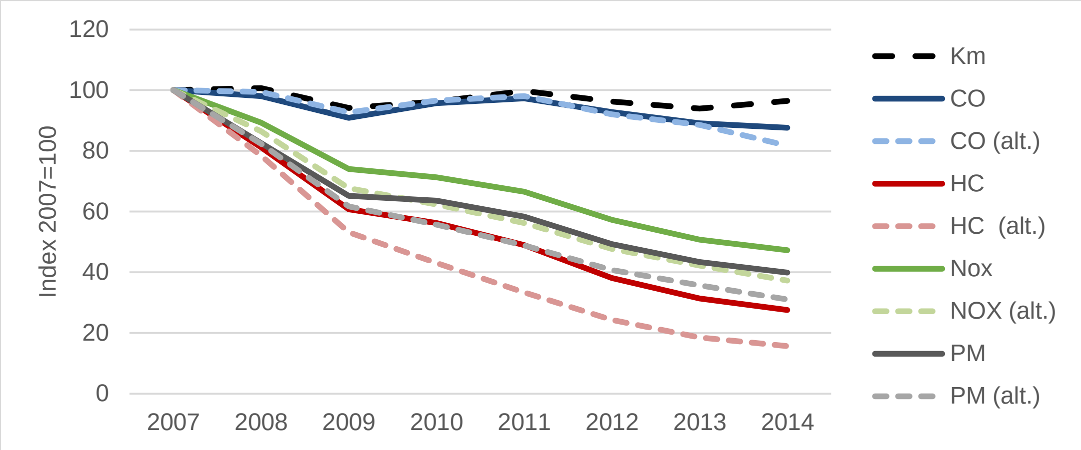

Figure 11: Swedish emissions (solid line) and the reduction of the Swedish emission with German distribution of Euro class in the mileage (dashed line), 2007- 2014, Index: 2007= 100

Further, we translate the hypothetical reduction of the emissions (in tonnes) into monetary terms and compute the socio-economic costs of the fact that the transports in Sweden are performed by less clean trucks than on the transports German toll roads. This calculation is based on the assumption that 85% of the mileage are performed in rural areas (and cause regional impacts) and 15% in cities (and cause local impacts). The unit values for HC, NO_x and PM recommended in the Swedish CBA-guidelines are applied, Trafikverket (2015). The result is that the added environmental costs stemming from the fact that road transports in Sweden are performed by "less clean trucks" than those on the German toll roads are about € 16 million per year. To put that number in perspective, it corresponds to almost one fifth of Sweden's total Eurovignette revenues in 2014.

The discussion above illustrates a clear principle that all European carriers have incentives to use their cleanest trucks where the infrastructure charges per vehicle-kilometre are high for less clean cars. This is typically in countries like Germany where differentiated distance-based tolls are applied. The other way round, the carriers have incentives to use their dirtiest trucks where the infrastructure charges per vehicle-kilometre are low, which is typically in countries like Sweden where the time-based Eurovignette applies.

The consequence is that there all spill-overs between the different countries in the sense that the policies introduced in e.g. Germany will influence the environmental impact from road freight transports in e.g. Sweden. This, in turn, puts further pressure on countries as Sweden to implement stronger policies to counter the spill-over effect. Thus, a situation arises that is similar to the one studied in Mandell & Proost (2015) which show that one country may introduce distance charges to avoid tax revenue

[18] As mentioned in section 4.2 the share of heavy trucks increased while the amount of trucks between 3.5 - 12 tonnes decreased by about 7% while the fleet of trucks over 12 tonnes increased by about 3%. This might be another reason why the CO emissions do not decrease much.

losses accruing from trucks fuelling abroad. The best response for the neighbouring countries is also to introduce distance charges. In some sense, the policy is contagious. The selection process described here would seem to reinforce that mechanism. By implementing high and Euro class differentiated charges in, say, Germany, an externality is created in that the dirtier trucks will be used in, say, Sweden. To handle this externality, Sweden must provide incentives for using clean trucks. One way of doing this is to implement a similar pricing scheme as in Germany.

5 Concluding remarks

Germany and Sweden apply very different road freight transport policies for heavy trucks. Sweden uses the time-based Eurovignette to charge for the use of the road infrastructure. Germany charges distance-based tolls and has subsidised the purchase of clean trucks. The tariffs in both charging systems are differentiated by emission class (Euro class) but level and the design of the charges differ. This produces different impacts on the state budgets, the truck fleet's composition, the vehicle-kilometres driven and the emissions.

In 2014, the revenues per vehicle-kilometre of the German road toll were about eight times higher than the Swedish revenues from the Eurovignette (€ 0.158 vehicle-kilometre vs. € 0.019/vehicle-kilometre). Changing the charges levied in the Eurovignette seems difficult. There has been no change since 2008. This is one reason for why the revenues per vehicle-kilometre in Sweden have been quite stable over the last ten years. In contrast, the level of the German road toll has continuously increased since the implementation in 2005, with the exception of 2015 when it was reduced due to it exceeding the infrastructure costs. So not only is it the case that the German revenues are higher, the German system is also more flexible. Presumably because Germany may, within the limits set by the EU, change the system itself while to make changes within the Eurovignette requires an agreement between the participating countries. (Denmark and the Benelux-countries have discussed the introduction of a distance-based toll as well as Sweden.)

That road freight transports in Germany are subject to higher and, with respect to Euro classes, more differentiated tolls provides incentives to use cleaner trucks in Germany. It is however also the case that Germany has subsidised cleaner trucks. It is difficult to disentangle the effect of the tolls from the effect of the subsidies. Compared to the toll revenues of about € 29 billion earned in Germany 2007-2013 the subsidies for clean trucks during the same period were about 0.7 % (€ 199 million). Thus, the amount of money received in subsidies is somewhat marginal as compared to that paid in tolls, which may suggest that the major impact on the truck fleet and its use stems from the tolls.

According to the transport statistics, Swedish carriers use cleaner trucks more frequent abroad than at home. In principle, all European firms have incentives to use their cleanest trucks where the infrastructure charges per vehicle-kilometre are high, e.g., Germany. Vice versa, carriers have incentives to use their dirtiest trucks where the infrastructure charges per vehicle-kilometre are low, e.g., where the Eurovignette applies. Thus, there are spill-overs between the countries. Arguably, these spill-overs result in a pressure on the Eurovignette countries to prevent that only the dirtiest trucks are used in their countries. A likely response may be to follow Germany's example, i.e., leave the Eurovignette and introduce higher and more differentiated tolls that neutralizes the incentive to use the clean trucks abroad.

To illustrate the magnitude of the problem we calculate the value of the decreased environmental impact that would follow from having the same fleet composition, with respect to Euro classes, in Sweden as the actual composition in Germany. Based on the Swedish CBA-guidelines, the environmental costs are estimated to be about € 16 million per year. These costs are due the fact that road transports in Sweden are performed by less clean trucks than those on the German toll roads.

Given that many countries in central Europe has introduced charging schemes similar to that in Germany, the Eurovignette seems to be outdated. Even so, we are careful to recommend alternative solutions as we addressed only the emissions aspect in our paper. A comprehensive study needs to include all external effects that the transports cause and cover organizational questions including completing subsidies.

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