Economic Impacts of Introducing Tolls for Heavy-Goods Vehicles

A Comparison of Spain and Germany

Claus Doll, Lucia Mejia-Dorantes, Jose Manuel Vassallo,
and Katharina Wachter

This paper focuses on the wider economic and environmental impacts of introducing or expanding road toll systems for heavy-goods vehicles in selected Spanish provinces and how these impacts compare with those of the German toll system. For this purpose, literature and statistical analyses are supported by applications of the European system dynamics model, ASTRA-EC, and stakeholder interviews. The main conclusions of this study are that positive as well as negative impacts of road pricing systems are often overestimated. Enhancing the environmental friendliness of truck fleets through differentiated tariffs and the generation of additional funds for roads and other investments are positive arguments for toll systems. However, the review of existing systems and transport model applications showed limited to negligible effects on the competitiveness of the transport sector, logistics patterns, modal shares, and wider economic impacts with the current charge levels in Germany and Spain. Some specific user groups, such as small- and medium-sized transport enterprises based in peripheral locations, would face considerable difficulties. The success of newly revised truck tolling regimes depends heavily on local conditions, the design of tariffs, the revenues spent, and active participation by stakeholders.

Since the 1950s and, in particular, after the liberalization of European freight markets in the early 1990s, truck freight or road haulage has evolved to become the dominant mode in national and international logistics. Despite major efforts of the European Union (EU) and some member states to support railways and freight transfer to this sector, the market share of trucks at tons lifted in the 28 member countries of the EU has stabilized at just below 80%. Of course, freight transport share by mode varies by country. In Spain, trucks perform close to 100% of freight movements, while nonroad modes in Germany carry more than 30% of goods, with railways attaining 23.5% of the freight share in 2013 (1).

The European Commission (EC) has attempted to reduce and better manage road freight; however, regulations, taxes, and charge levels are still rather heterogeneous across the EU. Since 1960, the idea of charging transport users has been under debate for fairness

and efficiency objectives based on marginal pricing principles. The Eurovignette Directive, first issued in 1999 (2) and revised twice since then, sets the rules and conditions for charging heavy-goods vehicles (HGVs) for air and noise pollution costs, along with the economic costs of road construction, maintenance, and operation (which are also the primary focus of such charges in the United States). The strategic goals of the EC's charging policy are to reduce congestion problems and benefit those companies that invest in efficient logistics, less-polluting vehicles, and more-sustainable transport (3). However, adoption of the Eurovignette Directive varies among EU member states, and some have not adopted it at all.

Many countries already apply the eurovignette charging model on public roads; these include Switzerland, Austria, Germany, the Czech Republic and, more recently, Belgium, Portugal, and Poland. Others apply this model with private concessions for construction, maintenance, operation, and toll collection.

In the United States, the National Highway System is known to be the largest in the world, comprising almost 260,000 km (4). Even if some similarities with the German road network have been highlighted (5), a wide variety of toll systems in different sections, including toll-free highways, can be found in the United States. There are only a few cases in which HGVs are tolled, taking into account other factors such as number of axles or distance, such as two sections of 285 km and 95 km in Kansas (6). Discussion of vehicle charging for trucks has revolved around accurate costing for road impacts and coverage of maintenance costs, given that the impact of one properly loaded 18-wheeler is equivalent to 9,000 passes by a passenger vehicle. A more accurate user-pays market might better support the National Highway System in the long term.

In Germany, an important justification for implementation of the HGV toll was the level of foreign road freight traffic, which hardly contributes to financing national roads through vehicle and fuel taxes. In 2014, Germany had 77,123 million tons of goods coming from the 28 EU member countries (1). In terms of truck kilometers on toll roads, nearly 40% are performed by foreign companies. This is not the case for countries at the European periphery such as Spain. Here the share of goods from and to other countries is only 6,301 million tons or 8% of the German volume.

Would it be possible to use the successful example of Germany to transform the Spanish traditional system? How successful is the German case really? Would it mean more efficiency and fairness for the Spanish transport sector if social cost-based pricing principles were used? What have the impacts been in Germany, and what would they be in Spain? This paper (a) presents the detailed results of the economic and environmental impacts of introducing or expanding road toll systems for HGVs in Spain, focusing specifically on two

Spanish regions, and (b) compares the Spanish and German cases. Research questions regarding the socioeconomic impacts in both countries were analyzed. The core objective of the study was to shed light on the discussion of the wider economic impacts of toll roads on the transport sector as well as on regions and countries. Results shed some light on how difficult it is to transfer a system to other places, because geographical and socioeconomic factors play a major role in the expected outcomes.

This paper is divided into six sections. Following the introduction, the first two sections present a description of the toll systems in Germany and Spain. The next two sections cover methodology, data, and results, followed by a final section that offers concluding remarks and a final discussion.

THE GERMAN LKW-MAUT SYSTEM

History of the Lkw-Maut System

The idea for the German HGV motorway toll (Lkw-Maut) dates back to a report commissioned by the German government on transport infrastructure charges (7). By a reorganization of the tax-based funding system of federal roads into a user-pays system, the planning bases for extending, maintaining, and operating the road network could be substantially improved. The tariffs thus would reflect the income needed to maintain and renew the network, rather than to repay historical investments. In this spirit, the first report on the cost of road infrastructure followed an entrepreneurial, future-oriented accounting principle, which arrived at an average toll rate of 15 cents per kilometer for HGVs above a 12-ton gross weight on motorways (8). Given the rate of earmarking fuel tax payments for diesel, the effective funding needs were estimated at 12.4 cents per kilometer, which was the average level of the Lkw-Maut upon introduction in 2005.

