Total Factor Productivity Growth and Endogenous Demand: Establishing a Benchmark Index for the Selection of Operational Performance Measures in Public Bus Firms

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Abstract

Performance measurement in the public sector is recognised as important for tracking progress. The selection of indicators of performance is somewhat arbitrary, and made difficult by the absence of any benchmarks for screening to establish a systematic link with the overall measurement of performance. In this paper we promote the idea of establishing a reference benchmark index in the guise of an index of total factor productivity growth. The index is used to provide a mapping between itself and a number of operational indicators as a way of assisting organisations in implementing change which is compatible with improvements in overall productivity. The paper questions the wisdom of using an exogenously specified demand-side measure of output and proposes a procedure in which an exogenous supply-side measure of output is linked to an endogenous demand side measure of output. The empirical study draws on seven years of data from the eight public bus operators in Australia to highlight the value of the approach.

1. Introduction

Productivity indicators are recognised as a useful management tool for tracking the performance of a firm and for guiding actions to improve performance. Public bus operators throughout Australia use a large number of partial indicators to assist them in understanding their business, and in the context of targets to establish how well they are performing. The current set of commonly applied indicators have intuitive appeal to an operator. Examples include total vehicle hours per employee, vehicle kilometres per active vehicle, and revenue vehicle capacity kilometres per total recurrent cost (Lee 1989, Mackie and Nash 1982, Hensher 1991). The simplicity of their computation coupled with intuitive appeal has spawned a smorgasbord of measures but little guidance on how to select a suitable subset which reflect the contribution that all inputs and outputs make to overall performance. This general absence of benchmark guidelines is the major motivation for this paper. Fielding (1991) cites the limitations of regional performance incentive schemes such as those proposed for St Louis, the Delaware Valley and an actual scheme in Los Angeles:

> *The schemes used too many indicators and operators*
> *were able to dispute results and create uncertainties*
> *that elected officials were unwilling to arbitrate*

Partial measures of performance consider only a subset of the inputs used by a firm and sometimes only a subset of outputs. To the extent that a firm may increase productivity with respect to one input at the expense of reducing the productivity of other inputs, partial measures will inaccurately portray the overall gains/losses in productivity (Windle and Dresner 1991). What is needed is a framework within which all inputs and outputs (and descriptions of the operating context) can be taken into account, and in which the non-homogeneous nature of the inputs and outputs can be correctly accommodated (Benjamin and Obeng 1991, Talvitie and Obeng 1991).

Economists have promoted the concept of total factor productivity as a single index representing the efficiency of inputs in the production of outputs (Caves et.al.1982). There is a rich literature on how heterogeneous inputs and outputs are aggregated to arrive at a single index of factor productivity. Diewert (1989) has recently reviewed this literature. The majority of this literature uses partial equilibrium models which exogenise the demand conditions (typically through the use of an exogenous demand side measure of output such as passenger trips, passenger kilometres or revenue). (For example, Hensher 1987, Windle 1988, Obeng 1985). A market equilibrium approach provides a more realistic interpretation of the role that demand levels have on productivity (Appelbaum and Berechman 1991). In this paper we propose a modification of the partial equilibrium approach which involves the inclusion of a demand equation which is linked to a cost function via the common supply-side measure of output, namely annual vehicle kilometres. Intuitively it makes more sense to directly relate inputs to a supply-side measure of output and then to relate a demand-side measure of output to the level of service provided.

The model system outlined in this paper is used to estimate the growth in total factor productivity (tfpg) for all urban public bus operators in Australia over the period 1980-1987. The index of tfpg is decomposed to identify the contribution due to a shift in the cost function (technical change) and movements along the cost function (scale economies). The tfpg index is then regressed against a behaviourally linked set of operational variables to provide guidance to operators on sources of potential improvement in performance. The theoretical framework, followed by the modelling approach and the empirical outputs form the major sections of the paper.

