

How to achieve less emissions from freight transport in Sweden

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Abstract

Purpose – For the case of Sweden, this paper aims to determine how a range of different infrastructure fees and taxes influences modal split, port throughputs, air emissions, societal costs of greenhouse gas (GHG) emissions and air pollution, as well as logistics costs.

Design/methodology/approach – The Swedish national freight model is used to simulate a range of different proposed infrastructure fees, one by one and in combination. The volume of emissions of CO₂-equivalents, NO_x, SO_x and PM under the different scenarios is calculated in both volume and monetary terms, by applying national emission factors and EU values for external costs.

Findings – Road user fees are calculated to have the largest impact on the modal split, GHG emissions and air pollution. The impact increases slightly when road user fees are combined with higher fees for sea and rail and/or gate fees in all Swedish ports. The imposition of gate fees over €30 per truck in all ports leads to shifts in cargo to land-based modes and to ports outside Sweden. The logistics costs in Sweden are found to be three to ten times higher than the benefits of reduced GHG emissions and air pollution, although other benefits to society need to be considered as well.

Research limitations/implications – Methods which attempt to evaluate alternative approaches to the internalisation of the external costs caused by transport need to be further developed. In particular, they need to encompass a more holistic perspective on “benefits to society”, other than merely reductions in GHG emissions and air pollution. To facilitate international acceptance and adoption, such methods require agreements to be reached on common definitions and routines.

Practical implications – The results can be used as basis for policy-making. They illustrate the environmental impacts of the fees and taxes one by one and in combination and to what extent these reinforce each other and should be co-ordinated.

Social implications – The outcomes are relevant to national and international policymakers and authorities, as well as port authorities, shippers and transport companies who need to determine unilateral



strategies on how to reduce GHG emissions and air pollution, without undermining their wider business objectives.

Originality/value – The approach is original in facilitating the testing of policies which impact on the transport system and the environment across different dimensions. The work has additional value in informing policy because of its use of Sweden's national freight transport model.

Keywords Greenhouse gases, Pricing

Paper type Research paper

1. Introduction

The [OECD \(1997\)](#) has specifically identified the environmental effects associated with freight transport as air pollution, global climate issues, water pollution, noise, habitat/land use issues and accidents. As a consequence of the continuous growth in world trade over recent years and its reliance on fossil fuels, the carbon emissions associated with freight transport have emerged as an issue of significant and particular concern. [McKinnon \(2018\)](#) suggests that the worldwide logistics industry accounts for approximately 9-10 per cent of global CO₂ emissions, and the [OECD/ITF \(2015\)](#) has predicted that carbon dioxide (CO₂) emissions from global freight transport will virtually quadruple from an estimated 2.1 billion tonnes in 2010 to 8.1 billion tonnes in 2050; a situation where freight transport will emit more CO₂ than passenger cars.

[Creutzig \(2016\)](#) identifies the main options for reducing the greenhouse gas (GHG) emissions of transport in general as reducing the carbon intensity of fuels, enhancing the energy efficiency of vehicles, shifting modes and reducing demand ([Bongardt et al., 2013](#); [Figueroa et al., 2014](#); [Sorrell, 2015](#)). While the first two categories are largely technical in nature, achieving a modal shift or demand reduction both clearly requires some sort of behavioural change.

A number of different specific policy instruments that aim to help achieve one of these four main options may be applied to reduce GHGs and air pollution from freight transport. [Grubb \(2014\)](#) promulgates a generic system of categorising these specific policy instruments in terms of the three “policy pillars” of “standards and engagement”, “markets and prices” and “strategic investment”. Under each of these “policy pillars”, there is a range of policy instruments that have been, or could be, applied to contribute to the reduction of GHG emissions from the freight transport sector. This paper focuses on the “markets and prices” category and, specifically on the potential for utilising the internalisation of external costs as an appropriate policy instrument ([Baranzini et al., 2015](#)).

