COST EFFICIENCY AND ASYMETRIC INFORMATION IN THE EUROPEAN RAILWAYS INDUSTRY

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Preliminary

Abstract
The objective of this article is to analyze European railways' incentives to improve efficiency in the recent liberalization context. We build and estimate a structural model accounting for regulatory pressures faced by the firms. Our model includes demand equations, a capacity constraints and a cost function, in which are specified an exogenous technical efficiency component and an endogenous cost reducing effort parameter. We find a significant positive effect of implementing the reforms on cost reducing activities.

Keywords: cost efficiency, asymmetric information, network industries, panel data.

JEL codes: L92, L43, L51, C23.

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1. Introduction

Railways activities have traditionally been conceived and operated with a national perspective by domestic companies, enjoying exclusive rights or dominant market power in their respective national territory. This conception of the sector came from the idea of considering railways services as a form of "universal service". However, even railway companies being quasimonopolies and heavily subsidized, their market shares were at best stable.

The European Commission has tried to revitalize the railway sector from the last decade. During the 1990's, Europe attained levels of congestion that could threaten its economic competitiveness. The European Commission in its white paper estimates that congestion costs would attain 1% of the European Union GDP by 2010. In this document the European Commission establishes that "Rail transport is literally the strategic sector, on which the success of the efforts to shift the balance will depend, particularly in the case of goods". Following the way marked by some countries which started to introduce reforms in the late 80's, such as Sweden, the European Commission has proposed several measures to promote railways. In particular, the first package of measures is formed by the directive 91/440. The objective is to stimulate competition in this industry in order to improve efficiency. The main measures proposed by the European Commission aiming at boosting demand and reaching a sound level of competition and efficiency are threefold. They consist first in the separation of operations from infrastructure activities, second in the creation of an independent regulatory institution, and third in the provision of access to the network to third parties.[3]

The effects of railways regulation have been studied in the literature. A series of articles have lead to the conclusion that efficiency can be highly determined by the constraints imposed by the regulatory environment to the railways management. Among them Gathon and Pestieau (1995), Cantos et al. (1999), Gathon and Perelman (1992), Oum and Yu (1994) for the European market, and Caves et al (1998) for the US market.

Going a step further, two papers study the effects of different types of regulatory measures on railway companies' efficiency level. Cantos et al (1999) analyze the impact of four types of reforms on technical and revenue efficiency: separation of infrastructure from operations, changes in legal structure, regulation of fares and public regulation of railway investment. The separation between infrastructure and services achieved the most beneficial

[3] To ensure the effective enforcement of access rights, two complementary directives were created in 1995. They clarify the conditions of access on several aspects such as licensing, capacity allocation and charging.

impact according to their analysis. Friebel et al (2006) adopt another approach. They measure the impact on efficiency of a series of reforms as being introduced either sequentially over time or all together at the same moment of time. They find a significant and positive effect of deregulation on efficiency for countries where reforms were implemented sequentially, and a negative effect for countries where all the reforms were introduced as a package.

However, these studies do not take into account the endogenous reaction of the railways managers' to the regulatory changes. More specifically they do not consider the effort railways operators exert to improve efficiency, in this new regulatory framework. As suggested by Laffont (1994), the producer's endogenous effort depends on the constraints exerted by the regulatory environment that it faces. Following Gagnepain and Ivaldi (2002) and Gagnepain and Marin (2006) we assume that the new competitive pressure and the reduction in subsidies due to the deregulation provide good incentives for the operators to reduce costs. Our approach consists in estimating simultaneously a structural system of equations, demand, capacity and costs, taking into account in the latter an exogenous component for efficiency and an endogenous term measuring cost-reducing effort.

The structure of our article is the following one. In Section 2 we present the economic model and the associated estimation method. Section 3 displays the application and data we use to test our model. Section 4 presents the results and some conclusions are drawn in Section 5.

2. The model

Our objective is to evaluate the incentives railways operators face to improve efficiency, after the implementation of the deregulation process in the European railways industry. In our approach we concentrate on operating activities only, and we do not consider infrastructure management. Efficiency can be estimated both with a production function or a cost function approach. Data requirements and specificities of the industry under analysis are the main factors determining the relevant methodology to follow. In our framework, firms produce multiple outputs (passenger and freight traffic), which makes the estimation of the cost frontier appropriate. Required data are available and will be presented in details in Section 3. Moreover, the estimation of cost efficiency assumes a behavioral objective of producers, which is relevant in our framework. The distinctions between production and cost functions approaches are exposed with more details in Kumbhakar and Lovell (2000). We present now in details the cost function we estimate, and which allows us to measure the incentives railway operators face to improve efficiency.

A standard cost function is defined as the sum of the expenses related to several inputs. In our framework, our objective is to evaluate the incentives railway operators face to reduce their costs after the deregulation process started. We need to consider costs as dependent on two additional and unobservable components: an exogenous inefficiency term and an endogenous cost-reducing effort variable. This effort is undertaken by the operators to offset the effects of inefficiency. The cost function to be estimated at the end is the dual cost function to the production process, resulting from the following program of each firm:

$$\begin{aligned} &\underset{x}{Min}\, C\left(wx,\theta,e\right) \\ &subject\ to \\ &f\left(x\right)\geq Q\ , \end{aligned} \tag{1}$$

where x is the vector of input quantities, w the vector of input prices, θ the inefficiency term, e the cost-reducing effort variable, Q the vector of output quantities. $f\left(.\right)$ is the production function.

Now we expose the specificities and the assumptions we make in order to estimate the final cost function.

First, both terms θ and e are unobservable, so they are considered as parts of the error term of the cost function. This error term is then composed of the following terms: a random noise measuring random shocks outside the firm control and measurement error, and a global inefficiency term which is made of both θ and e. Moreover, we allow the exogenous inefficiency to vary with time. The random noise and the global efficiency components are independent. Second, we consider that firms produce two outputs, passenger and freight traffic, with two inputs, labor and energy. We tried to introduce a variable measuring the price of capital[4] as we are studying a long period of time and we can assume capital is a variable input in our framework. However, many observations are missing for this variable which happened not to be significant in our estimations, so we decided to omit it until we manage to find a better measure for it. Remember that in this analysis we focus on the incentives faced by railways operators only and we exclude the infrastructure activity. Third, following the

[4] We defined the price of capital as capital expenses divided by the total number of locomotives and automotives.

