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NOTES and COMMENTS

Measuring Rail Productivity in Ireland: A Note

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Abstract. This note is concerned with comparing partial and total measures of productivity as they apply to Irish railways. A comparison of a partial exercise undertaken by Barrett and a total productivity approach confirms that partial measures are limited and tend to underestimate productivity growth. In addition, it is shown that cross-sectional comparisons are meaningless because of the incompatibility of international railway data. From a policy point of view little reliance should be placed on partial measures of productivity because of their propensity to misstate productivity differences across time and between firms.

I INTRODUCTION

In a recent study, Barrett (1991) undertook a cross-sectional comparison of eleven European railways in order to determine their relative productivity performance. The purpose of this note is to question the validity of using partial cross-sectional measures of productivity and to present alternative results obtained from a total productivity approach which gives a better indication of productivity trends in Irish railways.

II THE BARRETT APPROACH

Table 1 below reproduces Barrett's estimates of railway productivity in selected EC countries for 1986.[1] From Table 1 taking Irish output of 253.7

1. There is a slight alteration to Table 1, in that Barrett's figures for Spain actually relate to Sweden.

traffic units per staff member as 100, the average for the eleven railway systems combined has an index of 144. According to Barrett Irish rail productivity was 69 per cent of the average for the eleven systems combined.

Table 1: *Railway Productivity in EC Countries, 1986*

Country	*Passenger Km ('000)*	*Freight Km ('000)*	*Staff ('000)*	*Traffic Units per Staff*	*Index*
Ireland	1,075	574	6.5	253.7	100
Belgium	6,069	7,442	54.9	246.1	97
Denmark	4,536	1,791	21.4	295.7	116
France	59,862	51,690	233.4	477.9	188
Germany	41,397	59,630	257.0	393.1	155
Greece	1,950	702	14.6	181.6	72
Italy	40,500	17,410	214.8	269.6	106
The Netherlands	8,919	3,107	27.9	431.0	170
Portugal	5,803	1,448	23.0	315.3	124
Sweden	6,363	18,552	66.3	375.9	148
UK	30,800	18,153	142.7	343.0	135
Total	207,395	180,488	1,062.9	364.9	144

The principal defect in Barrett's approach is that it attempts to effect a cross-sectional comparison of operators at different levels of development, and whose operating conditions are dissimilar. The use of a set of sample observations which fails to incorporate these diverse service environments suggests that all railways are of equal status in the sample. In other words, the level of output, in comparative terms, is unaffected by differences in capital investment, Government policy, economic geography and competitive position.

Further, the approach reflects only a partial measure of productivity. It ignores completely the utilisation of other assets such as rolling stock, signalling etc., and the substitution possibilities between labour and these other inputs.

To effect a meaningful cross-sectional comparison of European railway performance would require a considerable data base inclusive of hours worked, capital user cost, fuel, etc. However, individual railways have their own accounting conventions and financial structures so that data compatibility would be a serious problem even if it was readily available.

In that context, cross-sectional comparisons of European railways are of little relevance unless they are subject to a considerable number of qualifications and caveats. This suggests that productivity growth would be better measured by using inter-temporal data at the firm-specific level, hence allowing for the use of a more detailed and consistent set of data in the estimation procedure, where total output and total inputs can be measured.

With an inter-temporal approach partial and total productivity measures can be compared to see if significant differences arise between them in terms of productivity growth rates for the individual firm over time.

III TOTAL PRODUCTIVITY MEASUREMENT

In recent years the measurement of productivity has received considerable theoretical attention with particular emphasis being placed on the development of duality theory and the utilisation of generalised functional forms. Researchers are now moving away from the partial measures, utilised by Barrett, towards measures which include total output and total input.

In a recent study McGeehan (1993) used a total factor productivity approach and found that rail productivity in Ireland had increased significantly in the period 1973 to 1983. Total productivity was measured using econometric estimation of a variable cost function, and productivity growth was viewed as a shift in the cost function. Differentiation of the estimated cost function with respect to time gave direct estimates of productivity growth. This study has been updated to 1992 and the econometric results and the data set are described in the Appendix.

Two measures of productivity growth were determined, one defined as the rate at which outputs can grow over time with inputs held constant (TFP1) and the other defined as the rate at which inputs can decrease over time with outputs held constant (TFP2.) A translog approximation was used to represent the variable cost function with the usual behavioural constraints imposed (homogeneity in prices, symmetry etc.).

The results are shown in Table 2, for the two measures of productivity growth mentioned above. Both measures show fairly similar patterns of growth although TFP2 is somewhat lower than TFP1. Overall between 1985 and 1992 rail productivity increased by 77 per cent (TFP1) and 70 per cent (TFP2) according to our two measures. These represent annual averages of 9.7 per cent and 8.7 per cent respectively.