[Tavassy et al. \(2016\)](#) analysed the impact of the internalisation of external costs on global supply chains, production and trade, as implemented through potential global emission trading systems or local transport charges. The authors find that the effects are generally small, but they can be significant for specific sectors, e.g. agriculture and mineral fuels. Regarding the internalisation of external costs via existing fees, a Dutch study ([Schroten et al., 2014](#)) accounted for half the distance to/from destinations abroad in the analysis, while Swedish studies ([Vierth, 2016](#); [Trafikanalys, 2018](#)) account only for the external costs that are caused by vessels in Swedish waters that call at Swedish ports. A similar approach to this is applied in Norway ([Magnussen et al., 2015](#)). Sweden calculates the marginal costs in a systematic way; the objective is to provide a platform for implementing a welfare enhancing policy for pricing infrastructure ([Nilsson et al., 2018](#)). The focus of the majority of studies is on the internalisation of the costs on the “links” in the infrastructure network ([Vierth and Lindé, 2018](#)); to the best of our knowledge, the Norwegian study by [Rødseth et al. \(2017\)](#) is the only one that calculates external costs caused by loading and unloading cargoes in ports.

Being important interfaces in the freight transport system, ports apply different types of fees to reduce GHG and air pollution at sea and on the land side. [Bergqvist and Egels-Zandén \(2012\)](#) study the different attitudes of stakeholders to environmentally differentiated port dues related to hinterland activities. They find that the implementation of this system of port dues has the greatest probability to be implemented:

- in situations where modal shifts require substantial infrastructure investments;
- in ports with congestion in the hinterland; and
- in publicly owned ports.

[Gonzalez-Aregall et al. \(2018\)](#) argue that the reduction of emissions to air and other externalities caused by hinterland transport are at least partly the ports' responsibility. They find that about 20 per cent of 365 ports across the globe have implemented 165 measures in total to improve the environmental performance of their hinterland transport. Ten of these measures are pricing measures, with the objective to promote modal shift and intermodality (four measures) and reduce emissions to air (five measures) and land congestion (one measure). With respect to the potential scale of this sort of measure, [Bäckström \(2018\)](#) applies a hypothetical gate fee of SEK 200 per truck in Swedish ports[1], a figure which is utilised within the analysis contained within this work.

This paper addresses the Swedish case, where infrastructure fees and taxes based on marginal external costs are either already applied or under discussion for all modes. However, at least for the time being, the Swedish Maritime Administration levies fairway dues and pilot fees that cover the SMA's production costs of the services. The impacts of infrastructure fees and taxes that are applied to reduce GHG emissions and air pollution caused by trucks, freight trains and vessels on Swedish territory are analysed. The objective is to determine the impacts of the infrastructure fees (including port dues) and taxes, one by one and in combination, on the choice of the freight transport chains that comprise the different modes, ports and other terminals. The focus of the analysis is on long-distance freight transport where the shipper and/or consignee are located in Sweden. Typically, this category of transport is more regular and repetitive than long-distance sea transport movements. Of all tonne-kilometres moved in Sweden, roughly 20 per cent relate to transport chains that involve a transfer to/from a vessel or ferry in a Swedish port.

2. Methodology

2.1 Policies analysed

The following actual and potential policy instruments are analysed in isolation and in combination:

- an increase of 40 per cent in rail track fees that is planned for implementation in 2025 to cover the external costs of wear and tear, accidents and noise, GHG emissions and air pollution by rail transport ([Trafikverket, 2013](#)); the increase for rail freight transport is specifically based on an estimation made by [Westin \(2018\)](#);
- implementation of kilometre-based road user fees for trucks instead of the existing Eurovignette, as proposed in a government investigation ([Regeringskansliet, 2017](#));
- increases of about 5 per cent fairway dues and 8 per cent higher pilot fees that have been put in place since 1 January 2018 ([Sjöfartsverket, 2017](#));
- the implementation of hypothetical gate fees of SEK 50, 100, 200, 300, 500 and 1,000 per truck passage in all Swedish ports, based on [Bäckström \(2018\)](#); and

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- the implementation of hypothetical gate fees of SEK 50, 100, 200, 300, 500 and 1,000 per truck passage in specific ports based on [Bäckström \(2018\)](#).