The Lkw-Maut was supposed to be introduced in 2003, but it encountered technical problems at the outset. After a smooth technical implementation in 2005, expectations in terms of revenues were met (9). At its start in January 2005, 100,000 haulage companies, of which a third were extraterritorial, were registered, and 84% of all trips and 91% of trips by German haulage companies paid via the electronic on-board unit (OBU) payment system. Thirty-four percent of the projected income of €3.0 billion in 2005 came from non-German undertakings.

After a legal dispute between Germany and the EC on a planned toll compensation procedure, the second infrastructure cost study suggested an average toll level of 16.9 cents per kilometer (10), but with a stronger differentiation of tariffs according to the vehicle's exhaust emission standards. This tariff change, which was introduced at the onset of the world economic crisis in 2009, was also intended to encourage the use of low-emission vehicles. After the successive inclusion of detour-prone federal roads into the tolling systems from 2012 on, all 1,100 km of motorway-like federal roads were included in the Toll Collect System.

Technology and Organization of the Toll Collect System

The German motorway system consists of a huge number of entry and exit points, which makes the application of a conventional system with toll booths difficult. Therefore, a highly flexible system based on satellite technology was specified in the call for tender for the toll system. In 2001, the contract was awarded to the toll collect

consortium formed by Daimler, Deutsche Telekom, and the French Vinci Group. The system consists of the following elements:

- Registration. Vehicles participating in the toll systems must register with the Toll Collect System.
- Electronic toll collection via OBUs. OBUs must be built into the vehicles with connections to vehicle electronics and motor controls. The OBU registers the environmental standard of the vehicle, the presence of a trailer, and the position of the vehicle via GPS. Via the mobile phone network, the OBU communicates actual toll payments and updates on tolled roads and tariff structures with the Toll Collect System.
- Manual booking. Drivers can also book and pay for a trip via the Internet or on toll collect terminals available in parking and rest areas along the motorway.
- Control of toll payments by both the Toll Collect System, via camera systems on toll bridges, and by the Federal Office for Freight Transport. The Federal Office for Freight Transport undertakes manual controls on roads using control vehicles and mobile roadside devices and employed 775 people for these activities in 2012.

Tariff Levels and Tariff Structures

The contract with the Toll Collect System is set for 15 years, that is, from 2005 to 2020. System costs are around €500 million for the motorways plus an estimated €70 million for the federal road sections added in 2012 (11).

The use of toll revenues was originally allocated to all modes: 50% to the federal motorways, 38% to rail, and 12% to inland waterways. When the federal states protested, the allocation system was changed in 2009. Revenues in 2015 were spent entirely on the road sector: 83% for infrastructure investments and maintenance, 15% for harmonizing measures supporting the road haulage sector, and 3% for other purposes. The investment, planning, and administration of the revenues are done by the Transport Infrastructure Financing Association (*Verkehrsinfrastrukturfinanzierungs-Gesellschaft*, VIFG).

The revenues of the Toll Collect System continuously rose, even during the economic crisis, until 2011 but have stagnated since then. Correcting for the additional €100 million of expected revenues attributable to the inclusion of motorway-like federal trunk roads in 2012, the decline in revenues from motorways was €200 million. System costs declined from 20% of total toll revenues, when the toll collect system was launched, to 10.4% in 2011. With the inclusion of trunk roads this cost returned to 15%. The effective average toll paid per HGV kilometer changed from 11 cents per vehicle kilometer in 2005 to 17.7 cents per vehicle kilometer in 2010 and back down to 14.6 cents per vehicle kilometer after the toll level revision in 2015.

THE SPANISH SYSTEM OF ROAD CONCESSIONS

The Spanish Road Network

As of 2014, the Spanish road network was 166,284 km long, with 26,124 km managed by the central government. This network catered to 51.2% of total vehicle movements in Spain, and 62.8% of these movements were attributable to HGVs. Regions (*comunidades autónomas*) managed 71,397 km where 42.9% of the national vehicle movements occurred. The remainder of the 68,763 km were managed by the Spanish councils (*diputaciones*) (12). Ninety percent of the high-capacity road network in Spain has two lanes per

traffic direction (13). Figure 1 is a map showing types of road in Spain and highlighting the two regions—La Rioja and Jaén—that are examined in this paper.

According to Eurostat, the European Statistics Agency, the Spanish motorway high-capacity network has experienced remarkable growth (15). In 2000, the most extensive network within the EU15 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom) was in Germany, followed by France and Spain; however, in 2012, Germany accounted for 12,879 km, France for 11,465 km, and Spain for 14,701 km.

History of Road Concessions

The Spanish toll concession system started at the end of the 1960s, when almost the entire Spanish road network was composed of single lane roads. In 1977, 1,100 km were built as toll roads. In 1996, the network comprised 2,000 km, and by 2006, 3,000 km were toll roads. Nowadays, there are 3,307 km of toll roads with no plans for extension. When tolls were first implemented, they were a good alternative to conventional roads because the newly built motorways came with considerable travel time savings. Because of their benefits, social acceptability was very high (16). Concerns over

problems arising from bankruptcy rescues of some toll motorways, expansions of the lifetimes of some concessions, and uneven distribution of income over regions have increased questions about tolls as a solution.