The productivity measure used by Barrett was static and cross-sectional. In order to compare the total indices with Barrett, an inter-temporal partial index was calculated (for Irish railways only) defined as traffic units per labour employed. The resulting growth rates are also shown in Table 2 and suggest that productivity grew by just over 50 per cent.

This confirms evidence elsewhere (Windle, *et al.*, 1992) that simple partial measures of productivity can seriously mis-state productivity differences across time and between firms.

Table 2: *Irish Rail Productivity Growth (Per cent)*

Year	*TFP1*	*TFP2*	*Partial Productivity*
1985	+ 10.6	+ 10.4	+ 13.6
1986	+ 13.9	+ 12.8	+ 3.6
1987	+ 9.3	+ 8.9	+ 6.1
1988	+ 7.9	+ 7.2	+ 5.1
1989	+ 10.0	+ 8.8	+ 10.6
1990	+ 6.6	+ 5.4	+ 3.1
1991	+ 10.2	+ 8.9	+ 8.6
1992	+ 8.9	+ 7.4	+ 0.1
1985-1992	77.4	69.9	50.8

The trend in rail productivity growth for both types of measure is upward, but annual changes are quite dissimilar at certain points. Hence, if one was to measure partial productivity for 1992, then the growth rate would be a mere 0.1 per cent. With the total productivity measures, the growth rates range between 7 and 9 per cent.

At a specific level, the similarity in terms of burgeoning productivity growth rates between the total and partial indices, is primarily due to the dominant share of labour input in total costs and to significant increases in passenger kilometres in the early part of the study period.

This latter reflects the introduction of the DART services in 1984. Passenger kilometres for the total rail network increased by 32 per cent between 1984 and 1987 and this "explains" why there is a significant increase in the partial index.

However, it is obvious that the impetus for growth was on the capital input side which led to consequent increases in service frequency and quality. The partial measure, by definition, would ascribe all of the growth in output to the labour input. However, the structure of production had changed due to labour being replaced by capital and this substitution had a fundamental impact on productivity.

This, of course, underlines the real weakness of partial productivity measures in that they cannot describe or justify the underlying structure of production in terms of elasticities of substitution, factor price elasticities, economies of scale, etc. Logically, because of input substitution any decline in the contribution to output of any input (say, labour) could be compensated by increases in contributions from other inputs (say, capital). A partial productivity approach cannot capture these substitution effects, nor can it be used as a basis to justify significant reductions in employment.

IV CONCLUSION

The purpose of this note has been to question the validity of partial productivity measurement in the rail industry and to present alternative results using a total productivity approach which gives a better indication of productivity trends in Irish railways. In addition, it has been shown that cross-sectional comparisons are meaningless because of the qualifications and caveats inherent in their measurement. Even then the results should be treated with caution. A comparison of a partial exercise undertaken by Barrett and the total productivity approach, showed that the partial method underestimated productivity growth in Irish railways. From a policy point of view little reliance should be placed on partial measures of productivity because of their propensity to mis-state productivity differences across time and between firms.

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APPENDIX

The data set consists of quarterly observations for 1985 to 1992 inclusive. There are two output indexes, ton miles and passenger miles, and three variable input indexes, labour, fuel and equipment. Lines and works, buildings and land are treated as quasi-fixed so that they cannot be adjusted in the short run. Technological change is represented by a simple time trend.

In general terms the variable cost function can be specified as:

$$C_V = f(Y, Q, P_L, P_E, P_F, K, T) \qquad (1)$$

Where C_V is variable cost, Y is freight ton-miles, Q is passenger miles, P_L, P_E, and P_F are the prices of labour, equipment and fuel respectively, K is the quasi-fixed factor, and T is the time trend.

We employ the translog approximation to represent the variable cost function. The estimating equation is shown in Equation (2) below where all the variables are defined around a point of expansion (point-of-means):

$$
\begin{aligned}
\ln C = {} & \alpha_0 + \alpha_L \ln P_L + \alpha_E \ln P_E + \alpha_F \ln P_F \\
& + \beta_Y \ln Y + \beta_Q \ln Q + \gamma_T T + \delta_K \ln K \\
& + \tfrac{1}{2}\alpha_{L_L}(\ln P_L)^2 + \alpha_{L_E} \ln P_L \ln P_E + \alpha_{L_F} \ln P_L \ln P_F \\
& + \tfrac{1}{2}\alpha_{E_E}(\ln P_E)^2 + \alpha_{E_F} \ln P_E \ln P_F + \tfrac{1}{2}\alpha_{F_F}(\ln P_F)^2 \\
& + \theta_{L_Y} \ln P_L \ln Y + \theta_{E_Y} \ln P_E \ln Y + \theta_{F_Y} \ln P_F \ln Y \\
& + \lambda_{L_Q} \ln P_L \ln Q + \lambda_{E_Q} \ln P_E \ln Q + \lambda_{F_Q} \ln P_F \ln Q \\
& + \rho_{L_T} \ln P_L T + \rho_{E_T} \ln P_E T + \rho_{F_T} \ln P_F T \\
& + \eta_{L_K} \ln P_L \ln K + \eta_{E_K} \ln P_E \ln K + \eta_{f_K} \ln P_F \ln K \\
& + \tfrac{1}{2}\beta_{Y_Y}(\ln Y)^2 + \tfrac{1}{2}\beta_{Q_Q}(\ln Q)^2 \\
& + \tfrac{1}{2}\gamma_{T_T}(T)^2 + \tfrac{1}{2}\delta_{K_K}(\ln K)^2 \\
& + \tau_{Y_Y} T \ln Y + \mu_{Y_K} \ln Y \ln K + \varphi_{Y_Q} \ln Y \ln Q \\
& + \omega_{Q_T} T \ln Q + \pi_{Q_K} \ln Q \ln K + \lambda_{T_K} T \ln K
\end{aligned}
\tag{2}
$$