2. The Theoretical Framework

Total factor productivity defines the ratio of total output to total inputs, or the growth in total output minus the growth in total inputs. The simple definition is complicated by the presence of more than one type of output (Q), such as passenger kilometres from scheduled route services and from permanent school contracts, and a number of input (x) categories such as labour, fuel, non-labour maintenance and capital. Output can be measured on the supply side (Q_s) in terms of the provision of annual vehicle kilometres, and on the demand side (Q_d) in terms of passenger kilometres. A preferred specification involves the functional specification of a relationship between passenger kilometres and vehicle kilometres: $Q_d = f(F, Q_s, Z)$, where F is the exogenously determined fare per passenger and Z is a vector of other influences on bus use.

The total factor productivity index is commonly derived from a parametric specification of a transformation function G(Qs, x, t) = 0 which represents the underlying technology facing a bus operation. The time (t) variable captures the shifts in technology which represent changes in technical efficiency. A bus operator is assumed to operate under a regime which is equivalent to

$$\max\{FQ_d - px: G(Q_s, x, t) = 0, Q_d = f(F, Q_s, Z)\} \qquad (1)$$

where p is a vector of input prices. The cost function of a bus operator can be defined as

$$C(p, Q_s, t) \equiv \min_x \{px: G(Qs, x, t) = 0\} \qquad (2)$$

where C is total cost. Equation (2) can be substituted into (1) to give

$$\max\{FQ_d - C(p, Q_s, t), Q_d = f(F, Q_s, Z)\}$$
(3)

Totally differentiating (2) with respect to time, we have

$$(dC/dt) = \sum_i \left(\frac{\partial g}{\partial p_i}\cdot\frac{\partial p_i}{\partial t}\right) + \frac{\partial g}{\partial Q}\cdot\frac{\partial Q}{\partial t} + \frac{\partial g}{\partial t} \qquad (4)$$

Given the well known result from Shepherd's lemma, i.e. $\frac{\partial g}{\partial p_i} = X_i$ and the definition of the elasticity of cost with respect to output ε_{cq} of $\frac{\partial g}{\partial Q}\cdot\frac{Q}{C}$ equation (4) is equivalent to:

$$\frac{\partial C}{\partial t}\cdot\frac{1}{C} = \dot{C} = \sum_i (p_i X_i/C)\dot{p} + \varepsilon_{cq}\dot{Q} + C^{-1}\left(\frac{\partial g}{\partial t}\right) \qquad (5)$$

where $\dot{C}$ is the proportionate change in total cost, $\dot{P}_i$ is the proportionate change in the price of input i and $\dot{Q}$ is the proportionate change in output. In discrete time the proportionate change can be approximated by $\Delta \log Q = \log Q_t - \log Q_{t-1}$. The end term in equation (5) is the proportionate shift over time in the cost function ($\dot{B}$) equal to the change in cost minus the change in aggregate inputs minus the change in aggregate output. Equation (5) establishes that if there are multiple inputs the weight for aggregating such inputs is the share (S_i) of cost due to each input in each time period; if there are multiple outputs, the weights are the contribution of each output to cost in each time period, measured by the cost elasticity of output. The derivation above has assumed a single output. The term $\varepsilon_{cq}\dot{Q}$ is the scale effect . If the cost elasticity of output is not available revenue is typically used which is an appropriate weight only if the firm prices at marginal cost and exhibits constant returns to scale.

Define $\dot{TFP}$ as the proportionate rate of growth of output minus the proportionate rate of growth of inputs. The proportionate shift in the cost function is not strictly equivalent to the rate of growth of TFP. Denny, Fuss and Waveman (1981) have shown that only when the production function exhibits constant returns to scale is $\dot{TFP}$ equal to $\dot{B}$. To derive $\dot{TFP}$ from equation (5) when $\varepsilon_{cq} \neq 1$ we have to adjust $\dot{TFP}$ by $(1-\varepsilon_{cq})\dot{Q}$. Thus

