COST STRUCTURE, EFFICIENCY AND PRODUCTIVITY IN HELLENIC RAILWAYS

by

Efthymios G. Tsionas[1],

Nicholas C. Baltas[2],

and

Dionysios P. Chionis[3]

DISCUSSION PAPER No. 194
July 2008

The Discussion Papers in this series circulate mainly for early presentation and discussion, as well as for the information of the Academic Community and all interested in our current research activity.

The authors assume full responsibility for the accuracy of this paper as well as for the opinions expressed therein.

Department of Economics
Athens University of Economics and Business
76 Patission Str., Athens 104 34, Greece
Tel. (++30) 210-8203911 - Fax: (++30) 210-8203301

[1] Associate Professor, Dept. of Economics, Athens University of Economics and Business
[2] Professor, Dept. of Economics, Athens University of Economics and Business
[3] Professor, Dept. of International Economics and Development, Democritus University of Thrace

COST STRUCTURE, EFFICIENCY AND PRODUCTIVITY IN HELLENIC RAILWAYS

Efthymios G. Tsionas
Athens University of Economics and Business

Nicholas C. Baltas
Athens University of Economics and Business

Dionysios P. Chionis[1]
Democritus University of Thrace

Abstract

In this paper we analyze the cost structure of Hellenic Railways (OSE) over the period 2000-2006 using plant-level data. Our estimates provide marginal costs, which are essential for rational pricing policies in view of Article 7 in the Commission Directive 2001/14/EC. We find cost efficiency close to 64% in rail circulation and 84% in maintenance. Technical progress has been substantial in maintenance of rail track but almost zero in rail circulation. Policy measures and recommendations are provided based on our empirical results.

JEL Classification: F13, H54, L62

Keywords: Cost, Efficiency, Productivity, Transportation

[1] E.G.Tsionas and N.C. Baltas are Associate Professor, and Professor in the Department of Economics of the Athens University of Economics and Business, respectively, and D. Chionis is Professor in the Department of International Economics and Development of the Democritus University of Thrace.
Corresponding author: Professor Nicholas C. Baltas, Department of Economics, 76 Patission Street, Athens 104 34, Greece, baltas@aueb.gr.

1. Introduction

Empirical research and cost estimation in railways has been an active issue of research for many years. Existing research has focused on estimation of scale economies, efficiency, technical change and productivity. This has been facilitated by the prolific research and implementation on flexible functional forms such as the translog cost function. However, few studies have been concerned with the problem of pricing and financial sustainability of the railways, and none has been concerned with how and to what extent technical inefficiency affects the financial sustainability of the enterprise.

Of the few studies that take up the issue of pricing, all of them focus on estimating marginal costs. The reason is that, despite the fact that marginal cost pricing is not followed by all EU railways; the marginal cost still provides guidance to optimal pricing that can be valuable for management. In this paper, we estimate a cost function to derive marginal costs. Marginal cost is simply the derivative of the cost function with respect to output. For a thorough literature review with an emphasis on empirical estimates of marginal costs and the role of utilization rate, the reader is directed to Thomas (2002). The data required to implement this kind of analysis typically differ considerably relative to studies that focus on productivity and efficiency. In the latter case, one often has input prices and outputs in real terms (such as passengers and freight), but the data are aggregated and annual. In the former case, one has data disaggregated by line of operation (or similar divisions) on an annual basis but does not have data on input prices, and often one does not have data on outputs in real terms.

One major goal of the European Union (EU) within the ongoing deregulation programme is the liberalization of the European railway sector. This market has been dominated by national natural monopolies that were under public control. However, due to a sub-additive cost structure with respect to the track infrastructure, a competitive system in this sector cannot be established easily. Therefore the EU has decided that monopoly in the provision of the track infrastructure will be maintained, under regulatory restrictions, securing a high standard of efficiency.

In order to secure use of non-discriminatory access to the rail infrastructure, the infrastructure businesses must establish an appropriate set of charges for infrastructure use. Commission directives require that responsibility for access charge regimes be independent of any train operator, which they promote efficient use of infrastructure and they do not discriminate among operators wishing to make use of the infrastructure.

The economic principles behind an appropriate access regime are well established. Access charges should reflect the marginal cost that each user imposes on the infrastructure provider. To these marginal costs should be added the external costs (pollution, accidents, congestion, etc.) that each user generates. This is social marginal cost pricing and, if implemented correctly, will result in the most efficient use of the rail infrastructure.