cost minimizing program of each firm in Equation (1), total costs for each railway operator are a function of output quantities, input prices, some exogenous variables and the composed error term. For a railway operator *i*, $i = 1,...,N$ and at time *t*, $t = 1,...,T$, the stochastic cost function can be written:

$$\begin{aligned} C_{it} &= \beta_0 Q_{pax_{it}}^{\beta_p} Q_{fr_{it}}^{\beta_f} w_{L_{it}}^{\beta_l} w_{E_{it}}^{\beta_e} z_{it}^{\beta_z} \exp(\varepsilon_{it}), \\ \varepsilon_{it} &= \theta_{it} - e_{it} + u_{c_{it}}, \\ \theta_{it} &= \theta_i \exp(\eta t), \end{aligned} \tag{2}$$

where Q_{pax} and Q_{fr} represent respectively passenger and freight traffic, w_L and w_E are prices for labour and energy, and *t* is a time trend. The variable z is introduced to control for structural changes which occurred recently in four countries: Denmark, The Netherlands, Portugal and Sweden.[5] These changes are also taken into account in the data. z is a dummy variable taking value 1 before separation of freight activities and 0 otherwise. The β's and η are parameters to be estimated. The error term ε is expressed as the sum of a random noise component u_c, the time-varying exogenous inefficiency term θ and the component e which is the endogenous effort exerted by operators to reduce their costs. This cost-reducing effort enters negatively in the cost function. We consider it is costly for the managers to implement the level of effort e, that is to say it creates an additional cost which increases with this level of effort. We assume the cost associated to the effort level e is a convex function of the form:

$$\Psi(e_{it}) = \exp(\mu e_{it}) - 1, \quad \mu > 0. \tag{3}$$

The next step consists in modeling the effects of the deregulation on incentives to improve efficiency using the cost function described above. Our approach is to account for these effects as being translated into variations of the cost-reducing effort variable, e. Remember this variable is endogenous. We assume that railways operators are residual claimant for cost savings after the first reform is implemented, but not before. In other words, we assume that firms do not have any incentive to reduce costs before implementing the reforms, as subsidies usually help to cover the costs. On the other hand, once firms enter the

[5] Freight and passenger activities were split into different entities in Denmark (2001), The Netherlands (2000) and Sweden (2000). In Portugal (1997), all the rolling stock was transferred to an independent company.

liberalization process, the new competitive pressure and the reduction in subsidies provide good incentives for the operators to reduce costs. We call these two effort levels e^R and e^D when they are provided respectively before and after deregulation. The effort e^R is set to be equal to zero and the effort level e^D is computed in the following way. When reforms are implemented, firms are willing to improve the company's performance. But the effort provision comes with a cost, $\Psi(e)$, and firms determine the optimal effort level e which maximizes their profit. Each firm's profit is expressed as the difference between revenues and total costs. The program of the firm is the following one:

$$\max_{e_{it}} \pi_{it} = q_{pax_{it}}(.)\, p_{pax_{it}} + q_{fr_{it}}(.)\, p_{fr_{it}} - C\left(Q_{pax_{it}}, Q_{fr_{it}}, w_{L_{it}}, w_{E_{it}}, z_{it}, \theta_{it}, e_{it}\right) - \Psi\left(e_{it}\right), \qquad (4)$$

where π is the profit, q the demand for transport service, p the price of the service to be sold.[6] The first order condition of this program is:

$$-\frac{\partial C\left(Q_{pax_{it}}, Q_{fr_{it}}, w_{L_{it}}, w_{E_{it}}, z_{it}, \theta_{it}, e_{it}\right)}{\partial e_{it}} = \Psi'\left(e_{it}\right). \qquad (5)$$

The optimal effort level equalizes marginal cost savings and marginal disutility of effort. The expression of this effort level can be written:

$$e_{it}^D = \frac{1}{\mu+1}\left(\ln\beta_0 + \beta_p \ln Q_{pax_{it}} + \beta_f \ln Q_{fr_{it}} + \beta_L \ln w_{L_{it}} + \beta_E \ln w_{E_{it}} + \beta_z \ln z_{it} + \theta_{it} - \ln\mu + u_{c_{it}}\right), \qquad (6)$$

and we have:

$$e_{it}^R = 0, \qquad (7)$$

before the liberalization process started.

[6] Note that maximizing profit with respect to effort is equivalent to minimizing total costs with respect to effort. This is why we do not specify a two-sided revenue term which would account for passenger and freight traffic.

By substituting the expressions of e^R and e^D in our primal cost function in (2), we obtain the specification for costs before and after deregulation, and the final cost function can be written:

$$\begin{aligned} C_{it} = {} & \xi_{it}^R \left[\beta_0 Q_{pax_{it}}^{\beta_p} Q_{fr_{it}}^{\beta_f} w_{L_{it}}^{\beta_L} w_{E_{it}}^{\beta_E} z_{it}^{\beta_z} \exp\left(\theta_{it} + u_{c_{it}}\right)\right] \\ & + \xi_{it}^D \left[c_0 w_{L_{it}}^{\gamma\beta_L} w_{E_{it}}^{\gamma\beta_E} Q_{pax_{it}}^{\gamma\beta_p} Q_{fr_{it}}^{\gamma\beta_f} z_{it}^{\gamma\beta_z} \exp\gamma\left(\theta_{it} + u_{c_{it}}\right)\right], \end{aligned} \tag{8}$$

with $\gamma = \dfrac{\mu}{1+\mu}$ and $c_0 = \beta_0 \exp\left(\dfrac{\ln\mu - \ln\beta_0}{1+\mu}\right)$. ξ^R and ξ^D are dummy variables. ξ^R takes the value 1 if firms operate before the first reform is implemented, and 0 otherwise, and ξ^D takes value 1 if firms operate after the first reform is implemented and 0 otherwise. The cost function specified in Equation (8) is the final structural expression of costs accounting for inefficiencies and incentives to reduce these inefficiencies, relative to the implementation of the European directive 91/440. After loglinearization, this is the cost function we are estimating.

The estimation of the cost function as expressed in (8) requires some distributional assumptions. In particular, θ_i are not observable so we assume they are iid and that they follow a Half-Normal distribution[7] of parameters 0 and σ_θ^2, as they correspond to inefficiency and have to have a positive effect on costs. The u_c are iid and follow a Normal distribution of parameters 0 and $\sigma_{u_c}^2$. We have:

$$\begin{aligned} & \theta_i \sim N^+\left(0, \sigma_\theta^2\right) \\ & \text{and } u_{c_{it}} \sim N\left(0, \sigma_{u_c}^2\right). \end{aligned} \tag{9}$$

θ_i and u_c are distributed independently of each other and of the regressors.

At this stage we face a potential problem of endogeneity in the cost function, due to regulatory pressures on output quantities. They may be determined by the regulators according to the cost structures of the firms. In order to avoid this problem, we need to

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[7] We have tried several distributions for θ_i however the program has some difficulties to converge with generalized distribution functions such as the truncated Normal or the Gamma distribution. According to Ritter and Simar (1997) this problem may be due to the small size of our sample.

consider a more structural model and create a link between demand and supply for transport. Our model is now composed of a cost equation, two demand equations for passengers and freight traffic, and two capacity equations which link demand for transport services and outputs quantities. For passenger and freight transport, load factors are different from 1: the capacity offered on the tracks is always higher than the quantity demanded, and for freight transport some trains are towing empty wagons to reach a destination where they are going to be loaded.

The demand for traffic, either passenger or freight, is a assumed to be a function of the price for this service, past demand for the service and an exogenous macroeconomic variable. The two demand equations can be written:

$$\begin{aligned} q_{pax_{it}} &= \alpha_0 + \alpha_p p_{pax_{it}} + \alpha_{lq} Lq_{pax_{it}} + \alpha_{GDP} GDP_{it} + u_{qp_{it}}, \\ q_{fr_{it}} &= \delta_0 + \delta_p p_{fr_{it}} + \delta_{lq} Lq_{fr_{it}} + \delta_{GDP} GDP_{it} + \delta_z z_{it} + u_{qf_{it}}, \end{aligned} \qquad (10)$$

where q_{pax} (q_{fr})is the demand for passenger traffic (freight traffic), Lq_{pax} (Lq_{fr}) is the demand for passenger traffic (freight traffic) in *t*-1. GDP is the Gross Domestic Product per capita and *t* is a time trend. α and δ are parameter vectors to be estimated. u_{qp} and u_{qf} are the error terms of the passenger and freight demand equations respectively. Both these error terms are assumed to follow a Normal distribution.