$$\dot{TFP}_g = -\dot{B} + (1-\varepsilon_{cq})\dot{Q}. \qquad (6)$$

Equation (6) defines $\dot{TFP}$ in terms of intertemporal shifts or technical change and scale effects. In the empirical study we define returns to scale in terms of annual vehicle kilometres. $\dot{B}$ can be derived directly from the cost function as a fully parametric derivation in which cost is then an estimate ($\tilde{C}$), or from a measured calculation given ε_{cq} in which it is the residual from the change in *actual* costs minus the change in aggregate input, where factor shares are the *actual shares*, minus the scale effect. In the empirical analysis we have selected the fully parametric approach, so that

$$\dot{TFP}_g = -\partial \log \tilde{C}/\partial t + (1-\varepsilon_{cq})\dot{Q} \qquad (7)$$

3. The Modelling Approach

The necessary inputs into $\dot{TFP}_g$ are derived from a cost model of the translog functional form. Given the available data we assume that each bus firm uses four competitively priced inputs - labour, fuel, maintenance materials and capital - to produce annual vehicle kilometres. The data for seven financial periods from 1980/81 to 1986/87 was compiled from a questionnaire sent to each of the eight urban public bus operators in Australia. The cost function is given in equation (8).

$$\begin{aligned} Ln(C/p_k) = {} & \alpha_0 + \beta_1 \ln Q_s + \tfrac{1}{2}\beta_2 (\ln Q_s)^2 + \Sigma\delta_i \ln(p_i/p_k) + \tfrac{1}{2}\Sigma\Sigma\delta_{ij} \ln(p_i/p_k)\ln(p_j/p_k) \\ & + \Sigma\Sigma\sigma_i \ln(p_i/p_k)\ln Q_s + \Omega_t t + \Sigma\delta_{it}\ln(p_i/p_k)t + \beta_t \ln Q_s t \end{aligned} \qquad (8)$$

The translog form provides a second-order approximation of the true cost function at a point. We have selected the sample means for all explanatory variables at the point of approximation. The financial data are expressed in 1980/81 dollars. To satisfy symmetry and linear homogeneity in input prices we impose the following restrictions and divide each of the price variables and total cost by the unit price of one of the inputs, selected as capital:

$\delta_{ij} = \delta_{ji}$, $\Sigma\delta_i = 1$, $\Sigma\delta_{ij} = 0$, $\Sigma\sigma_i = 0$, $\Sigma\delta_{it} = 0$

Time is interacted with the prices of each input and output so that the relationship through time between cost, input prices and output is relatively unrestricted. From equation (8) the input share equations are:

$$S_i = \delta_i + \sum_j \delta_{ij} \ln(p_j/p_k) + \sum_i \sigma_i \ln Q_s + \delta_{it} t, \quad i = L, F, M \tag{9}$$

The inclusion of the share equations aids in reducing the high correlation between many of the cross-products terms, and the dropping of one share equation, any one when maximum likelihood estimation (MLE) is used, ensures non-singularity in the error variance-covariance matrix (Greene 1990).

The demand equation is assumed to be log-linear with exogenous variables representing fares, level of service, income and the cost of alternative forms of transport.:

$$\ln Q_d = \kappa_0 + \kappa_f \ln(\text{fare}) + \kappa_{los} \ln(\text{vkm}) + \kappa_y \ln(\text{income}) + \kappa_a \ln(\text{auto cost}) \tag{10}$$

Iterative MLE for seemingly unrelated regression is used to obtain parameter estimates for the system of demand and cost equations. The estimated cost model is used to derive the cost elasticity with respect to output and the estimate of intertemporal shifts in the cost function. Fixed effects are introduced to allow for the mean effect of unobserved operator-specific effects.

The input prices are defined as follows. Labour is expressed in terms of dollars per hour, fuel in dollars per litre, non-labour maintenance in dollars per vehicle kilometre, and the economic cost of capital in dollars per vehicle kilometre.