Article 7 of the Directive 2001/14/EC imposes the requirements of marginal cost pricing. Two alternative approaches, used by a number of EU member states and considered to be best practice in terms of consistency with the provisions of the Directive 2001/14/EC are:

- an econometric approach which estimates a total cost function and then takes the first derivative of total cost with respect to gross tonne km to derive the marginal cost (seen in Finland, Sweden and Austria); and
- an approach which allocates total variable cost across all the different vehicles running on the network, using detailed causation engineering relationships (used in Britain).

However, each country appears to treat wear and tear differently and there are different definitions and ways of accounting for operating, maintenance and renewal costs. As a result, each country arrives at very different figures for marginal cost. The differences may partly reflect the overall cost levels in the different countries and the different levels of efficiency with which rail infrastructure is constructed and maintained. They also reflect differences in local circumstances and different objectives concerning the government contribution to infrastructure costs. Differences in the level of charges can also reflect excess costs for some railways when the network is over-dimensioned for current demand. But it is important that in any approach, full account be taken of operating, maintenance and renewal costs if charges are to reflect the total marginal costs of operating a train service.

From January 1, 2006, Hellenic Railways (OSE) is a holding company with the mother company having the dominant role. This type of splitting into two entities (infrastructure and operation) is an outcome of the harmonization of the Greek legislation with that of the EU Directives. The new group structure will provide a major benefit. It will ensure that infrastructure expenditure will be transparent. Additionally, it will ensure that no indirect subsidization of the rail operations takes place, as happens with all the other public means of transportation. Furthermore, each subsidiary will focus on a specific area of OSE's current operations and the main task will be the maximization of returns of investment.

Another main management priority is the improvement of the company's finances resulting in diminishing its needs for borrowing funds and decreasing its dependence on state subsidies for its operation. This will be beneficial to both OSE's customers and to the taxpayer who pays the deficits. The restructuring is also expected to improve quality services. Over the last years, the amount for works and studies reached nearly 1 billion Euros, of which national and EU funding was about 30%, while 70% came from resources of OSE. OSE is also interested in joint ventures and in strategic partnerships. In the framework of the restructuring of the Greek railway transport system and the reorganization of OSE, an appropriate legal framework is being established which will facilitate joint ventures and strategic partnerships with OSE. Participation of the private sector in the development of the Greek railways is of particular importance.

Empirical research in railways has concentrated on various aspects such as technical efficiency (Perelman and Pestieau, 1988, and Gathon, 1989) and the measurement of productivity growth. Total factor productivity (TFP) measurement is undoubtedly an issue that has received much econometric interest in the past forty years. Typically, the researcher estimates a cost or production function, and derives a TFP index using estimated parameter values. TFP indices are used for productivity comparisons across countries, or across time for the same country. See for instance Baltagi and Griffin (1988), Baltagi, Griffin and Rich (1995), Berndt and Khaled (1979), Caves and Christensen (1988), Caves, Christensen and Tretheway (1980), and Hulten (1992), to name but a few. Studies more specific to the railways include Caves, Christensen and Swanson (1981a, b), Kumbhakar and Bhattacharyya (1996), Gathon and Perelman (1992), Oum and Yu (1994), and Perelman and Pestieau (1989) to name again only few. For a recent survey of empirical research see Oum and Waters (1997).

The purpose of this paper is to analyse the cost structure, efficiency and productivity in Hellenic Railways, in view of recent EU policies at maintaining high standards of efficiency and financial sustainability. To this end, OSE's management is promoting the signing of public service obligations contracts between the Greek State and OSE, through which the State will subsidize itineraries that are unprofitable for the organization but at the same time are considered vital from a social point of view.

In this paper, we use econometric estimation of cost functions estimated separately for traffic and maintenance in OSE (the Greek railways) during 2000-2006. We use Cobb-Douglas and translog cost functions to describe the technology and estimation techniques that allow for stochastic frontier analysis. The remainder of the paper is organized as follows. The econometric methodology is presented in section 2. The results are discussed in section 3. The final section concludes with a summary of the paper and policy recommendations.

2. Econometric model

The purpose of this section is to present the econometric model. We consider a cost function of the form $C = C(Q,t)$, where C is total cost, Q is quantity and *t* is a time trend. The usual form of the cost function is $C = C(Q,w,t)$, where w represents the vector of input prices. Since we plan to use line-by-line data, observations on prices are not available. However, we do not have reason to believe that prices vary substantially across lines or plants.