Capacity equations consist in expressing capacity supply as a function of traffic demand and a time trend:

$$\begin{aligned} Q_{pax_{it}} &= \lambda_0 q_{pax_{it}}^{\lambda_q} \exp\left(\lambda_t t + u_{Qp_{it}}\right), \\ Q_{fr_{it}} &= \gamma_0 q_{fr_{it}}^{\gamma_q} \exp\left(\gamma_t t + u_{Qf_{it}}\right), \end{aligned} \qquad (11)$$

where λ and γ are parameter vectors to be estimated, u_{Qp} and u_{Qf} are the error terms of the passenger and freight capacity equations respectively. These equations are then loglinearized for estimation purposes.

At this stage we have all the elements needed to perform our estimation. We estimate simultaneously this system of five equations, the cost function, the two demand functions and the two capacity functions, defined respectively in Equations (8), (10), (11). We use the Full Information Maximum Likelihood procedure to estimate this system. Taking into account the distributions of the residuals for all equations, and the distribution of the inefficiency term θ_i, the likelihood function for the system has the following expression:

$$L_{it} = \int_0^{\infty} L\left(u_{c_{it}}, u_{qp_{it}}, u_{qf_{it}}, u_{Qp_{it}}, u_{Qf_{it}} \mid \theta_i\right) \phi(\theta_i)\, d\theta_i, \qquad (12)$$

with $L\left(u_{c_{it}}, u_{qp_{it}}, u_{qf_{it}}, u_{Qp_{it}}, u_{Qf_{it}} \mid \theta_i\right)$ being the likelihood of a multivariate Normal distribution conditional on the parameter θ_i, with θ_i following a Half Normal distribution of density:

$$\phi(\theta_i) = \frac{2}{\sqrt{2\pi}\sigma_\theta} \exp\left(-\frac{\theta_i^2}{2\sigma_\theta^2}\right). \qquad (13)$$

We implement the estimation of the system of equations, that is to say we maximize the likelihood function as described in Equations (12) and (13) with the Maxlik module of the Gauss application.

Finally, we are able to compute values for time varying efficiency, following Battese and Coelli (1992).

3. Application and data

We are studying the European railways industry, and our model is specified to evaluate the effects of the liberalization process on firms' level of efficiency. We apply this model to eleven European countries: Austria, Belgium, Denmark, Finland, France, Germany[8], Italy, The Netherlands, Portugal, Spain and Sweden. These are the ones which implemented the reforms in a significant way. It would have been relevant also to include United Kingdom in our sample, as its national railway company went far in the deregulation process. However, due to all the significant changes implemented in the industry, the required information and data were not available and we could not incorporate this country in our analysis. The time period we are studying goes from 1980 to 2004, but this panel is unbalanced as data are

[8]Note that series for Germany have to be treated and interpreted with caution as the two national railway companies DB and DR merged in 1994, simultaneously with the implementation of the European directive 91/440.

missing for some countries, at certain points of time. Nevertheless, we have sufficient information before and after deregulation for each country to make this analysis pertinent. The five sources of data we use for building our database are the Union Internationale des Chemins de Fer (UIC), Eurostat, the International Monetary Fund (IMF), the Organization of Economic Co-operation and Development (OECD) and complementary information provided by the companies under our request.

When estimating our system of equations, we use the following variables. In the cost function, the measure we choose for costs is total operating expenses provided by the UIC. Measures of outputs are train-kilometers for passenger and freight traffic[9], gathered from the UIC. Input prices are wage per worker[10], from the UIC, and an index of energy prices provided by the OECD. It comprises fuel, electricity and gasoline prices.

Concerning demand and capacity equations, traffic demands are measured by passenger-kilometers and ton-kilometers provided by the UIC. Transport prices are average prices for both passenger and freight transport, computed respectively as revenues from passenger traffic divided by passenger-kilometers and revenues from freight traffic divided by ton-kilometers. Note that all monetary variables are expressed in constant 2000 euros.

In the Appendix we present some descriptive statistics of the variables we use in our estimation. Table 1 displays the mean values of some variables, for each country over the time period under consideration. In Graph 1 to Graph 11 are exposed the time series observations for the variables passenger train-kilometers, freight train-kilometers, operational costs and the relative measure of revenues over costs, in percent. Information gathered in Table 2 helps understanding the shape of the curves displayed in the preceding graphs. Table 2 exposes the dates at which countries started to implement some of the reforms required by the directive 91/440, and these are points of time for which we observe significant changes in the operators revenues or expenses.

4. The results

Results are presented in Table 3 to Table 5. We run estimations for three different specifications of our model, depending on the assumptions we make on efficiency and effort.

[9]More appropriate measures for passenger and freight outputs are offered seat-kilometers and offered ton-kilometers, but available time series for these variables at Eurostat are too short.

[10] Wage per worker is computed as total wages divided by average operational staff. Wages include social security costs.

Our first model assumes that there is no inefficiency and no regulatory changes, that is to say no effort level. The second model includes an inefficiency term but still does not consider any effect of regulation. The third model is the one presented in Section 3 and takes into account both the inefficiency term and the endogenous effort level. For these three scenarios the five equations are estimated simultaneously by FIML. As results for demand and capacity are similar in the three cases, we only present demand estimates for the third specification. The three scenarios to be tested consist in changes affecting the cost function, so the three sets of cost parameter estimates are presented.

The results of the estimation of demand and capacity equations are displayed in Table 3 and Table 4 respectively. All the parameters have the expected signs, even if some of them are not significant, specifically time trends and price for passenger demand.

We focus our attention on the estimates of the cost function for the three scenarios, presented in Table 5. Almost all parameters are highly significant and exhibit the right sign. The only exceptions are parameters β_w and β_E which are not always significant.

In order to choose the model which fits the data the best we perform a Vuong (1989) test for non nested models. The null hypothesis assumes that the two compared models are equivalent while the alternative hypothesis sustains that one model is closer to the true data generating process than the other. The Vuong statistic has a limiting standard Normal distribution and is bidirectional. In our case, the value of the test is higher than 2, which means that the case with inefficiency and effort is preferred. Indeed, the parameter reflecting the effort as a result of the implementation of the reforms, μ, is positive and significant. In our model this means that willingness to improve performance is significant from the moment the deregulation was implemented in each country. The coefficients of input prices and output measures in the cost function are multiplied by $\gamma = \frac{\mu}{1+\mu} = 0.941$.

These estimations allow us to recover values for technical efficiency and effort level over time for each country. The measures of time varying cost efficiency are displayed in Table 6 and Table 7. As expected, efficiency is increasing for all countries, with the highest value for The Netherlands, and the lowest for Belgium. Effort is increasing or constant for all countries except for Portugal and Sweden. The highest levels of effort are provided by Germany and France, whereas the lowest levels are provided by countries with a simple network configuration, that is to say Portugal and Finland. Moreover, even if we can not establish causality this could be explained by some structural changes which occurred during the period we study. In particular Sweden presents high values of effort at the beginning of the deregulation period. The effort starts by decreasing until 1993, then it increases until the date of the separation between freight and passengers activities (2001). After the effective separation, effort decreases again significantly. In the case of Portugal, the reduction in effort corresponds also to a period of structural changes in the company. In particular all infrastructure-related activities and assets were transferred from the national company, Caminhos de Ferro Portugueses, to Rede Ferriovaria Nacional REFER, and of all the rolling stock was transferred to Empresa de Manutençao de Equipamento Ferroviario, EMEF.