The treatment of capital assets, in particular bus capital has traditionally been a very superficial exercise in nearly all public bus operations in Australia. The appropriate cost of an asset to be charged against operations during any given period is the opportunity cost of using it during that period. When evaluating the opportunity cost of a bus, the relevant cost is the entire capital cost, to be regarded as an outlay in the period the bus is acquired minus its residual value on sale, and which is regarded as a cash receipt at the time the bus is disposed. Depreciation should not be charged against revenue produced by service provision for this is implicit in the procedure of comparing the discounted benefit and cost streams.

The relevant variables for operations planning are cash flows and opportunity costs rather than costs determined on the basis of arbitrary accounting allocations. An appropriate means of determining capital costs is to use capital recovery factors to determine the annual outlay which would be equivalent, in terms of net present value, to future cash outlays resulting from an investment decision. The average capital cost per annum (AKC) for a bus is defined in equation (11).

$$AKC = A + (P*S(1+r)^{-n})*CRF \tag{11}$$

where

CRF = the cost recovery factor = $r/(1-(1+r)^{-n})$

P = bus real purchase price

S = bus real scrap or residual value after L kilometres

r = the real rate of interest
A = the average annual outlays of bus insurance and registration
n = the average vehicle life, determined elsewhere as 15 years.

The riskless cost of borrowing in Australia stood at 17.03% at the end of 1989. A corporate borrowing premium of 1% brings this to 18%. The riskless rate plus the general risk premium of 7% is the cost of equity. If we were to equate the rate of return on a bus firm's stock to the rate of return on the market portfolio (i.e. a beta coefficient of 1.0), then the risk-adjusted nominal cost of borrowing would be 25.03%. If a bus firm has government protection as do all public bus operators in Australia and we treat it as a riskless entity, then the nominal rate of return would be 10.03%, approximately equivalent to an 8% real rate of interest.

To obtain an estimate of the residual value, we sampled a number of market prices obtained from vehicles disposed in 1988 in the private bus sector. The prices have been averaged to ensure a uniform change in relative prices between years. The prices are then converted to constant dollars by calculating the compound rate of increase of a new bus over a 15 year period (approximately 13%) and applying it to the nominal bus prices. The decline in value per annum is then calculated, and the value projected to a constant 15 year life. We have selected 15 years in order to be consistent with the mean life assumed by the private bus sector. The ratio of the value projected in constant dollars to a constant 15 year life over the historical cost can be expressed as the average percentage residual or scrap value of a 15 year old bus. The suggested working percentage is 15%.

4. The Empirical Measure of Total Factor Productivity Growth

Equations (8), (9) and (10) were jointly estimated with the linear homogeneity and symmetry restrictions imposed. In addition we estimated equations (8) and (9) with a demand-side measure of output to investigate the empirical implications of exogenising demand. The results are given in Table 1. Using Model 2, we tested the joint hypothesis that the parameter estimates associated with the interactions between inputs and output, between inputs and time and between output and time were all equal to zero. This would imply that technical change is Hicks-neutral. The only condition that was satisfied on a likelihood ratio test was the interaction between inputs and time. We excluded this set of three interactions from the final models.

Table 1 The Translog Cost System
Model 1: Output = Annual passenger kilometres
Model 2: Output = Annual vehicle kilometres with endogenous annual passenger kilometres

		Model 1		Model 2	
Variable		**Parameter Estimates**	**T-Ratio**	**ParameterE stimates**	**T-Ratio**
Constant	α_0	15.103	12.07	12.076	13.62
Output	β_Q	2.721	5.71	1.1714	3.12
(Output)^2	β_{QQ}	-0.143	-0.69	-0.27617	-1.08
Price of Labour	δ_L	0.752	54.92	0.74707	150.71
(Price of Labour)^2	δ_{LL}	0.141	12.23	0.13201	9.81
Price of Fuel	δ_F	0.0177	17.29	0.07808	47.34
(Price of Fuel)^2	δ_{FF}	0.0399	7.37	0.03485	7.13
Price of Maintenance	δ_M	0.0611	15.25	0.05979	41.61