The same relative increase in taxes and fees is assumed across all commodities carried and all vehicle and vessel types. This simplifying assumption reinforces any differentiation which is already present within the baseline scenario, but it also negates the need for forecasting the nature, level and timing of any further differentiation into the future. Predicted changes in supply chains are the outcome of a modelling process, as are the changes in the environmental impacts due to changes in the supply chains. The model assumes the use of the same 33 vehicle and vessel types, as well as the same fuel or energy source, under each of the scenarios tested both before and following the implementation of the policies analysed.

2.2 *Samgods model*

The Swedish national freight transport model Samgods ([de Jong and Baak, 2016](#)) is used to simulate the impacts of the different policy instruments one by one and in combination[2]. The model consists of several components ([Trafikverket, 2016](#)). Some fundamental characteristics of the model are as follows.

Production consumption matrices (PC-matrices) describe the transport demand between production and consumption locations in, to, from and through Sweden for 34 commodities in tonnes. As the model cannot handle the effect of higher transport costs on demand, the PC-matrices are assumed to be constant. Indications show that the impacts of higher costs are small, [Konjunkturinstitutet \(2018\)](#):

- The infrastructure network has more than 25,000 nodes and 70,000 links.
- There are 33 different vehicle types: five road, eight rail, 19 sea and one air. For sea transport, there are different types of vessel (container, ro-ro and other) and ferries (road, rail) are included. Different average speeds are assumed for different vehicle/vessel types.
- The various logistics costs are divided into three groups: transport, warehouse and order costs. Transport costs comprise underway costs and transfer costs. The kilometre costs in turn comprise time-based costs and distance-based costs, as well as infrastructure fees and taxes.
- An optimisation routine that minimises the shippers' annual logistics costs and transforms the commodity-specific PC-flows into vehicle type specific origin-destination flows (OD-flows). The OD-flows can move directly from P to C or via one or more terminals. The economies of scale aspect is handled using different vehicle sizes.

Within the logistics model, the annual logistics costs of firms are minimised, taking into consideration the trade-off between transport costs and warehouse costs. The fact that the transport costs per unit can be reduced by using larger vehicles when transporting goods from one or several shippers is also considered. Transport costs per vehicle-kilometre are used as inputs; load factors and costs per tonne-kilometre are computed. The choice between predefined container and non-container transport chains is modelled. It is assumed that transport companies pass cost changes on to shippers. Infrastructure restrictions are also accounted for, in the form of maximum depth for vessels, maximum weight for trucks and maximum number of trains per track for rail. Capacity problems on road and rail modes are accounted for in the model, but the situation in Sweden is such that capacity problems in ports are realistically assumed to be negligible.

2.3 Output variables

Both the effects on the modal split (measured in tonne-kilometres) and the throughput (in tonnes) in the ports on the 14 stretches of the Swedish coast are calculated for the baseline scenario and the investigation scenarios that comprise different policy instruments. Particular attention is paid to the ports of Gothenburg in the West of Sweden, Trelleborg in the South and Stockholm in the East (Figure 1).

The baseline scenario is described in Table I, where the tonne-kilometres for the different modes and the volume of emissions of CO₂ equivalents, nitrogen oxides (NO_x), sulphur oxides (SO_x) and small particulate matter (PM 2.5) are given. As can clearly be seen in Table I, the emissions per tonne-kilometre are by far the lowest for rail. This is because the Swedish rail system almost exclusively uses energy from non-fossil based sources. The amount of emissions of CO₂ equivalents, NO_x, SO_x and PM 2.5 under the different scenarios is calculated both in tonnes and in monetary values. The values are based on the European Handbook on External Costs of Transport (Ricardo, 2014).

3. Results

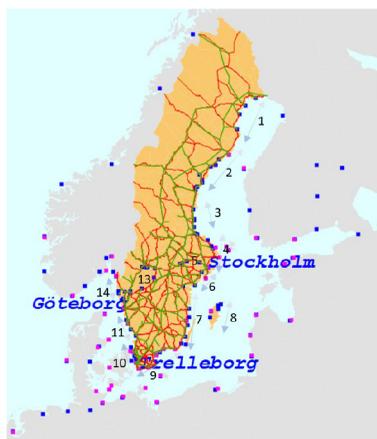
3.1 Modal split

The results indicate that the higher fairway dues and pilotage fees imply relatively small modal shifts (about 0.3 per cent less sea tonne-kms in Sweden) and low own-price and cross-price elasticities (Table II). The same is true for the higher rail track fees (about 1.0 per cent less rail tonne-kms). The impact is, as expected, greater for the introduction of distance-based road user fees (about 4.8 per cent less road tonne-kms).