The translog functional form has been found adequate in many empirical studies because of its transparency and flexibility. The translog form can approximate to second order any unknown functional form. For econometric purposes, the model is:

$$\log C = \alpha + \beta_1 \log Q + \tfrac{1}{2}\beta_2 \left(\log Q\right)^2 + \beta_3 t + \tfrac{1}{2}\beta_4 t^2 + \beta_5 \log Q.t + v + u \,, \tag{1}$$

where v is a two-sided error term representing random shocks in production beyond the control of the firm, and $u \geq 0$ is a nonnegative error representing technical inefficiency. This term captures technical and allocative inefficiency distortions that are important in analyzing the production structure of a public enterprise. The stochastic assumptions are $v \sim IN\left(0,\sigma_v^2\right)$ and independently $u \sim IN\left(0,\sigma_u^2\right)$ subject to $u \geq 0$, the well-known half normal distribution. The error terms are also assumed to be independent of Q and t. Under these assumptions, the probability density is given by

$$p\left(\log C \mid \log Q, \tau\right) = \frac{2}{\sigma}\varphi\left(\frac{\varepsilon}{\sigma}\right)\Phi\left(\lambda\frac{\varepsilon}{\sigma}\right), \tag{2}$$

where $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $\lambda = \sigma_u / \sigma_v$, the composed error:

$$\varepsilon = \log C - \alpha - \beta_1 \log Q - \tfrac{1}{2}\beta_2\left(\log Q\right)^2 - \beta_3 t - \tfrac{1}{2}\beta_4 t^2 - \beta_5 \log Q \cdot t \,,$$

and φ and Φ represent the density and distribution function of the standard normal distribution. The model can be estimated using the method of maximum likelihood. Given a balanced panel, with n cross sections and T time periods, the log likelihood function is:

$$\log L = nT \log\left(\sigma\right) + \sum_{i,t} \log\varphi\left(\varepsilon_{it}/\sigma\right) + \sum_{i,t} \log\Phi\left(\lambda\varepsilon_{it}/\sigma\right), \tag{3}$$

where $\varepsilon_{it} = \log C_{it} - \alpha - \beta_1 \log Q_{it} - \frac{1}{2}\beta_2 \left(\log Q_{it}\right)^2 - \beta_3 t_{it} - \frac{1}{2}\beta_4 t_{it}^2 - \beta_5 \log Q_{it} \cdot t_{it}$.

For Hellenic Railways, estimation of the marginal cost is essential for more rational pricing decisions. Marginal cost can be estimated easily. Given the cost elasticity:

$$\eta_{it} = \beta_1 + \beta_2 \log Q_{it} + \beta_5 t_{it}, \tag{4}$$

marginal cost is $MC_{it} = \eta_{it}\left(C_{it} / Q_{it}\right)$, where C_{it} / Q_{it} is average cost. Of course, it is a regularity condition for cost functions that all cost elasticities be positive.

Technical change shows whether or not structural measures in the past, have produced visible results. The technical change index is:

$$\psi_{it} = \beta_3 + \beta_5 \log Q_{it} + \beta_4 t_{it}. \tag{5}$$

Finally, estimation of technical efficiency is critical. The maximum likelihood estimator of cost inefficiency, is $\hat{u}_{it} = \max\left(0,\ \hat{\varepsilon}_{it}\right)$, where $\hat{\varepsilon}_{it}$ is the cost function residual evaluated at the maximum likelihood parameter estimates. Cost inefficiency contains technical and allocative components. Technical components are due to technical inefficiency in the production function. Allocative components are due to input prices being higher or lower compared to those under "ideal conditions". The point is that if observed prices are w, the management allocates resources by assuming that prices are $w^* \neq w$. There are several reasons why this may be so. When the management has perfect knowledge of prices, but still there are constraints in the operation of the firm, this is equivalent to assuming no restrictions at all coupled with an appropriate different price vector w^*. Comparison of costs corresponding to w and w^* provides a concise idea about the extent of input misallocations in the firm.

3. Estimation results

The first results were disappointing in the sense that most observations violate the regularity conditions. It turned out, however, that maximizing the penalized likelihood below is rather easy. The penalized log likelihood is $\log L - \lambda \sum_{i,t} \eta_{it}^2 \cdot I\left(\eta_{it} < 0\right)$, where I is an indicator function, and $\lambda > 0$ is the penalty parameter. This log likelihood penalizes parameter estimates that violate the regularity condition, namely that cost elasticity should be positive.