(Price of Maintenance)^2	δ_{MM}	0.0544	19.87	0.05712	17.93
$P_L * P_F$	δ_{LF}	-0.0265	-4.20	0.01911	-3.07
$P_L * P_M$	δ_{LM}	-0.0329	-7.37	-0.03212	-6.41
$P_M * P_F$	δ_{MF}	-0.0167	-5.52	-0.01540	-5.39
P_L * Output	σ_{LQ}	0.0176	4.28	0.01697	3.81
P_F * Output	σ_{FQ}	-0.005	-3.55	-0.004565	-2.96
P_M * Output	σ_{MQ}	-0.005	-4.23	-0.004435	-3.23
Time	Ω_t	-0.075	-0.52	0.04858	1.48
Time * Output	δ_{tQ}	-0.019	-0.43	0.07368	2.07
NSW		5.971	3.94	1.5258	-1.41
SA		4.777	3.54	1.2659	-1.33
QLD		3.898	3.36	1.6568	-1.97
VIC		3.341	3.42	1.4841	-2.00
WA		4.222	3.11	1.4999	-1.54
ACT		3.167	3.31	0.65277	-0.86
TAS		2.660	3.10	1.2945	-1.98
Constant-demand eqn.	κ_O			-0.036059	-1.08
Average Fare	κ_F			-0.10277	-1.49
Level of Service	κ_{LOS}			1.1350	36.5
Log likelihood at convergence		-32.6		-36.3	

Note:

SA	South Australia
NSW	New South Wales
WA	Western Australia
ACT	Australian Capital Territory
TAS	Tasmania
QLD	Queensland
VIC	Victoria
NT	Northern Territory

A comparison of the two models is very revealing. The implied scale economy at the mean of the sample is close to zero (-0.1714) when annual vehicle kilometres is the output measure, and the demand for passenger kilometres is itself a function of annual vehicle kilometres. This evidence supports the widespread view that the urban bus industry exhibits constant returns to scale. By contrast the treatment of output as the exogenous level of annual passenger kilometres suggests that the scale economy at the sample mean is minus 1.72, significant diseconomies of scale.

The demand equation contains only two significant variables, the average fare and level of service Fares are set by governments, with the operators relying heavily on changes in the overall level of service as measured by frequency and vehicle kilometres to increase revenue. Data on service frequency is not available and so annual vehicle kilometres are used as the measure of the overall level of service. The vehicle kilometre variable is statistically very significant, in contrast to the mean level of fare which is significant at the 93% level of confidence given the degrees of freedom. The parameter estimate for fare (-0.103) is the direct-price elasticity of demand for passenger kilometres. Likewise the direct-vehicle kilometre elasticity of demand for passenger kilometres is 1.14 suggesting that Australian urban bus user demand is elastic with respect to level of service. A one percent increase in vehicle kilometres leads to a 1.14 percent increase in passenger kilometres, ceteris paribus. It is important to note that the dimension of passenger demand is passenger kilometres, which is more likely to be elastic with respect to vehicle kilometres than is total passengers. Likewise the change in passenger kilometres with respect to fares is likely to be less responsive than would be passengers.

To account for unobserved operator specific effects we have included firm-specific dummy variables in the model. The Northern Territory operator is set to zero as the base. Since nearly 98% of the variability occurs between operators rather than within operators, the time invariant firm effects are appropriate indicators of additional differences between firms which are not accounted for by factor inputs, demand and supply side measures of output, time, and fares. The mean estimates of the firm effects are much smaller in the model system which includes endogenous demand. This suggests that differences in the profile of passenger demand have an important role in explaining the overall levels of costs of operation. A failure to recognise the correlation between the unobserved influences on both passenger kilometre demand and total costs of service provision is a source of specification error.

The application of equation (7) generates a matrix of indices of total factor productivity growth. The results are summarised in Table 2. The decomposition of TFP_g due to technical change and the scale effect are given in Table 3. The results are plotted in Figure 1. The mean annual TFPg derived from the market equilibrium model varies from 8.3% (New South Wales) to -13.9% (Northern Territory). The variation over time is also reasonably uniform within each firm. Two operators with negative TFPg (Northern Territory and Tasmania) have had little success in reversing the trend downwards; however Victoria and the ACT began to show improvements in the last three periods.