Currently, the 3,307 km of toll roads are managed by 32 concessionaire companies. These include so-called “shadow tolls,” that is, state contributions to the concessionaire per vehicle using the road (17). In 2013, measures that sought to promote tolled motorways were implemented. These included discounts for passenger vehicles and HGVs, such as on the AP-68 (from Bilbao to Zaragoza), which crosses the territory of La Rioja.

Slightly more than 83% of the kilometers of the toll road network are owned by the national government, while the rest are owned by regional governments (17). According to the same source, the total traffic in 2014 showed a decrease on average (light and heavy vehicles) of 4.14% from 2013.

In 2005, the Strategic Plan on Infrastructures and Transport (*Plan Estratégico de Infraestructuras y Transportes*) established priorities for the time horizon until 2020. This plan included shadow toll concessions to upgrade high-capacity road sections with design standards far below those desired to ensure safety, good maintenance, and high-quality operation. On the basis of this approach, 1,042 km of roads were awarded to different private consortia (17). These contracts, with durations of 30 years, pay the concessionaire on the

FIGURE 1 Toll road network in Spain (Fraunhofer ISI and (14)).

basis of both traffic and a set of quality indicators. For example, the A-4 section, Puerto Lápice–L.P. Ciudad Real to Jaén (Kilometer 184 to Kilometer 245), was constructed under this regime.

According to the *Ministerio de Fomento*, the sector employed 3,830 people in 2013, of whom 588 were related to general service, 2,340 to tolls, and 902 to maintenance (17).

Tariff Levels and Structures

Tariff regulations in the national network are adjusted by law (Law 14/2000, December 29, 2013) (17). Toll implementation is revisited at the beginning of each year. The average prices on December 31, 2013, were as follows:

- At a national level: €0.1101/km for passenger vehicles, €0.1659/km for HGV1 [trucks and buses with two axles with or without a trailer (one axle) or buses and trucks with three axles], and €0.2035/km for HGV2 (buses and trucks with four or more axles or two-axles trucks or buses with a trailer with two or more axles); and
- At the regional level: €0.1505/km for passenger vehicles, €0.2381/km for HGV1, and €0.2858/km for HGV2.

For comparison, the German motorway toll studies indicate tolls of €0.05/km for passenger cars and €0.15/km for trucks (7, 8). Assuming that the same span of costs is applicable to Spanish roads, a cross subsidization from trucks to cars can be construed. However, it was assumed that Spanish concessionaires take profit-maximizing monopoly charges, which take into account price elasticity and other properties in addition to cost causation.

In addition to tariff differences that depend on the concession and type of vehicle, there are other differences that depend on a variety of factors. For example, tariffs may differ because of high and low seasons, peak and night or non-peak hours and weekdays, traffic direction, and so on. There are some concessions, such as the AP-9, that have discounts for regular passenger vehicles. Other concessions apply premiums to certain HGVs when electronic toll collection devices are used.

METHODOLOGY AND DATA

This study was designed to combine qualitative and quantitative approaches. The quantitative approach used statistical material when available and the ASTRA-EC transport and economics system dynamics model. The qualitative tools comprise literature reviews and supporting expert interviews. Following Crang, the dialogue between these two techniques is considered to be effective in tackling complex challenges for which results cannot be achieved by either the quantitative or qualitative approach alone (18). Because of space constraints, the following paragraphs provide only a brief overview of the methodological elements applied to address the research questions.

Quantitative Analysis

The system dynamics model ASTRA-EC was used for the quantitative approach. It is an integrated assessment model for transport and energy applications that covers 27 EU member countries plus Norway and Switzerland. These are organized into 98 European regions (seven in Spain and 16 in Germany). ASTRA-EC integrates nine modules: vehicle fleets; transport activities; emissions and accidents; popula-

tion, foreign trade, and economy with 25 sector input–output tables; and government, employment, and investment models. In road freight, ASTRA-EC distinguishes between three truck sizes with five environmental standards each and three commodity types. ASTRA-EC follows a dynamic approach with manifold links between the modules and runs until 2050. It was designed for an integrated strategic assessment of the transport sector and energy, economic, and sustainability impacts of policy interventions. The complex internal feedback structure entails compromises in geographical accuracy: ASTRA-EC does not have an internal transport network but is calibrated with external transport network models. Detailed descriptions of the model are available elsewhere (19–22).

Scenarios are defined in a rather simple way by specifying average net toll levels by truck size and their evolution over time. Because of limitations of the ASTRA-EC model, the scenarios do not differentiate toll payments by time of day, location, or the vehicle's exhaust emission standard. Net revenues indicate that governmental compensation payments are considered in the toll levels. In this way three scenarios were defined for each of the regional entities:

- The base case scenario describes the situation of HGV tolls in Europe with regard to past and current developments and designs of toll systems in the foreseeable future.
- The no-toll scenario describes a case in which all existing tolls, including bridge and tunnel levies, are abolished for all three regional entities.
- The high-toll scenario denotes a condition of extended toll systems in all three areas. For Germany, this is the doubling of charge levels plus the extension of the charge to all major federal roads (as planned from 2018 on). For the Spanish regions around La Rioja and Jaén, this is basically the application of a toll similar to the base case in Germany with different assumptions about the probability of using toll roads.