In Table 1, reported are empirical results for the operation lines of OSE. There are 60 observations. The penalized ML estimates reported here are reasonable, given previous experience with similar data from OSE (internal report, 2006). From the empirical results, it turns out that cost elasticity is about 0.712, suggesting increasing returns to scale. These estimates range from 0.00 to 1.25. The technical regress is fairly high (1.9%) and ranges from 6.2% to -10%, suggesting that certain lines have benefited from the structural changes, but others have not. The distribution of the technical change measure (bottom left panel in Figure 1) is about uniform.

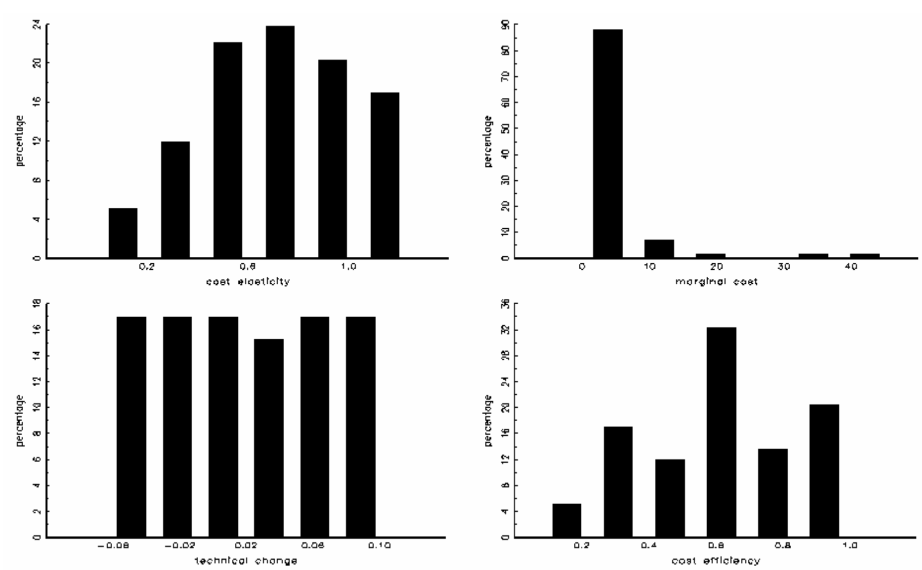
Efficiency is only 60.4%, and ranges from 7.8% to 100% across lines of operation. This, of course, suggests that there is considerable room for improvement that can result in large cost savings. Given the many constraints of a public enterprise, this may only be suggestive and it may not be possible to reduce costs. However, it gives an overall idea about the distortions introduced in production by outside and inside constraints. Finally, marginal costs average 5.11 and range from almost zero to 45.88. Finally, histograms of basic estimated measures are presented in Figure 1.

Table 1: Empirical results for operation

	η	MC	AC	ψ	efficiency
mean	0.7128	5.111	13.90	0.01977	0.6043
s.d.	0.3011	7.371	34.98	0.05385	0.2321
min	0.000	0.000	2.040	-0.06279	0.07830
max	1.249	45.88	205.4	0.1025	1.000

Notes: η is cost elasticity, MC is marginal cost, AC is average cost, ψ is the index of technical change and "efficiency" stands for the maximum likelihood estimate of cost efficiency. The penalty parameter is set to 10^5.

Figure 1: Histograms of estimated measures (operation)



Next, we turn attention to maintenance. We have 42 observations, but fitting a translog using all of them did not produce reasonable results in terms of regularity conditions. It was found necessary to use penalized ML with a penalty parameter equal to

$\lambda=10^5$. This is not surprising, given the fact that certain lines have large maintenance expenses that will distort the overall picture. The empirical results are presented in Table 2 and Figure 2.

The cost elasticity is on the average 0.54 and no lines seem to have elasticities in excess of unity, so maintenance operates also under increasing returns. Marginal costs average 6.2 and range from 1.2 to about 18.6. There is dramatic technical progress at a rate of 12.53% per year, ranging from 2.7% to over 22%. For all lines, there is, indeed, impressive technical progress. Contrary to operation, the distribution of the technical change measure is far from uniform, suggesting concentration of most plants around the mean (see bottom left panel in Figure 2).