Table 2 Total Factor Productivity Growth
(i) Output = Annual passenger kilometres
(ii) Output = Annual vehicle kilometres, with Endogenous passenger kilometres

(i)	**SA**	**NSW**	**WA**	**ACT**	**TAS**	**QLD**	**VIC**	**NT**
80/81 - 81/82	0.048	0.101	0.094	0.279	0.299	0.030	0.014	-0.221
81/82 - 82/83	-0.297	0.118	0.187	-0.230	0.041	-0.022	0.219	-0.084
82/83 - 83/94	-0.022	0.099	0.111	-0.133	-0.043	0.148	0.002	-0.343
83/84 - 84/85	0.152	0.052	0.134	-0.039	0.047	0.118	-0.179	-0.136
84/85 - 85/86	0.073	0.078	0.012	0.114	-0.005	0.074	-0.177	0.115
85/86 - 86/87	0.273	0.048	0.049	-0.006	0.119	0.105	0.095	-0.152
Overall Mean								
	0.038	0.083	0.098	-0.0025	0.076	0.076	-0.004	0.176

(ii)								
80/81 - 81/82	0.044	0.081	0.057	-0.006	-0.031	0.007	-0.022	-0.139
81/82 - 82/83	0.044	0.085	0.058	-0.002	-0.032	0.011	-0.020	-0.136
82/83 - 83/84	0.044	0.084	0.060	-0.001	-0.032	0.016	-0.021	-0.136
83/84 - 84/85	0.044	0.083	0.060	0.009	-0.032	0.018	-0.017	-0.136
84/85 - 85/86	0.043	0.082	0.061	0.003	-0.034	0.020	-0.018	-0.133
85/86 - 86/87	0.043	0.083	0.061	0.005	-0.035	0.022	-0.005	-0.127
Overall Mean								
	0.044	0.083	0.060	0.001	-0.033	0.016	-0.017	-0.139

Table 3 Decomposition of Total Factor Productivity Growth:

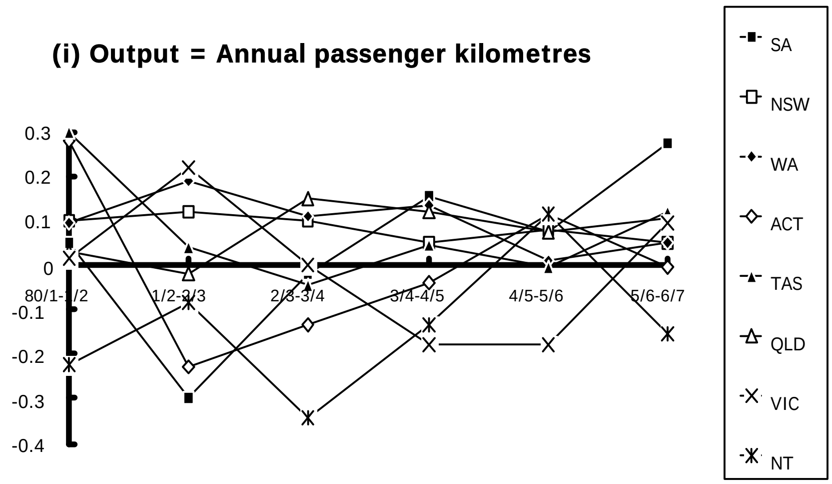
Contributions due to: **A**. Shift in the Cost Function (Technical Change)