5. Conclusion

In this paper we investigate the effects of deregulation in the European railways industry, and more particularly the incentives operators face to reduce costs. Our results show that after the liberalization process started, firms provide a significant effort level to reduce cost inefficiency. We are able to conduct such an analysis thanks to a database compiling recent and complete information from Eurostat and UIC. Moreover the implementation of reforms took place in the mid nineties for European countries and as our sample goes to 2004 we have sufficient information to evaluate with more details the impacts of such reforms on railways efficiency, compared with previous studies.

Some limitations to our study should be noted. First, concerning the data, relevant measures for United Kingdom are not available yet and we do not include this country in our estimations. Some other input prices would also be worth considering, such as price for capital and price for materials. Second, regarding the model and estimation, a more flexible cost function is desirable as we are studying a multi-output technology. This is left to further research. More general distributions for the inefficiency variable such as the truncated Normal or the Gamma distributions may be more appropriate to our framework and should be tested with our model. Third, more specific aspects of the reforms should be considered, such as types of reforms or sequencing of implementation.

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Appendix

Table 1. Descriptive statistics: country average values

	Passenger-kilometers (in millions)	Ton-kilometers (in millions)	Train-kilometers, passenger traffic (in thousands)	Train-kilometers, freight traffic (in thousands)	Network length (in km)
Austria	8171	12774	77883	41469	5701
Belgium	6812	8204	72716	20715	3570
Denmark	4654	1682*	45710	7692*	2305
Finland	3224	8481	25429	17438	5912
France	60975	54964	321716	169692	33264
Germany	63629	78298	649151	237154	39378
Italy	42249	20518	240895	71162	16072
The Netherlands	11958	3128*	105882	11313*	2807
Portugal	5188	1740	29689	8859	3199
Spain	15997	11280	116645	43036	12709
Sweden	6304	16870*	62577	38763*	10681

* Freight and passenger activities were split into different entities in Denmark (2001), The Netherlands (2000) and Sweden (2000). Averages are computed for the period preceding this separation.

Table 2. Deregulation reforms (three main aspects)

	Separation Infrastructure/0perations	Third Party Access	Independent Regulatory Entity
Austria	1997	1995	2000
Belgium	1998		
Denmark	1997	2000	
Finland	1995	1999	
France	1997	1997	
Germany	1994	1994	
Italy	1998	1999	
The Netherlands	1995	1995	
Portugal	1997		1997
Spain	1996	1995	
Sweden	1988	1989	
United Kingdom	1993	1993	1993

Table 3. Demand functions estimation

Demand Function Estimations					
Passengers			Freight		
Parameter	Estimate	Est. /s.e.	Parameter	Estimate	Est. /s.e.
α_0	-6.0152	-1.439	δ_0	-7.3563	-0.998
α_p	-4.8359	-1.046	δ_p	-11.4128	-1.923
α_{lq}	1.0033	137.331	δ_{lq}	0.9625	43.116
α_{GDP}	0.6549	1.463	δ_{GDP}	0.8695	1.117
			δ_z	-1.3597	-1.839

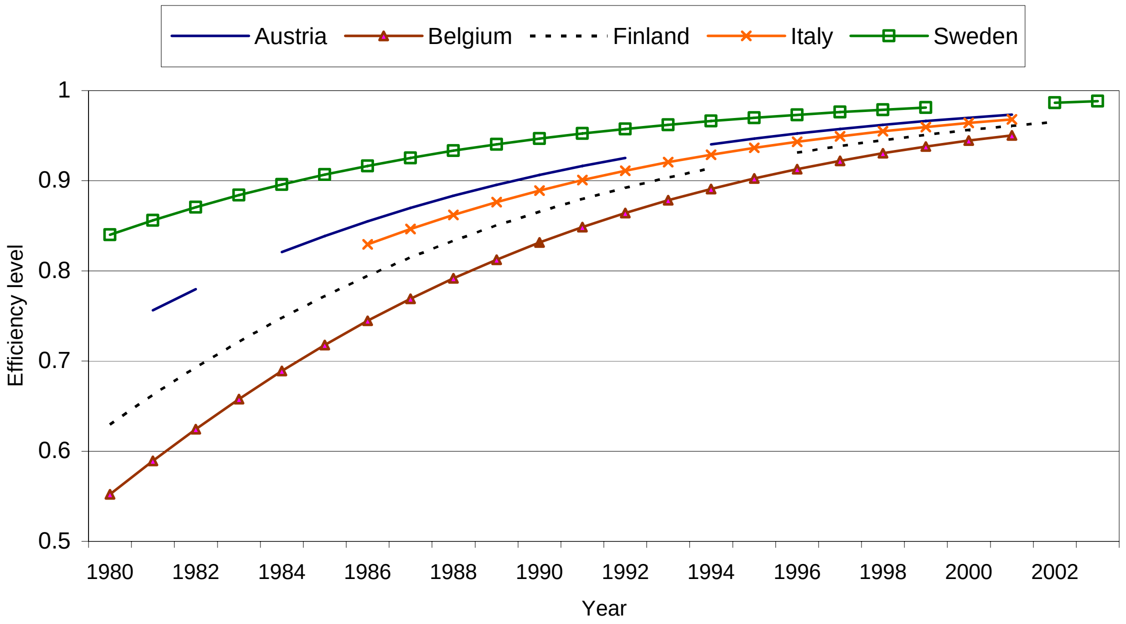
Table 4. Capacity functions estimation

Capacity Estimations					
Passengers			Freight		
Parameter	Estimate	Est. /s.e.	Parameter	Estimate	Est. /s.e.
λ_0	2.4143	39.960	γ_0	1.3187	18.384
λ_q	0.8700	37.639	γ_q	1.0027	34.737
λ_t	0.0005	0.240	γ_t	-0.0190	-5.193