The study compared regional entities, that is, all of Germany with two provinces in Spain. Although this approach is questionable from a statistical point of view, it was chosen to reflect the different regional settings in Spain: the port–hinterland road traffic from Bilbao in northwestern Spain (ES2) and the region in southern Spain bordering the Mediterranean (ES6).

The scenario assumptions used in this study are presented in Table 1.

Model outputs are presented as the difference between the no-toll and high-toll scenarios and the base case. The following output indicators from the ASTRA-EC model were used in this study:

- Gross domestic product (national),
- Employment rate (national),
- Transport flows within and between the German and Spanish regions by three commodity types and modes, and
- Air emissions by type—greenhouse gases, nitrogen oxides, and particulate matter by mode and country [external costs calculated by using the methodology in Maibach et al. (23) and van Essen et al. (24)].

Qualitative Analysis

Two qualitative approaches were used as a means to complement and contrast with the quantitative study. Supporting interviews were conducted with experts and stakeholders in Germany and in Spain to elicit information. Telephone interviews were carried out on various

TABLE 1 Scenarios Used in the ASTRA-EC Model

Parameter	Germany			ES2 Northwestern Spain		ES6 Southern Spain	
	2015	2020	2030	2015	2030	2015	2030
ASTRA							
Diesel price (€/l)	1.293	1.317	1.365	1.271	1.341	1.271	1.341
Truck costs intrazonal freight (€/VKT)	1.206	1.206	1.166	1.167	1.106	1.167	1.106
Truck costs international freight (€/VKT)	1.307	1.301	1.284	1.196	1.168	1.196	1.168
Base Case: Current Toll Scenario^a							
Average toll level (€/VKT)	0.160	0.140	0.140	0.105	0.105	0.126	0.126
Use of toll roads intrazonal freight	0.730	0.760	0.760	0.200	0.200	0.100	0.100
Use of toll roads, domestic freight	0.910	0.930	0.930	0.560	0.560	0.350	0.350
No-Toll Scenario^b							
Average toll level (€/VKT)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Extended-Toll Scenario^c							
Average toll level (€/VKT)	0.250	0.250	0.250	0.140	0.140	0.140	0.140
Use of toll roads, intrazonal freight	0.750	0.750	0.750	0.730	0.760	0.200	0.200
Use of toll roads, domestic freight	1.000	1.000	1.000	0.910	0.930	0.500	0.500

NOTE: VKT = vehicle kilometers traveled.

^aFor Germany = no changes after 2015; for ES2 = current toll system in northeast Spain; for ES6 = current toll system in southern Spain.

^bFor Germany = abolishment of all tolls as was the case in 2005; for ES2 and ES6 = abolishment of all existing tolls.

^cFor Germany = tariff of base case doubled, all federal roads; for ES2 = from 2005 toll system as in German base case; for ES6 = northeast Spain base case.

SOURCE: Fraunhofer ISI and ASTRA-EC model calculations.

topics during the first semester of 2016, each lasting approximately 30 min. Each participant was free to delve deeper into any of the topics listed below. The main questions covered were related to the following:

- Expertise and regional experience,
- The current situation of the transport market in national and international markets,
- The current tolling system and the eurovignette system,
- Pros and cons, and
- Other relevant information.

Additionally, questionnaires were sent to people and groups with expertise in the transport business including producers and manufacturers, transport operators, logistics companies, researchers, public administration, toll operators, infrastructure managers, and transport associations. Questions focused on expected behavioral changes in their companies, agencies, clients, and competitors (as applicable) as a result of hypothetical changes in toll regimes. Because of the controversial nature of the topic in Spain, only 12 responses were received from this country. This small survey is considered only as a supplement to the expert interviews.

Other important sources of information were also used, such as statistics, along with relevant data coming from a thorough literature review.

RESULTS

This study examined several scenarios of electronic highway tolling systems for trucks and their likely impact on transport efficiency, on transport companies, on the wider economy, and on sustainability. Of the suite of approaches used in this study, the system dynamics model ASTRA-EC provided the most comprehensive data for

drawing final conclusions. Table 2 provides the main results of the modeling by mode of transport and for domestic and cross-border shipments. The table provides a comparison of the two scenarios (no toll and high toll) to the current situation (base case) for the years 2015, 2020, and 2030. The table is organized in three blocks according to the geographical cases examined in the study.

Logistics Efficiency in Trucking and Use of Other Modes

Because international competition in service industries is high, national logistics markets have a vested interest in increasing efficiency to maintain or even to expand market share. Further pressure on efficiency comes from increases in road congestion and from a lack of truck drivers in many European countries. An idea of whether road tolls help in this situation can be formed by measuring transport efficiency in two ways: (a) by the share of empty-haul trips and the use of load space in loaded trucks and (b) by the use of alternative modes.

In Germany, the introduction of the Lkw-Maut has contributed to a further decrease in the share of empty-haul trips by 1% to 2%, although the sector has gone through a major efficiency improvement since the road logistics market liberalization in 1993 (9). Because of changing goods structures and more diversified destinations, use per truck as well as the overall efficiency in trucking remains on a declining path from 52% in 1998 to 47% in 2013. The Lkw-Maut had no visible impact on this trend.