The distance-based transport costs per tonne-kilometre increase by about 7 per cent for road, 3 per cent for rail and 0.5 per cent for sea. These changes are a combined effect of the increased fees and the modal shift.

Furthermore, the simulations show that gate fees of up to SEK 300 per truck in all ports do not lead to major impacts on the modal split (Figure 2). For a gate fee of SEK 300, shifts to the land-based modes of about 3.8 per cent more rail tonne-kms and about 1.2 per cent more road tonne-kms are observed. Shifts of cargo to ports outside Sweden are also calculated (Figure 3). It is obvious that the modes are not only competing but also complementary to each other.

Figure 1.
Main land-based infrastructure, ports within the 14 coastal stretches in Sweden and ports in neighbouring countries



3.2 Throughput in ports

Gate fees of 200 SEK per truck applied in all Swedish ports are calculated to reduce the throughput overall across all ports by about 2 per cent. The reduction in throughput is calculated to be greatest for Food and Agricultural products, Chemical products and Industrial products (Table III).

	Road	Rail	Sea	Total
Billion tonne-km	53	20	36	109
<i>Emissions</i>				
CO ₂ -equivalents (1,000 tonnes)	3,333	29	1,247	4,609
NO _x (tonnes)	12,621	365	17,972	30,958
SO _x (tonnes)	8	0	709	718
PM 2, 5 (tonnes)	207	13	360	581

Table I.
Tonne-kms and
emissions on
Swedish territory in
the baseline scenario

Sources: Transport analysis, statistics Sweden, Swedish environmental protection agency and own assumptions

Policy instrument(s)	Road (%)	Rail (%)	Sea (%)	Total (%)
1) Higher fairway dues and pilot fees	0,1	0,1	-0,3	0,0
2) Higher rail track fees	-0,1	-0,8	1,1	0,2
3) Kilometre-based road user fees	-4,7	4,4	2,8	0,2
1), 2) and 3)	-4,6	3,3	3,6	-0,1
4) Gate fee of 200 SEK/truck in all Swedish ports	0,6	1,4	-2,2	-0,3
5) Gate fee of 200 SEK/truck in ports of Goteborg, Trelleborg and Stockholm	-0,3	0,8	0,7	0,3
1), 2), 3) and 4)	-4,1	3,9	1,1	-0,7

Table II.
Calculated impact on
tonne-kms in Sweden
(compared to
baseline)



Figure 2.
Calculated impact on
tonne-kms in Sweden
for different levels of
gate fee per truck (per
mode and total)

MABR
4,1

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Figure 3.
Calculated impact of passage fee of SEK 300 per truck in all Swedish ports compared to baseline (tonnes)

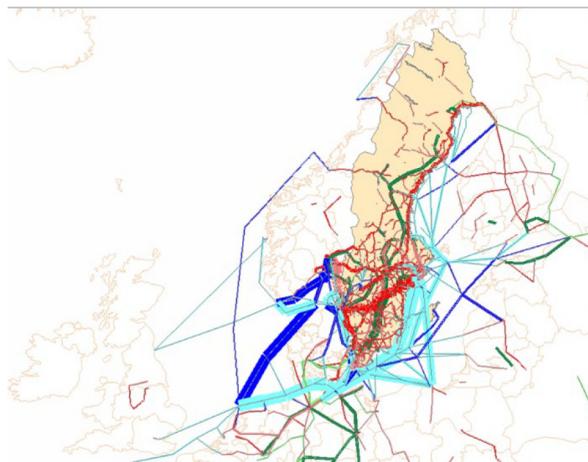


Table III.
Calculated impact of gate fees of 200 SEK per truck in all Swedish ports on throughput (in tonnes) in Swedish ports by STAN-commodity*