B. Movement along the Cost Function (Scale Effect)

(i) Output = Annual passenger kilometres

(ii) Output = Annual vehicle kilometres, with Endogenous passenger kilometres

	SA		**NSW**		**WA**		**ACT**		**TAS**		**QLD**		**VIC**		**NT**	
(i)	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
80/81 - 81/82	0.076	-0.027	0.092	0.009	0.086	0.009	0.054	0.225	0.055	0.244	0.077	-0.047	0.060	-0.046	0.017	-0.238
81/82 - 82/83	0.079	-0.376	0.093	0.026	0.086	0.101	0.058	-0.288	0.055	-0.015	0.078	-0.100	0.058	0.161	0.018	0.066
82/83 - 83/84	0.080	-0.103	0.093	0.006	0.085	0.026	0.058	-0.192	0.056	-0.013	0.076	0.071	0.057	-0.055	0.018	-0.362
83/84 - 84/85	0.079	0.072	0.093	-0.041	0.084	0.050	0.063	-0.102	0.056	-0.009	0.076	0.042	0.063	-0.242	0.019	-0.155
84/85 - 85/86	0.078	-0.006	0.093	-0.015	0.085	-0.073	0.059	0.055	0.055	-0.060	0.076	-0.004	0.062	-0.239	0.017	0.018
85/86 - 86/87	0.075	0.197	0.094	-0.045	0.084	-0.034	0.060	-0.067	0.053	0.066	0.075	0.030	0.066	0.029	0.019	-0.171
Overall Mean	0.078	-0.065	0.093	-0.01	0.085	0.013	0.059	-0.062	0.055	0.045	0.076	-0.001	0.061	-0.06	0.018	-0.101
(ii)																
80/81 - 81/82	0.046	-0.002	0.083	-0.001	0.057	0.0001	-0.004	-0.002	-0.033	0.002	0.012	-0.004	-0.02	-0.002	-0.136	-0.002
81/82 - 82/83	0.044	-0.0006	0.084	0.0007	0.060	-0.002	0.001	-0.003	-0.032	0.0007	0.017	-0.006	-0.020	-0.0005	-0.129	-0.007
82/83 - 83/84	0.045	-0.0002	0.083	0.0001	0.060	-0.0009	0.003	-0.004	-0.032	0.0006	0.018	-0.002	-0.022	-0.0003	-0.132	-0.005
83/84 - 84/85	0.044	-0.0001	0.083	0.003	0.060	0.0002	0.011	-0.002	-0.032	-0.0006	0.019	-0.001	-0.017	0.0	-0.132	0.003
84/85 - 85/86	0.043	-0.0002	0.083	-0.0003	0.062	-0.0008	0.001	0.002	-0.034	-0.0003	0.021	-0.001	-0.014	-0.004	-0.132	-0.001
85/86 - 86/87	0.043	-0.0002	0.083	-0.0001	0.061	-0.0001	0.006	-0.0009	-0.035	-0.0001	0.023	-0.0004	-0.005	-0.004	-0.123	-0.003
Overall Mean	0.044	-0.0006	0.083	0.0007	0.06	-0.0006	0.003	-0.001	-0.033	-0.0004	0.018	-0.002	-0.016	-0.002	-0.131	-0.003