Interview results suggest that, for Spain, the observed share of empty-haul trips is rather stable and shippers do not expect it to change with alternative road pricing scenarios. With 47% of empty-haul trips the overall efficiency of the Spanish trucking sector is, however, far below the German share of 20%. The cautious expectations put forward in the stakeholder interviews can thus be challenged.

TABLE 2 ASTRA-EC Results Comparing Key Indicators in No-Toll and High-Toll Scenarios with Base Case by Percentage Change

Indicator	No Toll to Base Case			High Toll to Base Case		
	2015	2020	2030	2015	2020	2030
Freight Volumes and Mode Share for Germany						
Road tkm ^a						
Domestic	0.85	0.82	0.82	-0.85	-1.03	-1.13
Cross border	1.25	1.20	1.17	-0.91	-1.09	-1.13
Total	1.06	1.02	1.01	-0.88	-1.06	-1.13
Rail tkm ^a						
Domestic	-5.79	-5.25	-4.91	5.94	6.81	6.92
Cross border	-2.18	-1.89	-1.73	1.50	1.70	1.76
Total	-3.46	-3.00	-2.71	3.07	3.39	3.35
Ship tkm ^a domestic	-2.04	-1.83	-1.86	2.90	3.41	3.40
Total tkm ^a						
Domestic	-0.25	-0.22	-0.19	0.28	0.31	0.29
Cross border	0.36	0.37	0.36	-0.28	-0.35	-0.32
Total	0.08	0.12	0.13	-0.02	-0.06	-0.07
Road ^b						
Base Case	78.31	77.43	76.36	78.31	77.43	76.36
Scenario	79.07	78.13	77.03	77.63	76.65	75.55
Freight Volumes and Mode Share for Northeast Spain (ES2) ^c						
Road tkm ^a						
Intra-ES2	0.20	0.52	0.54	-0.03	-0.37	-0.39
To and from ES2	0.02	0.17	0.17	0.02	-0.14	-0.14
Total ES2	0.04	0.22	0.22	0.01	-0.17	-0.17
Rail tkm ^a						
Intra-ES2	-1.57	-4.69	-4.63	1.68	4.93	4.94
To and from ES2	-0.39	-1.11	-1.13	0.34	1.06	1.09
Total ES2	-0.74	-2.19	-2.22	0.74	2.23	2.29
Ship tkm ^a total ES2	na	na	na	na	na	na
Total tkm ^a						
Intra-ES2	0.09	0.32	0.33	0.25	0.49	0.50
To and from ES2	0.13	0.30	0.30	0.17	0.34	0.35
Total ES2	0.12	0.30	0.30	0.18	0.36	0.37
Road ^b						
Base case	58.42	59.72	60.49	58.42	59.72	60.49
Scenario	58.52	60.03	60.81	58.32	59.41	60.16
Freight Volumes and Mode Share for Southern Spain (ES6) ^d						
Road tkm ^a						
Intra-ES6	1.22	1.30	1.36	-1.34	-1.39	-1.44
To and from ES6	0.30	0.30	0.30	-0.34	-0.33	-0.33
Total ES6	0.35	0.35	0.36	-0.39	-0.39	-0.39
Rail tkm ^a						
Intra-ES6	-11.47	-12.13	-12.38	11.13	11.70	11.87
To and from ES6	-2.07	-2.05	-2.08	1.89	1.86	1.87
Total ES6	-3.89	-4.08	-4.25	3.68	3.84	3.97
Ship tkm ^a total ES6	-1.16	-1.19	-1.21	0.95	0.99	0.98
Total tkm ^a						
Intra-ES6	-1.05	-1.11	-1.16	-0.87	-0.93	-0.97
To and from ES6	-0.18	-0.18	-0.18	-0.11	-0.12	-0.11
Total ES6	-0.22	-0.23	-0.24	-0.15	-0.16	-0.16
Road ^b						
Base case	43.13	43.43	43.63	43.13	43.43	43.63
Scenario	43.37	43.69	43.89	43.36	43.67	43.87

NOTE: tkm = tonne-kilometer; na = not applicable.

^aPercentage change to base case scenario.

^bAbsolute market share at land transport.

^cIncluding La Rioja, Basque country, Navarre, and Aragon.

^dAndalucia and the regions of Murcia, Ceuta, and Melilla.

SOURCE: Fraunhofer ISI.

Despite these cautious results, it is the authors' belief that the combination of new technologies in the transport sector, trading platforms, and especially new trends in the shared economy should not be disregarded. If the policy objective is to reduce the share of empty-haul trips, there may be room for improvement through these new mobility concepts. Thus, in the medium to long term it is expected that higher transport costs may cause changes to the location of production and warehouse facilities and thus reduce the distance traveled per goods consignment.

In contrast to the high rail freight shares in the United States, Europe's rail cargo carriers are stagnating or even declining, while close to 80% of tonne-kilometers are transported by truck. Excessive competition and social dumping are assumed to lead to an inefficiently high use of road transport (25, 26). A positive counterexample for a successful mode shift policy based on HGV charges can be found in Switzerland, where high tolls for trucks are accompanied by massive investment in rail capacity. Even in Germany, mode shift targets of the Lkw-Maut were not met despite positive expectations before its implementation (27). Expanding the German system to all roads with higher tariffs would alter the road share by just 1%, but would boost rail and inland navigation volumes by up to 5% according to ASTRA-EC model outputs.