STAN-commodity	Agriculture	Timber	Wood prod.	Food	Crude oil	Oil prod	Iron ore	Metal prod	Paper, pulp	Sand etc.	Chemicals	Industry prod.	Total
Change in %	-6,5	-0,7	-3,4	-8,9	0,8	-2,2	-0,3	-2,1	-1,3	-1,8	-2,7	-3,2	-2,3

Note: *STAN-commodities are aggregated from NSTR-commodities

Looking at the differential effect across different coastal stretches, throughput is calculated to decrease in the stretches where the ports of Stockholm (Norrtälje-Nynäshamn) and Trelleborg (Karlskrona-Trelleborg) are located, but not in the stretch where the port of Gothenburg (Gothenburg South of Trollhättekanal) is located. One explanation for the latter result is likely to be the high rail share of hinterland transport at the port of Gothenburg. Similarly, there is a small increase in the absolute throughput volume of the ports in Lake Vänern, which is also likely to be closely related to what happens in the port of Gothenburg. As might be anticipated, the imposition of gate fees of 200 SEK per truck only in the ports of Gothenburg, Trelleborg and Stockholm is calculated to lead to cargoes transferring from these ports to neighbouring alternative ports. A decrease of around 10 per cent is calculated for the combined throughput of the ports of Gothenburg, Trelleborg and Stockholm under this scenario (Figures 4 and 5). The application of road user fees is calculated to imply about 2 per cent higher throughput across all ports and a general shift of throughput from ports on the South coast to ports on the West and East coasts.

3.3 Greenhouse gas emissions and air pollution

Table IV reveals the calculated impact on the volume of CO₂-equivalents, NO_x, SO_x and PM 2.5 in tonnes (Columns 1-4) and in value (Column 5). The introduction of the kilometre-based

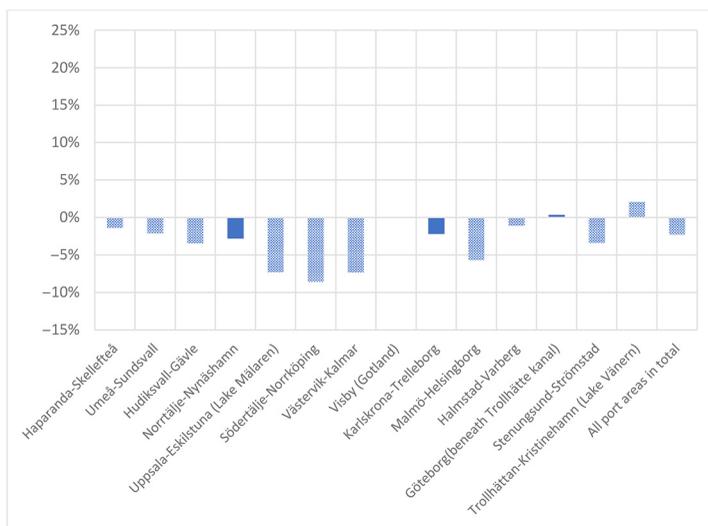


Figure 4.
Calculated impact of
gate fee of 200 SEK/
truck in all Swedish
ports on port
throughputs

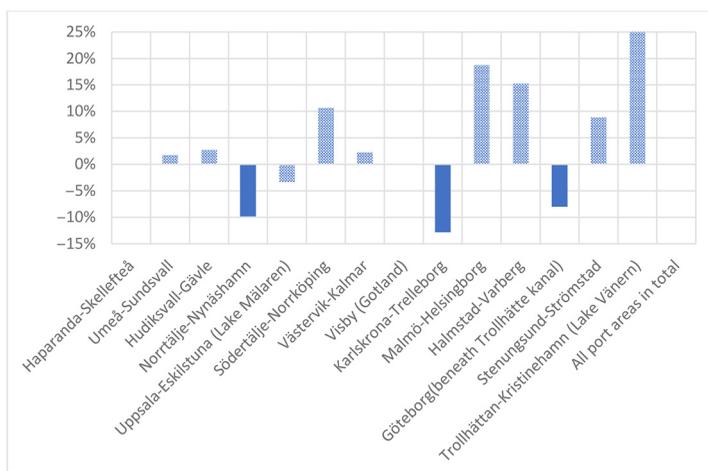


Figure 5.
Calculated impact of
gate fee of 200 SEK/
truck in the ports of
Gothenburg,
Trelleborg and
Stockholm on port
throughputs