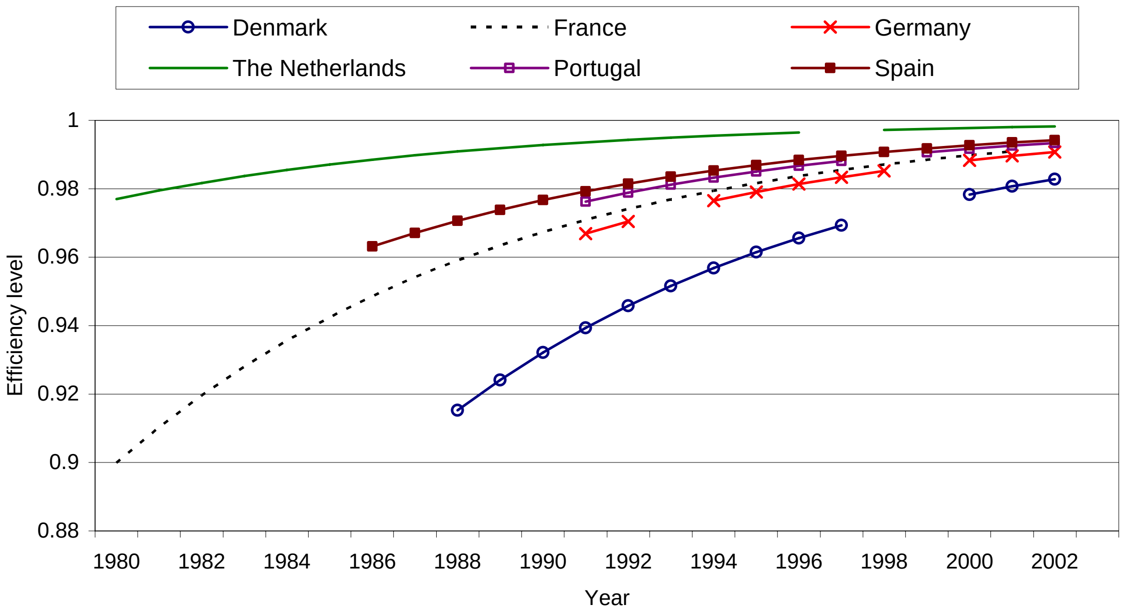
Table 5. Cost function estimation

	The three model specifications					
	Without e_i and θ_i		With θ_i, without e_i		With θ_i, with e_i	
Parameter	Estimate	Est./s.e.	Estimate	Est./s.e.	Estimate	Est./s.e.
β_0	2.2518	3.696	2.5244	4.795	2.7451	5.970
β_p	1.0557	20.249	1.0466	22.918	1.0398	23.293
β_f	0.1555	4.073	0.1520	4.561	0.1859	5.209
β_L	-0.1220	-0.849	-0.0361	-0.295	-0.0071	-0.066
β_E	0.0068	0.062	0.1217	1.407	0.3609	4.467
η			-0.1145	-8.036	-0.1176	-3.573
β_z	-0.5592	-5.560	-0.5051	-5.979	-0.4197	-5.079
μ					15.9809	8.457
σ_θ			0.4091	5.323	0.2420	2.815
Mean loglikelihood	-4.2698		-4.24135		-4.15574	
Nº observations	196		196		196	
Vuong test	3.8085		3.5575			

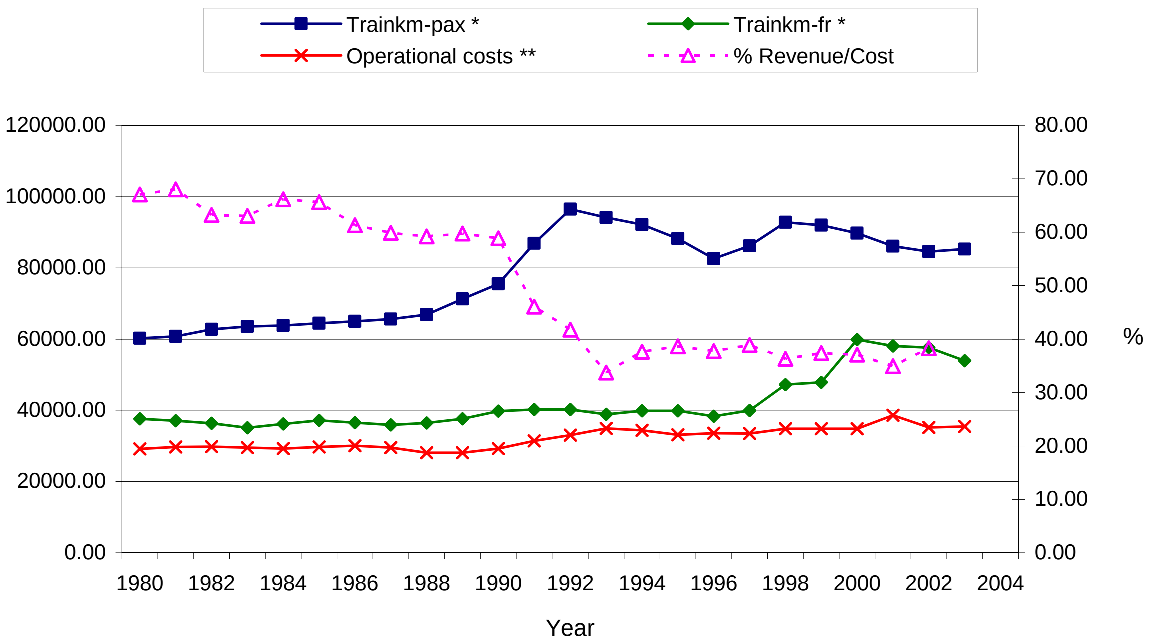
Graph 1. Efficiency level: Austria, Belgium, Finland, Italy; Sweden



Graph 2. Efficiency level: Denmark, France, Germany, The Netherlands, Portugal Spain