In Spain, the low market share of rail, difficult access to rail terminals, and a different track gage from the rest of Europe make shifts to rail even more unlikely than for Germany. This conclusion was confirmed by stakeholder interviews and transport model applications. However, the weak market share of the Spanish rail freight sector could lift current volumes by up to 12% in some regions.

Impacts on Company Structures

The review of the German Lkw-Maut confirms that large trucking companies are well able to pass on toll costs for loaded trips to their clients and, under some conditions, even to negotiate on compensation for empty-haul trips (9). Although these companies have profit margins of approximately 5%, the majority of small transport companies in Germany with a much weaker negotiating position have profit margins of only around 1%.

For the case of manufacturers and producers in Spain, there is a trade-off between transport costs and commercial margins. A minority of companies (25%) who operate their own transport would rearrange their production costs in the first year that distance-based tolls are introduced. In most cases, transport services are for hire and reward, which is a very atomized sector in Spain, as it is in the United States. Because these small businesses and sole proprietors are not in a position to shift or rearrange costs, the observed trend of relocating or merging companies to adapt to the new conditions is expected to continue.

Trucking undertakings would have to cope with increased transport costs, especially noticeable in provinces on the periphery of Spain where it is costlier to gain access to markets in central Europe. With respect to European markets, transport costs would be even higher for Spanish manufacturers and producers because they would need to pay tolls to cross all of Spain and to travel through or within other countries to reach the delivery destination for their goods. Exports of Spanish products have increased in recent years to counteract the weak internal market. This positive development could be challenged by higher HGV tolls all over Spain.

Small- and medium-sized enterprises, along with manufacturers and producers, may be threatened by toll roads. Because of the eco-

nomic situation in Spain, trucking companies have been reducing their costs, and in the case of own-services, they have not been able to renew their fleet. Therefore, compensation may be necessary to maintain a certain stability in the sector, as occurred with the introduction of the German toll system. The economic situation of the transport sector offers limited remuneration for truckers, and therefore, it would be very difficult to expect them to pay tolls while simultaneously renewing their fleets. Such trade-offs and incentives merit further exploration. The interviews and survey indicated that trucking companies' bargaining power was so limited that they would be the ones to assume toll costs.

Model calculations for Spain showed that consumer prices were expected to increase, but only in the first year after toll introduction (28). However, in the prevailing economic situation and market structure, truckers expect they would have to bear the lion's share of hypothetical toll increases without being able to invoice these costs to their clients. Observations from the German Lkw-Maut do not confirm this apprehension. With an average increase of trucking costs of 10% and a share of transport costs at product prices below 5% for most commodities, the one-off consumer price increases remain below 1%.

Public Revenue and Infrastructure Investment

Revenue from road pricing is much more stable in Germany than in Spain. The income from the Lkw-Maut of €4.5 billion annually constitutes the single most important source of revenue for the German Ministry for Transport, and it has increased continually from the outset at €3.0 billion in 2005. In contrast, revenue from car and truck tolling in Spain peaked at €2.1 billion around 2005 and then dropped to €1.6 billion in 2013. Consequently, some concessionaires in Spain are experiencing financial difficulties stemming from the economic development situation and the international traffic in the country.

International traffic helps stabilize revenue flows and creates acceptance of the toll system and additional income. Forty percent of the revenues from the German Lkw-Maut come from foreign truckers. The high share of transit traffic on German motorways constituted a core argument for acceptance of the Lkw-Maut system before its implementation and for the tariff increase during the years of the economic crisis. Moreover, after an initial distribution of revenue to all modes, since 2011 revenues have been earmarked entirely for federal roads to maintain acceptability of the system. The transit traffic component is largely missing for Spain, where most of the revenue stems from national trucking companies.

Finally, the ownership status of the infrastructure differs between the two countries: while public ownership in Germany ensures the survival of the tolling system, bankruptcy of operators is a problem in the concession-based Spanish system.

Creating appropriate infrastructure and market conditions for internationally competitive logistics operations is a long-term endeavor. According to the World Bank's Logistics Performance Index, Spain has already improved a good bit in the past few years, becoming a major gateway for European imports and exports (29). International freight volumes predicted from the ASTRA-EC model indicate that expansion of motorway toll regimes will not alter this picture. Interviews for this study also underscored this point. In the case of Germany, the system of charging for road use was implemented to affect not only the national HGV fleet but also to raise revenue from transiting freight traffic. Therefore, charging transit trucks would help

fund and maintain roads. In the case of Spain, transit traffic is much more limited, and thus, additional state income would be much more modest there than in Germany.

Alternative funding sources might help stabilize investments. Vignette solutions lower transaction costs and stabilize income flow. Parts of Europe still apply the eurovignette system of area charges. The charges are approximately 10% of the annual costs of the Lkw-Maut system for Germany. The transaction costs of such vignette systems are low, and they could be easily extended to a wider share of the road network; the regimes in place in Europe are now differentiated according to vehicle size and emission standards. Vignette charges could thus, to some extent, incentivize the modernization of truck fleets and address funding needs. They would also be able to generate additional income from foreign road users. On the other hand, as a fixed annual fee, vignette solutions would not incentivize mode shift or an efficient use of vehicles. This approach would, then, not contribute to greater efficiency in logistics.