road user fee is calculated to have by far the largest individual impact on reducing the external costs of GHG emissions and air pollution. The impact increases slightly when the km-fee is combined with higher fees for sea and rail transport and/or gate fees for trucks implemented across all Swedish ports. Higher rail track fees and gate fees in the ports of Gothenburg, Trelleborg and Stockholm alone are calculated to lead to slightly increased costs of GHG emissions and air pollution. The imposition of gate fees across all Swedish ports is calculated to lead to small reductions in the tonne-kms carried by sea (Table II) and the overall port throughput in Sweden (Figure 1). This is associated with a reduction in the costs of GHG emissions and air pollution.

Table IV.
Calculated impact on
emissions (compared
to baseline)

Policy instrument(s)	CO ₂ -equivalents (1,000 tonnes)	NOx (tonnes)	SOx (tonnes)	PM 2,5 (tonnes)	Costs caused by GHG and air pollution (million SEK)	Logistics costs (million SEK)
1) Higher fairway dues and pilot fees		-41	-2	-1	-2	6
2) Higher rail track fees	10	182	8	4	18	30
3) Kilometre-based road user fees	-120	-74	20	1	-117	908
1), 2), 3)	-108	79	25	4	-97	984
4) Gate fee of 200 SEK/truck in all Swedish ports	-7	-315	-16	-7	-22	104
5) Gate fee of 200 SEK/truck in ports of Goteborg, Trelleborg and Stockholm	-1	91	5	2	4	55
1), 2), 3) and 4)	-122	-306	8	-40	-129	1,072

A further question that needs to be answered is how the infrastructure fees and taxes, which are either revised or implemented to reduce GHG emissions and air pollution, influence the logistics costs of firms. According to our simulations, the increase in the logistics costs of firms in Sweden is somewhere in the range of three to ten times higher than the estimated beneficial value of reduced GHG emissions and air pollution. However, it is important that other benefits to society, such as reduced costs for wear and tear, congestion, accidents and noise, are also fully considered to gain a truly comprehensive evaluation of, and holistic perspective on, the policy measures tested herein. This underlines the need to stress that the specific results derived from the simulations conducted within this paper need to be treated with some caution.

4. Research implications

Methods which attempt to evaluate alternative approaches to the internalisation of the external costs caused by transport need to be further developed. In particular, they need to encompass a more holistic perspective on “benefits to society”, other than merely reductions in GHG emissions and air pollution. One important and constantly recurring issue relates to setting the geographic demarcations for assessing the impact of the external costs. Another aspect is that the internalisation of external costs is typically limited to the “links” in the infrastructure network. This analysis has shown that there is a need to also include the costs incurred in the ports (and in other “nodes”), especially where goods are transferred between the modes. This is especially the case since “nodes” are often the focus for policy instruments that align to the pillar of “strategic investments” (Grubb, 2014). Finally, to facilitate international acceptance and adoption, as a starting point, such methods require agreements to be reached on common definitions and routines. Once this is achieved, the comparative analysis of different national contexts is greatly facilitated and the prospects for learning and applying what has been implemented successfully elsewhere in the world becomes more feasible.

5. Policy implications

The results of this analysis are clearly directly beneficial as the basis for policy-making, i.e. by answering the question as to how much GHG emissions and air pollution from long-distance freight transport can be reduced under each of the policy measures proposed. They illustrate:

- to what extent infrastructure fees and taxes one by one and in combination can reduce GHG emissions and air pollution in the whole transport system;
- to what extent different infrastructure fees and taxes reinforce each other; and
- to what extent fees, at the local, national and international level, should be co-ordinated.

The outcomes are relevant to national and international policy-makers and authorities, as well as port authorities, shippers and transport companies who need to determine unilateral strategies on how to reduce GHG emissions and air pollution, without undermining their wider macroeconomic and business objectives.

Notes

1. €1 corresponds roughly to SEK 10.
2. Model version 1.1 is applied.

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