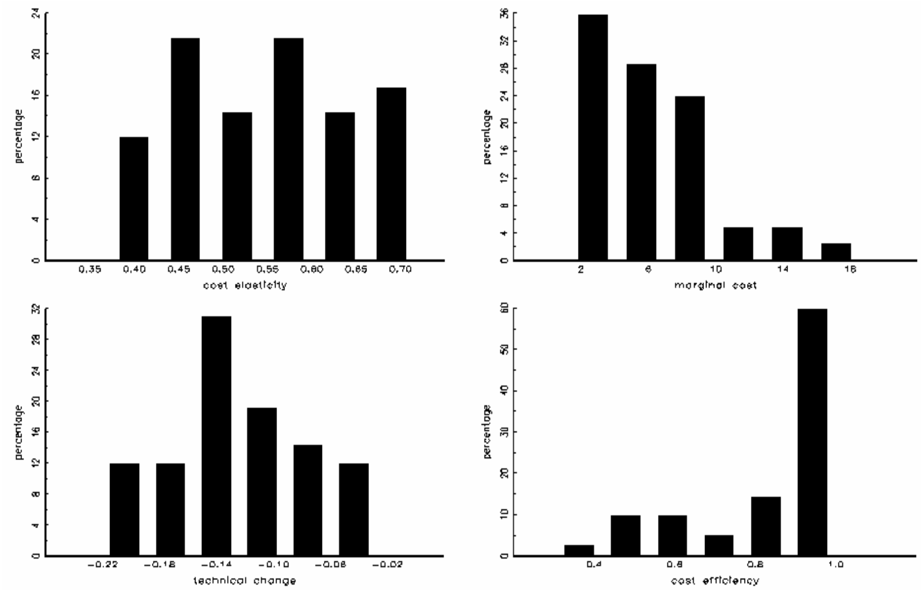
This is, indeed, a significant result showing that, in the period 2000-2006, the implemented structural changes affected mainly the maintenance part where the efforts of the management were mostly concentrated on cutting costs and increasing efficiency and productivity. Efficiency was at 85.01%, much higher than efficiency in operation, and ranged from 30.37% to 100%.

Table 2: Empirical results for maintenance

	η	**MC**	**AC**	**ψ**	**efficiency**
mean	0.5432	6.238	11.18	-0.1253	0.8501
s.d.	0.09298	3.764	6.083	0.04855	0.1969
min	0.3705	1.246	2.917	-0.2205	0.3037
max	0.7184	18.60	34.08	-0.02764	1.000

Notes: η is cost elasticity, MC is marginal cost, AC is average cost, ψ is the index of technical change and "efficiency" stands for the maximum likelihood estimate of cost efficiency. The penalty parameter was set to 10^2.

Figure 2: Histograms of estimated measures (maintenance)



Attempting to provide an overall analysis, we combine the operation and maintenance lines, and estimate an overall cost function, under the assumption that the technology in operation and maintenance is the same. The results are provided in Figure 3. Under the assumption that technology is the same, efficiency averages 60.6%, cost elasticity is 1.043, marginal cost is 12.24 (compared to 29.07 for average costs) and technical change averages -3.4%, ranging from -16.5% to 9.8%. Marginal costs range from 2.5 to 115.0. Of course, the question is whether technology is the same and we can use indeed a common cost function.

The maximum likelihood parameter estimates for the frontier cost functions in operation and maintenance are presented in Table 3. Parameter estimates are not very different (judging from 95% confidence intervals), but the characteristics of the frontier is, viz. the parameters σ_v and σ_u. Therefore, we can argue that technology is about the same but the efficiency properties of the two plants are quite different. This fact is also evident from reported histograms of technical efficiency in the bottom right panels of Figures 1 and 2.

Figure 3: Histograms of estimated measures (overall)