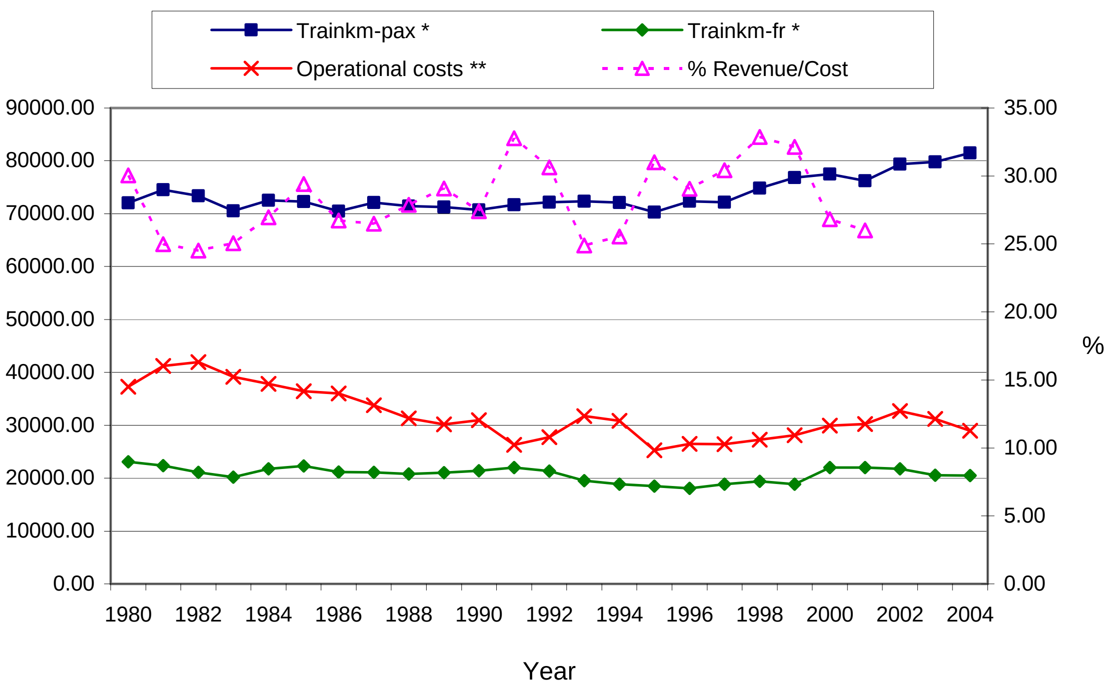


Graph 3. Traffic and costs evolution: Austria



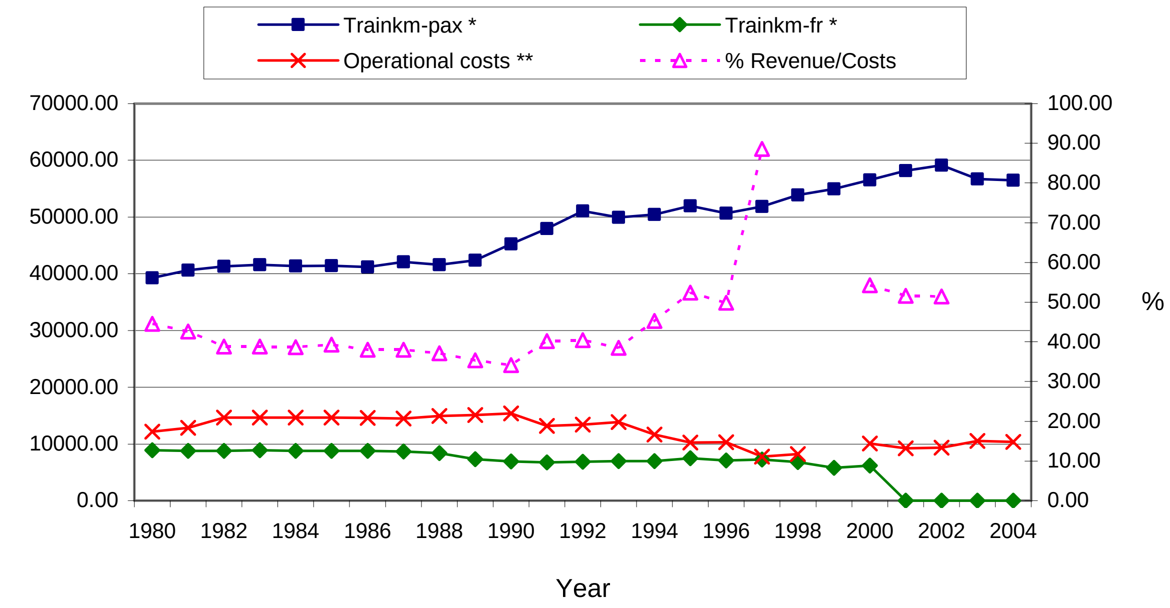
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 4. Traffic and costs evolution: Belgium



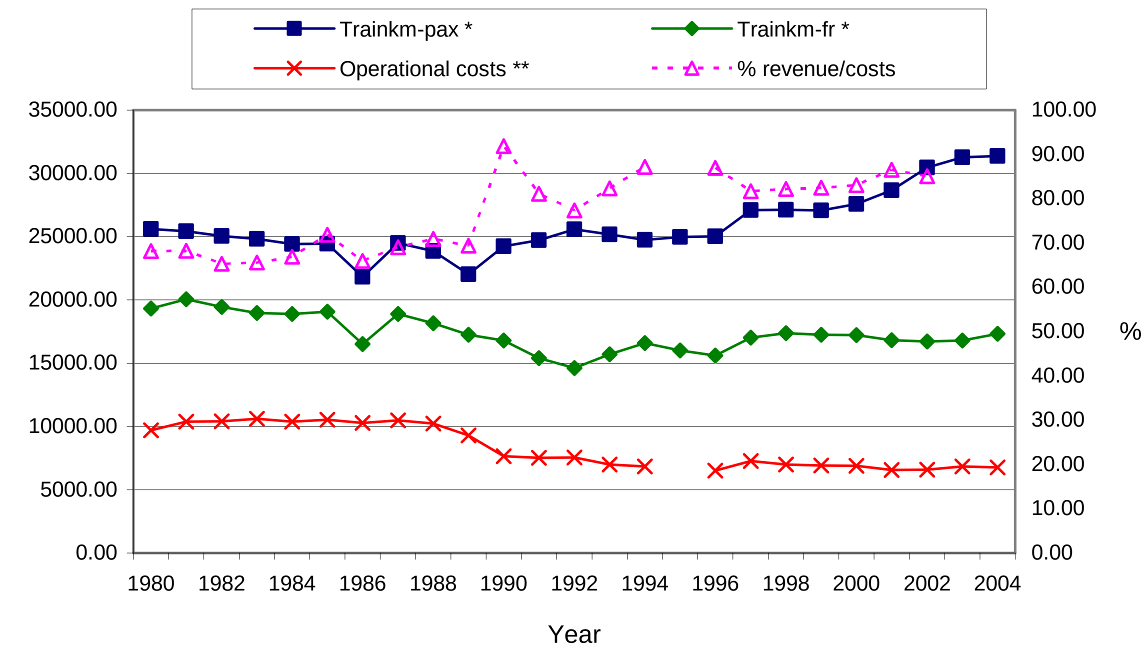
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 5. Traffic and costs evolution: Denmark



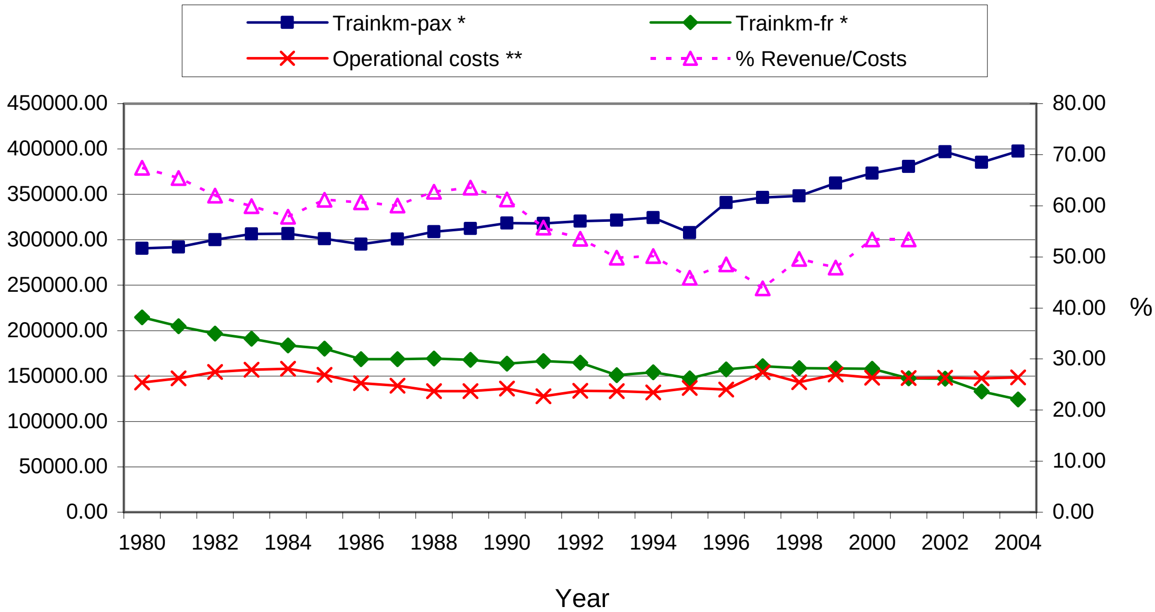
*Millions ton-kilometres
**Hundreds of thousands of constant 2000 euros