Homogeneity of degree one in input prices is imposed together with the symmetry condition which ensures that the cost function is continuously twice differentiable.

Given the large number of parameters to be estimated, it is usual to estimate the translog cost function jointly with factor cost share equations (Shephard's Lemma). These share equations are given as:

$$
\begin{aligned}
S_L &= \frac{\delta \ln C}{\delta \ln P_L} = \alpha_L + \alpha_{L_L} \ln P_L + \alpha_{L_E} \ln P_E + \alpha_{L_F} \ln P_F \\
&\quad + \theta_{L_Y} \ln Y + \lambda_{L_Q} \ln Q + \rho_{L_T} T + \eta_{L_K} \ln K \\
S_E &= \frac{\delta \ln C}{\delta \ln P_E} = \alpha_E + \alpha_{E_E} \ln P_E + \alpha_{L_E} \ln P_L + \alpha_{E_F} \ln P_F \\
&\quad + \theta_{E_Y} \ln Y + \lambda_{E_Q} \ln Q + \rho_{E_T} T + \eta_{E_K} \ln K \\
S_F &= \frac{\delta \ln C}{\delta \ln P_F} = \alpha_F + \alpha_{F_F} \ln P_F + \alpha_{L_F} \ln P_L + \alpha_{E_F} \ln P_E \\
&\quad + \theta_{F_Y} \ln Y + \lambda_{F_Q} \ln Q + \rho_{F_T} T + \eta_{F_K} \ln K
\end{aligned}
\tag{3}
$$

The estimated parameters are given in Table 3 together with their respective standard errors, the log likelihood function, and the coefficient of determination (R^2) for the cost equation.

The theory of cost and production requires that the estimated model satisfies the conditions of concavity and monotonicity. The parameter estimates in Table 3 satisfy these regularity conditions at the point-of-means.

The parameter estimates have similar characteristics to those reported in McGeehan (1993). For example, the first order output terms are positive and significant suggesting that as the two outputs increase short-run costs also increase.

The results also confirm that the cost function is non-homothetic and non-homogeneous and that partial elasticities of substitution are non-unitary.

Table 3: *Translog Cost Function Parameter Estimates*

Coeff.	*Estimate (St. Error)*	*Coeff.*	*Estimate (St. Error)*
α_L	0.748 (0.029)	λ_{EQ}	–0.025 (0.017)
α_E	0.205 (0.023)	ρ_{ET}	0.115 (0.026)
α_F	0.041 (0.013)	η_{EK}	–0.155 (0.049)
β_Y	0.318 (0.210)	α_{FF}	0.037 (0.005)
β_Q	0.409 (0.293)	θ_{FY}	–0.111 (0.009)
γ_T	–1.192 (0.700)	λ_{FQ}	0.001 (0.007)
δ_K	0.663 (1.276)	ρ_{FT}	0.017 (0.012)
α_{LL}	0.170 (0.015)	η_{FK}	–0.004 (0.022)
α_{LE}	–0.123 (0.012)	β_{YY}	–0.049 (0.378)
α_{LF}	–0.046 (0.008)	τ_{YT}	–0.044 (0.469)
θ_{LY}	0.043 (0.026)	μ_{YK}	–0.326 (0.937)
λ_{LQ}	0.024 (0.020)	ψ_{YQ}	0.734 (0.340)
ρ_{LT}	–0.132 (0.035)	β_{QQ}	–0.026 (0.369)
η_{LK}	0.160 (0.061)	ω_{QT}	–0.194 (0.331)
α_{EE}	0.113 (0.011)	π_{QK}	0.396 (0.603)
α_{EF}	0.010 (0.020)	γ_{TT}	0.921 (0.793)
θ_{EY}	–0.031 (0.020)	λ_{TK}	–0.761 (1.424)
		δ_{KK}	–0.150 (2.665)

Log Likelihood Function = 386.43
R^2 Cost Equation = 0.99