Tax-based solutions are cheap but inflexible. The transaction costs of solving funding needs through taxes are low, because these systems are already in place and just need to be adapted. However, the effect that such tolls have on creating an incentive to modernize vehicle fleets or use cleaner trucks is limited because of an inability to adequately address foreign drivers. Additionally, there might be avoidance effects; for example, tank tourism (EU drivers going to neighboring countries to take advantage of cheaper fuel prices) to avoid fuel taxes might be relevant. Moreover, taxes are, by definition, not linked to spending in the sector where they are levied. The stability of funding investments and maintenance of road and alternative transport infrastructure would, therefore, not be guaranteed.

Road tolls need closed funding cycles to guarantee effective maintenance. In Germany, which constitutes the largest and one of the richest economies in Europe, the quality indicators for the federal motorway and trunk road network are showing rapid deterioration, despite the fact that Lkw-Maut tariffs were calculated on the basis of funds required for closing the investment gap of €4 million to €8 million estimated for the network. In contrast, responses to interviews conducted for this study in Spain indicated clearly that interviewees would like less congestion and better pavement conditions for toll roads. While, in general, road conditions are particularly poor in non-toll road regions like northeastern Spain, the concession contracts between national and regional governments and concessionaires guarantee certain quality standards and are thus considered a suitable instrument for an effective use of funds. The Austrian system of an autonomous funding and road operation agency may be a good compromise between concession and state-owned models.

Intermodal infrastructure needs public funding. One of the few public models for large-scale cross-funding of rail infrastructure by road user charges is the Swiss heavy-vehicle fee. Other models, like the intermodal earmarking of the German Lkw-Maut and the planned ecotax in France, had to be withdrawn after strong protests from the trucking sector. The key factor in the Swiss model's success is the participation of citizens, which cannot be easily transferred to other European countries.

Environmental Sustainability and Traffic Safety

With the prevailing tariff and incentive structures of the German Lkw-Maut, nitrogen oxides and particle emissions in freight transport were found to be reduced by around 1% compared with a no-toll scenario. This reduction was achieved through a combina-

tion of (a) charge structures, (b) investment aids for transport companies that provided incentives for the use of cleaner vehicles, and (c) the impact of toll levels on overall road transport volumes. The more intensive use of trucks with high-emission standards during the recession after the world economic crisis indicates that the potential impacts may exceed this estimate. With undifferentiated charges, as in the Spanish system, demand effects lead to an emission reduction of 0.1% in road transport only.

Nonemission-related external costs account for 15% to 30% of external costs in freight transport. These are accident costs (8% to 25%) and, to a lesser extent, noise costs (5% to 7%). In particular, accident costs differ widely between Germany—15% of total costs in 2015—and Spain—25% of total costs.

ASTRA-EC emission factors and the economic valuation suggest that by 2030 the external costs of road haulage will decline considerably for Spain. While emission factors and accident rates will decline for all modes of transport, the economic assessment indicates that climate emissions will increase over time. For this reason, the external costs of trucking in Germany, with its truck fleet that is already modern, will grow by 20%, while the expected fleet renewal in the Spanish haulage sector will cause overall climate cost estimates per ton of goods moved to drop by 20%. Adding a vast improvement in safety standards for Spanish trucks compared with small improvements in Germany, the average external costs, including all cost categories of trucking in Spain, are expected to decline by 48% between 2015 and 2030, while they are expected to grow by 2% in Germany.

These results must be considered with some caution because the ASTRA-EC model cannot predict diverted traffic from toll roads. Although observations for Germany showed minor tendencies for traffic to divert to nontolled routes, simulation work for Ohio state turnpikes revealed considerable diversion trends, adding considerably to crashes and air emissions (25, 26). These results may be more relevant for the Spanish network than for the German case.

Thus, it appears that the primary objective and effect of road tolls are funding and cost internalization rather than improving sustainability. Through the introduction of the German Lkw-Maut, external costs of €24.5 million were saved. In contrast, operating costs by the toll collect consortium were €540 million, and an additional €450 million was spent to incentivize the purchase of low-emission trucks. Accordingly, road user charges should be considered as a financing instrument rather than an instrument whose primary function is to reduce social impacts.

CONCLUSIONS

Overview of Results

Table 3 provides a brief overview of the various aspects highlighted by the methodological toolbox used in this study. Without preempting the findings of this study, this table provides qualifiers on the direction and relevance of toll impacts on aspects of companies, the economy, and sustainability.

Discussion of Results

Several conclusions can be drawn with respect to introducing or expanding HGV tolls in areas on geographic peripheries, as in the Spanish case. The analyses carried out for this study did not go into financing or institutional theories or other subjects of high importance