Graph 6. Traffic and costs evolution: Finland



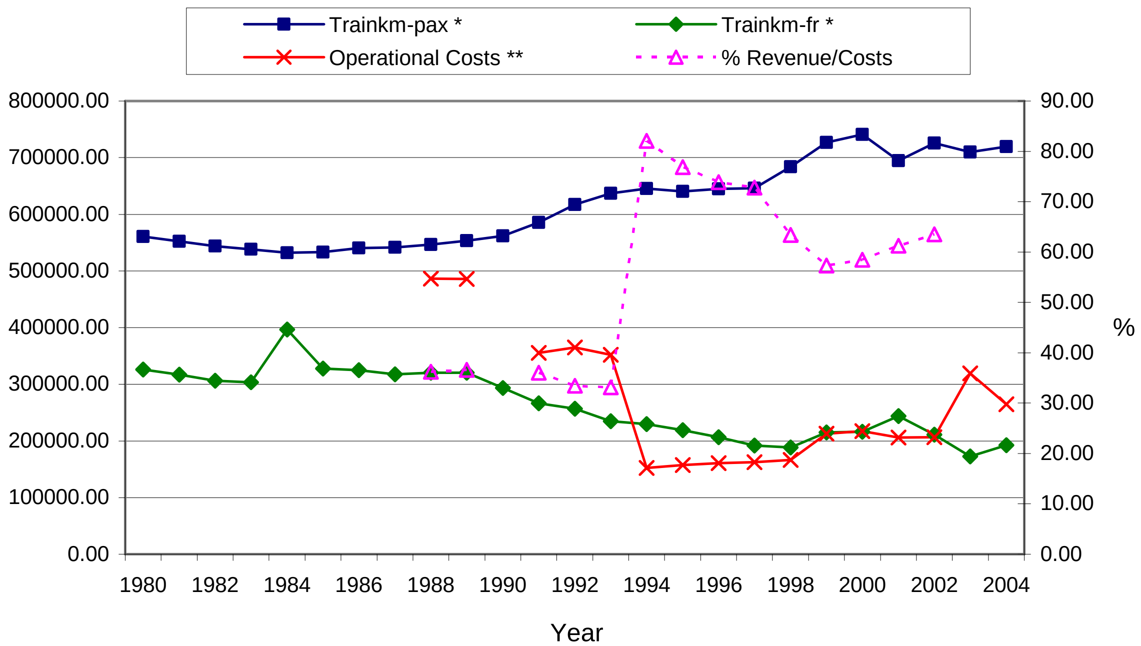
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 7. Traffic and costs evolution: France



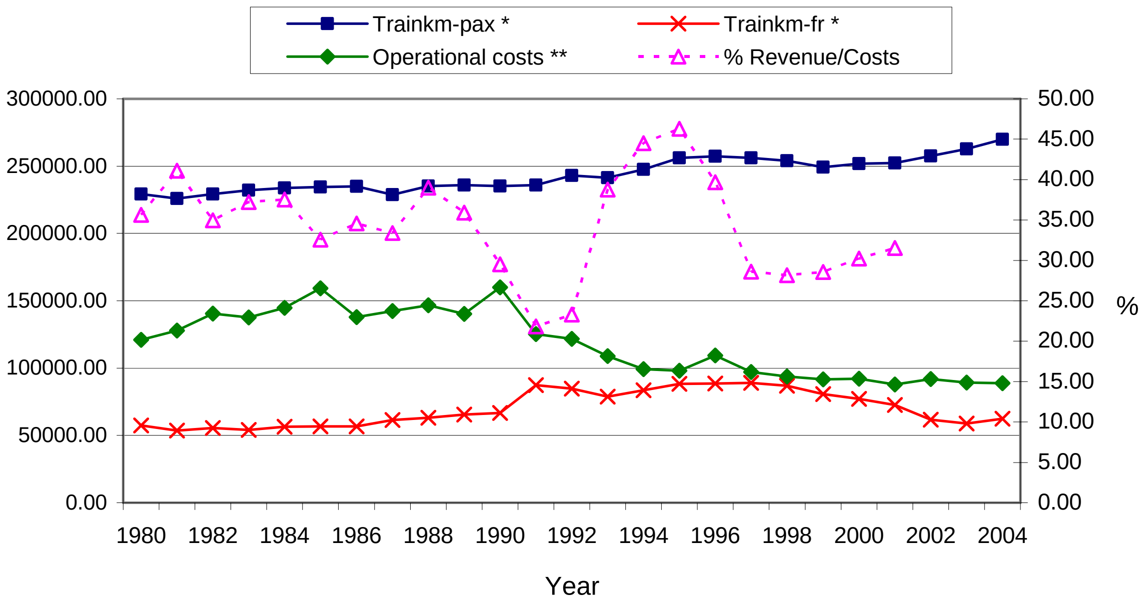
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 8. Traffic and costs evolution: Germany



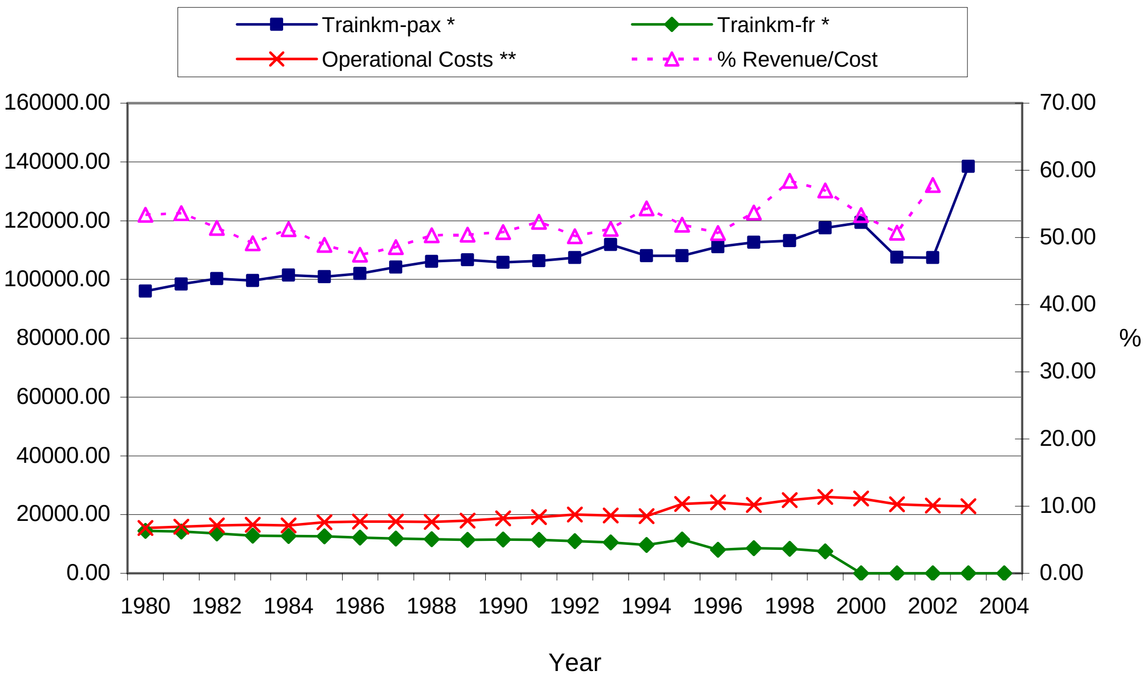
*Millions ton-kilometres
**Hundreds of thousands of constant 2000 euros