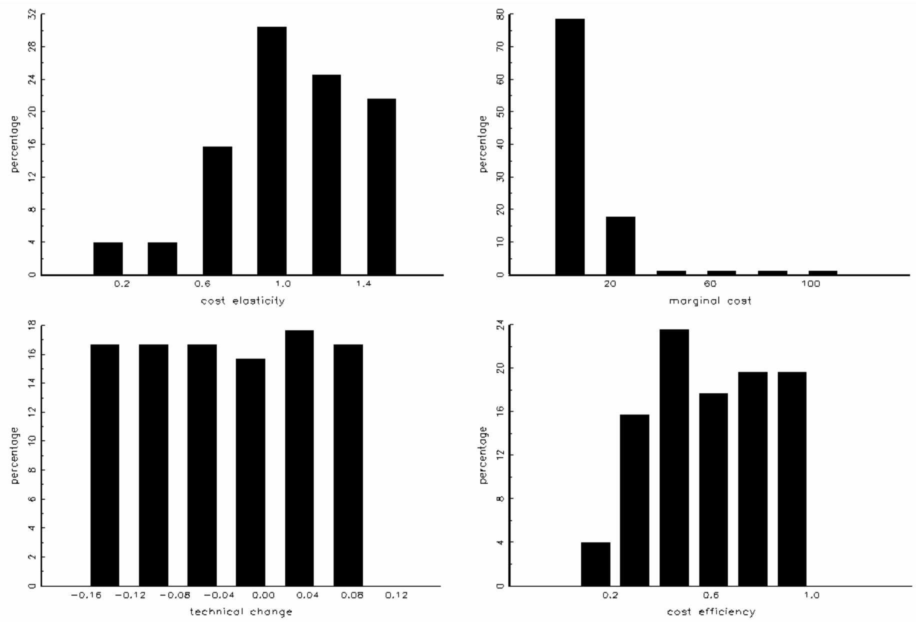


Table 3: Maximum likelihood parameter estimates

	Operation		Maintenance	
	estimate	std. error	estimate	std. error
α	1.1144	0.1949	2.5907	0.3053
β_1	0.2006	0.2023	0.7336	0.4367
β_2	0.2450	0.1126	0.0894	0.6984
β_3	0.1263	0.1065	-0.0528	0.2058
β_4	-0.0315	0.0372	-0.0188	0.0593
β_5	0.0075	0.0496	0.1047	0.0815
σ_v	0.1560	0.0820	0.4908	0.0497
σ_u	0.7687	0.1363	0.0030	0.0117

Notes: standard errors are computed using the QML technique.

From the same parameter estimates, we see that σ_u is negligible relative to σ_v in maintenance but not in operation. Thus the statistically important cost reductions through more efficient operation can, to great extent, come only from the operation side of the network. In fact, the estimates of σ_v and σ_u, show an important fact: The error term is almost purely inefficient in operation and almost pure noise in maintenance. The conclusion is that management should concentrate its efforts on operation in order to secure efficient functioning of the organization.

Estimates of β_5 provide the effect of scale of operation on technical progress. These parameters are positive, but not statistically significant; suggesting that expanding the scale induces technical regress or has no effect at all. This is the well-known non-neutral effect, which seems to be present in OSE, given our parameter estimates. The implication is that, in terms of overall capacity, the enterprise has reached a limit and further expansion of scale can only increase average and marginal costs. Expansion of operation can become feasible only after modernization is completed and new more productive equipment has been installed.

Marginal costs are related to the cost elasticity:

$$\eta_{it} = \beta_1 + \beta_2 \log Q_{it} + \beta_5 t_{it} \qquad (6).$$

Therefore, β_2 shows the effect of scale and β_5 is the neutral effect on marginal costs. The neutral effect is positive (but significant only in operation) and so marginal costs tend to increase over time in operation, but probably not in maintenance.

The effect of scale is positive in operation and negative in maintenance, suggesting that lowering marginal cost will require increased maintenance and less traffic. This is not unreasonable, given that operation has a tremendous effect of maintaining and servicing the lines, especially in view of the fact that modernization has not been fully completed in OSE.

Indeed, OSE is currently carrying out numerous track-maintenance projects, as well as projects of infrastructure renovation, improvement of lines, train-station refurbishments and improvement of safety, etc. In addition, OSE upgrades gradually its rolling stock, using the method of auctions monitored by a particular committee, with participation from all the political parties. With the completion of the infrastructure works, the renewal of the rolling stock and the organizational restructuring, OSE strengthens its position towards meeting the standards of a big, modern, railway operator.

4. Concluding remarks and recommendation

The purpose of this paper has been to analyze the cost structure, efficiency and productivity for the Greek railway system, in view of recent EU policies at maintaining high standards of efficiency and financial sustainability. The empirical results indicate that technical progress is fairly high and ranges from 6.2 to -10%, suggesting that certain lines have benefited from the structural changes but others have not. Over the period 2000-2006, the implemented structural changes affected mainly the maintenance part, where the efforts of the management were mostly concentrated on cutting costs and increasing efficiency and productivity. Technology in operation and maintenance is about the same, but the efficiency properties of the two plants are quite different.

These results provide clear policy recommendations. First, efficiency can be improved a great deal, especially in operation where it is only 60%, compared to about 85% in maintenance. Second, the scale of operation can be profitably reduced, if lowering marginal costs were essential. Otherwise, modernization of lines and more efficient maintenance are necessary, along with installation of new more productive transportation equipment. Third, the structural measures adopted in OSE yielded impressive results in cost reductions over time in maintenance, but not in operation. There is impressive technical progress in maintenance, but this is not the case in operation, where installation of new equipment and modernization of plants is necessary. Therefore, the structural measures need to be continued further to increase productivity and lower marginal costs.