TABLE 3 Summary of Study Results for Germany and Spain

Objective	Germany After Introduction of Lkw-Maut		Northeast and Southern Spain	
	Rating	Observation	Rating	Expectation for Toll Expansion
Logistics efficiency	+	Slight improvements of load rates but with some bankruptcy Sector already competitive through past liberalization	++	Great potential as haulage sector highly atomized, but at cost of many bankruptcies
Shift to alternative roads	0	Despite high hopes, no measurable effect Theoretical potential –1% for road, +5% for rail and shipping	+	Some effect on shipping possible No shift to rail because of low quality and accessibility
Profit margins in transport	–	10%–15% cost increase that can mostly be passed on to clients but smaller companies in a worse bargaining position to do so than larger companies	—	Higher cost increases because of lower wage levels Many small companies, thus costs may not be passed on as in Germany.
Economic growth and employment	0	ASTRA-EC considers only a positive employment effect of 0.01% against base case with a doubling of German Lkw-Maut from 2005, corresponding to +40,000 jobs. Model considers a GDP decline of –0.02% toward 2030 compared with base case scenario.	—	Employment impact in ES2 range approximately $\pm 0.3\%$ relative to region's base case employment. Regional GDP would decline by –0.3% in 2030. In ES6 (where Jaén is) regional impacts vary between –0.01% and 0.05% and also a regional GDP decline of –0.3% in 2030.
Additional revenue	++	Approximately €3 billion–€3.5 billion after system costs and compensation because of 40% foreign traffic on German motorways.	+	Mostly reallocation of funds in Spain because of low foreign traffic and high network costs
Benefit of alternative funding sources	0	Because of dense HGV traffic in Germany, rather expensive Toll Collect System is efficient.	++	Vignette-based solutions may yield similar results at lower costs in low-density Spanish regions.
Environment and external costs	++	Cleaner fleet because of emission-differentiated charges, but external costs do not outweigh system costs.	++	If emission differentiation similar to Germany's, fast renewal of older Spanish truck fleet

NOTE: GDP = gross domestic product; ++ = strongly positive; + = moderately positive; 0 = neutral or no effect; – = moderately negative; — = strongly negative.

for investment strategies, but they may be of use for developing implementation strategies as reorganizing continues in the sector.

The strengths and weaknesses of distance-based HGV toll systems should be kept in mind. Such toll systems are primarily a funding instrument. Sustainability and mode shift aspects can be supported by road pricing and tolls, but, for efficiency, the transport sector needs to provide clear signals—including differentiated tariff structures and accompanying regulatory and fiscal instruments—about what behavior is desired.

Sensitive planning is needed because of the following factors: missing transit traffic, which would contribute to funding of the Spanish road network, and the long distances Spanish haulers must travel to get to the European core markets. Because of the large number of small transport companies, the Spanish logistics sector is rather sensitive to tolling. Changes in tolling systems, thus, must be well evaluated and prepared through stakeholder participation processes and in-depth sector studies.

If a shift to rail or waterborne transport were among the objectives of the Spanish transport policy, the quality of available or desired modes should be addressed first. Availability and quality may also vary across corridors and require evaluation. For rail, the problem of track gages must be addressed because rail freight transport needs a long-distance relation to the European main market. Development plans of the Trans-European Transport Network address this issue along major European freight corridors. Road pricing supports, but does not carry, a modal shift once high-standard key performance indicators are met.

For altering or expanding road charging systems, a well-prepared and structured implementation process needs to be set up. It is essential to reach a consensus with all the sectors affected by such a measure well before its implementation. An in-depth study is needed to understand the situation in Spain for all stakeholders. For this study,

surveys and interviews were tested as part of a qualitative approach. However, more input from all sectors must be gathered through quantitative approaches.

It is necessary to bear in mind the situation of the forwarders and transport companies. They oppose tolls because, in the Spanish economic context, they have limited margin to maneuver; for example, the French government had to withdraw plans for an ecotax allowing cross-funding from road to other modes because of the level of truck drivers' protests. In an atomized freight transport sector, such as the Spanish one, it is very difficult to absorb extra costs. An option for strengthening the position of transport enterprises would be to oblige forwarders to pay toll costs.

The secondary road network must be part of implementation plans for new road-pricing systems. Considering the importance of road freight in Spain and the current wear-and-tear situation of the Spanish network, more economic resources are needed to maintain the Spanish roads. However, some users will take detours, and conventional roads are not prepared for this traffic: safety issues, road wear, road destruction, and other issues such as congestion or pollution can arise, as predicted in studies about the United States by Swan and Belzer (25, 26).

The principle of equity must be considered when transport infrastructure is being planned. All aspects of a project must be evaluated to seek equity for all stakeholders. The interviews and the survey carried out for this study support the importance of this point. For example, regional equity across the Spanish territory must be considered. Spanish studies that have examined the impacts of toll charging are limited because they looked only at the case in which all freight traffic moved around the Spanish territory. The Spanish project to model road pricing [*Modelo Español de Tarificación de Carreteras (META)*] modeled toll scenarios for Spain (13); however, because the analysis was carried out before the economic crisis, the results

might not accurately reflect what would occur in current conditions. Moreover, especially in the last few years, international trade has been an important motor for the economy. Therefore, in a toll-charging scenario, transporters in the southern regions would need to cross the Spanish territory and then get to their European destinations, which would ultimately increase the total cost of products. Additional tolls on the Spanish territory would thus compromise producers' competitiveness.

Smart ways of increasing transport efficiency without compromising small transport companies need to be explored and exploited. The combination of new technologies in the transport sector, cooperative trading platforms and, especially, new trends in a shared economy, should be considered. If a goal is to reduce the share of empty-haul trips, there may be room for improvement through these new mobility concepts.

Spain is a country on the geographic periphery of Europe with a lower level of industrialization than its trading partners, which also use surface transport, and with moderate economic perspectives. The geography of the United States, with its economic hot spots near the coasts on both sides of the continent, differs from the more center-oriented European picture. However, regions close to the Mexican border or in the Midwest with long distances to U.S. core markets, dominant agricultural sectors, and lower economic dynamics may derive insight from the Spanish example examined in this study.

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