Graph 9. Traffic and costs evolution: Itlaly



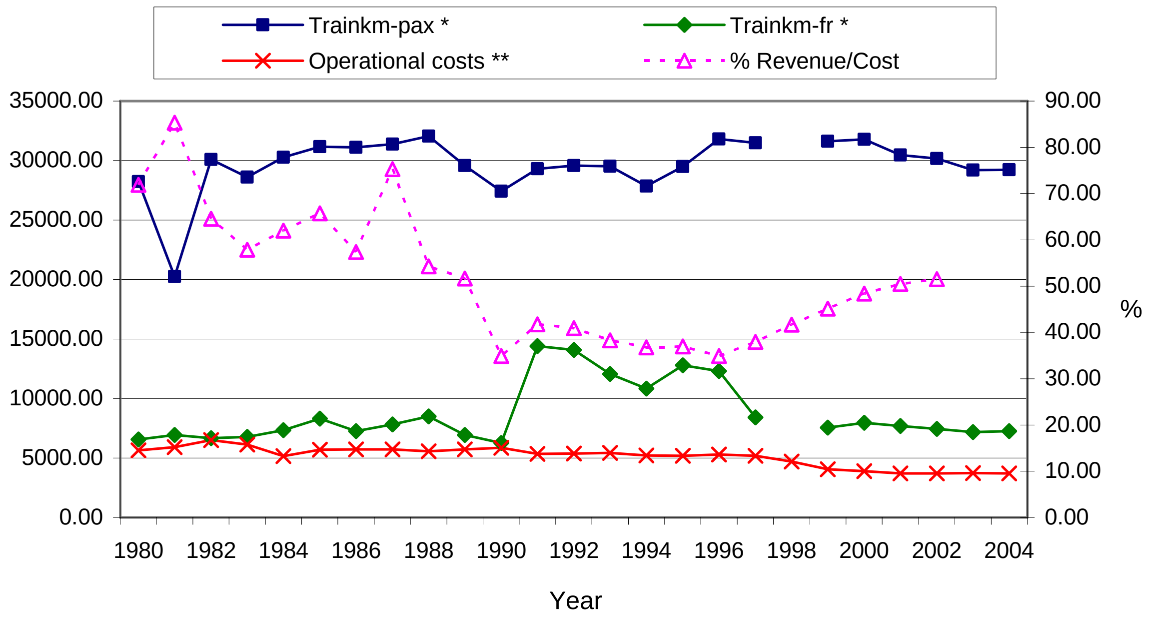
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 10. Traffic and costs evolution: The Netherlands



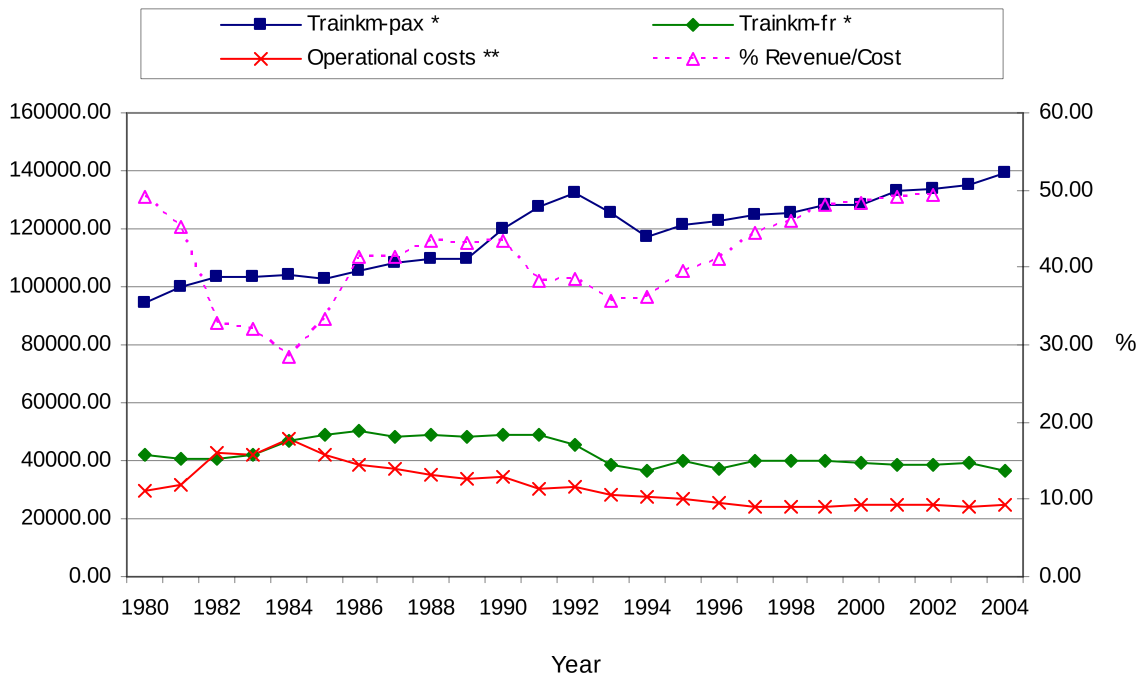
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 11. Traffic and costs evolution: Portugal



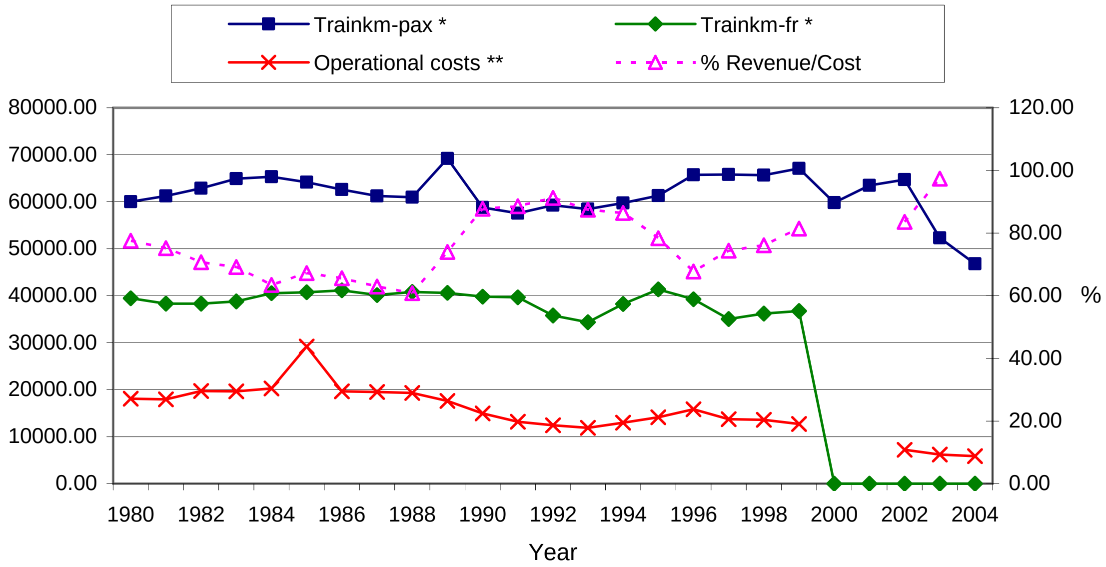
*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros

Graph 12. Traffic and costs evolution: Spain



*Millions ton-kilometres
**Hundreds of thousands of constant 2000 euros

Graph 13. Traffic and costs evolution: Sweden



*Millions ton-kilometers
**Hundreds of thousands of constant 2000 euros