As for financial sustainability, our estimates suggest that marginal costs are on the average 11.3 euros (5.1 in operation and 6.2 in maintenance) per train-km. At this level, the enterprise is not sustainable. Assuming full efficiency, average costs would have to be 10.94, and marginal costs would stay the same. Internal reports from OSE show that to break even, the enterprise would need marginal costs close to 4 euros per train-km. There are engineering-based reasons to believe that an estimate of 10.94 euros is quite high and must be deflated to allow for the poor condition of lines, the fact that latest technologies are not used, etc. This estimate, using engineering adjustments, turns out to be about half our own estimate. It is not our purpose here to discuss whether or not such adjustments must be made. The fact is that marginal costs are too high and measures must be taken to reduce them in the medium run.

It should not be forgotten that inefficiency is 40% in operation and 15% in maintenance. Therefore, huge cost savings can be realized in monetary terms under full efficiency. If plant i has total cost C_i, then total cost savings (or current waste) would be $S = \sum_i C_i u_i$ for a typical year. This yields total cost savings of 25.7% for the typical year, and this is not at all negligible! As a matter of fact, it would represent definite progress and it would change the financial status of the organization to a great extent. Given that maintenance seems to be relatively efficient, these total savings reduce to about 11%. Alternatively, if management concentrates on operation and succeeds in securing efficiency, total costs would reduce by about 11%.

References

Baltagi, H.B. and M. J. Griffin, (1988), “A General Index of Technical Change”, *Journal of Political Economy* ***96***, 21-41.

Baltagi, H.B., M. J. Griffin, and P.D. Rich, (1995), “The Measurement of Firm Specific Indexes of Technical Change’’, *The Review of Economics and Statistics,* **77**, 654-663.

Berndt E.R. and M.S. Khaled, (1979), “Parametric Productivity Measurement and Choice among Flexible Functional Forms”, *Journal of Political Economy,* **87**, 1220-46.

Brown, R.S., D.W. Caves, and L.R. Christensen, (1979), ‘Modelling the Structure of Cost and Production for Multi-Product Firms’, *Southern Economic Journal*, **16**, 256-73.

Caves, D.W. and L. R. Christensen, (1988): "The Importance of Economies of Scale, Capacity Utilisation and Density in Explaining Inter-Industry Differences in Productivity Growth", *Logistics and Transportation Review, vol.* **24**, 3-32.

Caves, D.W., L.R. Christensen, and M.W. Tretheway, (1980), "Flexible Cost Functions for Multiproduct Firms", *The Review of Economics and Statistics*, **62**, 477-81.

Caves, D.W., L.R. Christensen, and T.A. Swanson, (1981a), "Economic Performance in Regulated and Uregulated Enviroments; A Comparison of U.S. and Canadian Railroads", *Quarterly Journal of Economics*, **26**, 259-81.

Caves D.W., L.R. Christensen and T. A. Swanson, (1981b), "Productivity Growth, Scale Economics and Capacity Utilization in U.S. Railroads, 1951-1974", *American Economic Review*, **71**, 994-1002.

Gathon, H.J., and S. Perelman, (1992), "Measuring Technical Efficiency in European Railways: A Panel Data Approach'', *Journal of Productivity Analysis,* **3**, 135-151.

Kumbhakar, C.S. and A. Bhattacharyya, (1996), ''Productivity Growth in Passenger -Bus Transportation: A Heteroskedasticity Error Component Model with Unbalanced Panel Data'', *Empirical Economics,* **21**, 557-573.

Loizides, I., and B. Giahalis, (1995), "The Performance of Public Enterprises: A Case Study of the Greek Railway Operation", *International Journal of Transport Economics*, **22**, 283-306.

Loizides, I., and E. G. Tsionas, (2002), "Productivity Growth in European Railways: A New Approach", *Transportation Research*, part A, **36**, 633-644.

Loizides, I., and E. G. Tsionas, (2004), "Dynamic Distributions of Productivity Growth in European Railways", *Journal of Transport Economics and Policy*, **38** (1), 45-76.

Munduch, G., A. Pfister, L. Sogner, and A. Stassny, (2002), "Estimating Marginal Costs for the Austrian Railway System", Department of Economics, Vienna University of Economics.

Oum, T. H. and C. Yu. (1994), "Economic Efficiency of Railways and Implications for Public Policy: A Comparative Study of the OECD Countries' Railways", *Journal of Transport Economics and Policy,* vol.**28**, 121-138.

Oum, T. H. and W. G. Waters II, (1997), "A Survey of Recent Developments in Transportation Cost Function Research". *Logistics and Transportation Review,* vol. **32**, 423-463.

Perelman, S. and P. Pestieau (1988), "Technical Performance in Public Enterprises: A Comparative Study of Railways and Postal Services", *European Economic Review* **32**, 432-441.

Tervonen, J., and T. Istrom, (2004), "Marginal rail infrastructure costs in Finland 1997-2002", Finnish Rail Administration A6/2004.

Thomas, J., (2002), *EU Task force on Rail Infrastructure Charging: Summary Findings on Best Practice in Marginal Cost Pricing*, IMPRINT-EUROPE.

Tsamboulas, D., and A. G. Kopsacheili, (2004), "Rail Access Pricing for Suburban Services in Europe", *Transportation Research Record* 1872, 28-36.

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

DEPARTMENT OF ECONOMICS

DISCUSSION PAPERS

(An electronic version of the paper may be downloaded from: www.de.aueb.gr)

184. **Emmanuel Drandakis**. THE ENVELOPE THEOREM AT WORK:B. UTILITY (OUTPUT) MAXIMIZATION UNDER STRAIGHT RATIONING. (April 2007).
185. **Yannis Katsoulacos**, AUEB **and David Ulph**, University of St. Andrews. SOCIAL WELFARE LOSSES UNDER R&D RIVALRY AND PRODUCT DIFFERENTIATION. (June 2007).
186. **George C. Bitros**, AUEB, **Natali Hritonenko**, Prairie View A&M University **and Yuri Yatsenko**, Houston Baptist University. INVESTMENT, REPLACEMENT AND SCRAPPING IN A VINTAGE CAPITAL MODEL WITH EMBODIED TECHNOLOGICAL CHANGE. (June 2007).
187. **George C. Bitros,** AUEB **and Anastassios D. Karayiannis,** Univ. of Piraeus. VALUES AND INSTITUTIONS AS DETERMINANTS OF ENTREPRENEURSHIP IN ANCIENT ATHENS. Forthcoming in: *Journal of Institutional Economics*.
188. **Nicholas C. Baltas**. INVESTMENT IN THE GREEK PROCESSING OF AGRICULTURAL PRODUCTS AND FOOD: A PANEL DATA APPROACH. Published in: *The Journal of Applied Business Research*, Vol. 23, No. 4, pp. 105-116, 2007.
189. **George D. Demopoulos,** European Chair Jean Monnet and AUEB, **Nicholas A. Yannacopoulos**, University of Piraeus, **and Athanassios N. Yannacopoulos,** AUEB. CURRENCY AREAS, ECONOMIC ASYMMETRIES, AND THE DYNAMIC OF ECONOMIC INTEGRATION. (Jan. 2008).
190. **Yannis Katsoulacos**, AUEB **and David Ulph**, University of St. Andrews. ON OPTIMAL LEGAL STANDARDS FOR COMPETITION POLICY WHEN FIRMS DO NOT KNOW THE SOCIAL WELFARE IMPLICATIONS OF THEIR ACTIONS. (Feb. 2008).
191. **Nicholas C. Baltas**. AN ANALYSIS OF INVESTMENT ACTIVITY IN THE GREEK AGRICULTURAL PRODUCTS AND FOOD MANUFACTURING SECTOR. Forthcoming in: *Journal of Economic Asymmetries*, 2008.
192. **George C. Bitros**, AUEB. THE PROPORTIONALITY HYPOTHESIS IN CAPITAL THEORY: AN ASSESSMENT OF THE LITERATURE. (March 2008).
193. **George C. Bitros**, AUEB. AGGREGATION OF PRODUCER DURABLES WITH EXOGENOUS TECHNICAL CHANGE AND ENDOGENOUS USEFUL LIVES. (March 2008).
194. **Efthymios Tsionas,** AUEB, **Nicholas C. Baltas**, AUEB and **Dionysios P. Chionis**, Democritus Univ. of Thrace. COST STRUCTURE, EFFICIENCY AND PRODUCTIVITY IN HELLENIC RAILWAYS. Forthcoming in: *Journal of Economic Asymmetries*, 2008.