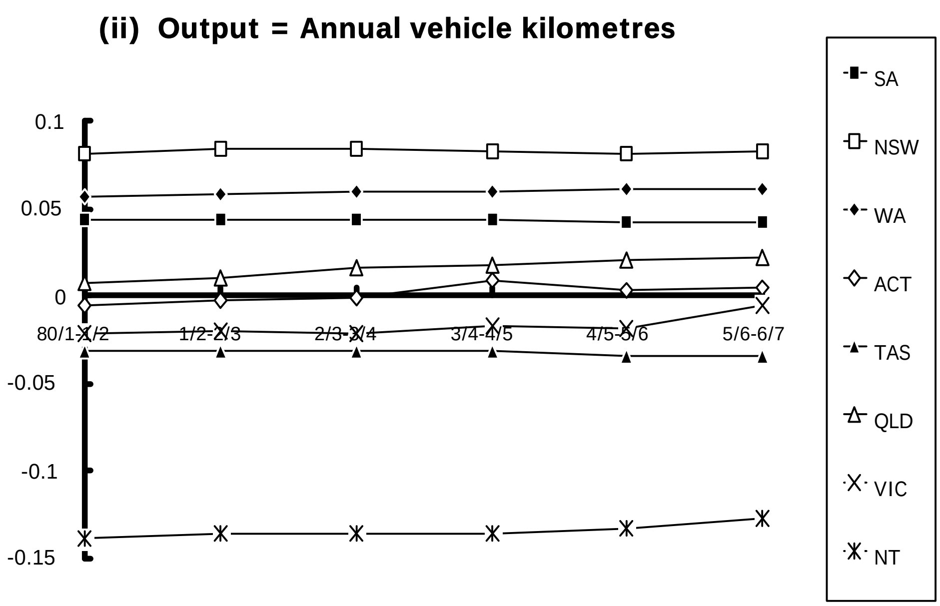


Figure 1. Alternative Treatments of Output in the Calculation of TFP_g

When TFPg is decomposed into the contributions due to the shift in the cost function and movement along the cost function, we can establish the source of growth. For example, South Australia's TFPg is due almost entirely to shifts in the cost function; the mean scale effect of -0.0006 is negligible in the downward direction. In contrast however, for the ACT the small but positive contribution of technical change (except in the first year) is discounted quite substantially by the small but negative scale effect. With the exception of the ACT, the scale effect contributes very little to the overall growth in TFP.

The partial equilibrium model with exogenous demand gives quite different results, except at the overall firm mean through time for SA and NSW (Table 2). Figure 1(i) highlights the major shifts through time in growth rates for all bus firms. The mean TFPg ranges from 9.8 percent (NSW) to 17.6 percent (NT), but with wide variations within each firm. The rank orderings at the mean also change with VIC and NT the only operators with the same ranking (6th and 8th respectively). The different treatments of output highlights the dependence of the findings on the treatment of output in general and the role of demand in particular. Without the inclusion of the demand equation it is not possible to allow for the possibility that negative TFPg may reflect a decline in patronage rather than a decline in productivity per se. The intuitive technical relationship between vehicle kilometres and factor inputs together with the role of vehicle kilometres as a service proxy in influencing passenger demand provides a more appealing framework in which to establish the annual changes in total factor productivity.

5. The Relationship Between the Benchmark Index and Operational Performance Measures

The TFPg results are useful in establishing a profile of performance overall and as a means of comparison between operations in a global sense. From an operator's perspective, TFPg provides little operational guidance on what to do to improve productivity. To be useful as a reference benchmark it is necessary to establish a mapping between a set of operationally meaningful partial measures of performance and the global index.

A way of establishing the linkage is to regress TFPg against a behaviourally linked set of partial indicators which may be either a univariate ratio indicator such as fleet size per unit of labour or an operating environment variable such as total route kilometres (see Hensher 1989, Obeng 1985a). Table 4 summarises a number of candidate indicators. We began by considering the subset of performance indicators recommended by Fielding et.al. (1985) as the best or alternative marker indicators which can be derived from our data set. The indicators are (i) vehicle kilometres per active vehicle, (ii) vehicle kilometres per maintenance employee, (iii) revenue vehicle capacity kilometres per total recurrent cost, (iv) vehicle kilometres per operating expense, and (v) number of peak vehicles per maintenance and support service employees. In addition we considered a large number of other measures. Many of the partial measures are highly correlated, and thus a final set will have to take this into account. Three univariate ratio indicators and one environmental variable were found to be statistically significant and to explain nearly 95 percent of the variation in TFPg across the entire sample of pooled observations. The results are given in Table 5.

Table 4. Descriptive Statistics
Average over 7 Financial Periods; All $ items in 80/81 Constant Dollars

Performance Measures	ALL	SA	NSW	WA	ACT	TAS	QLD	VIC	NT
Fleet Size	616	751	1713	913	375	288	556	293	39
Labour	1825	2345	6141	2104	840	570	1466	1054	86
Drivers	1136	1488	3820	1429	506	361	850	577	57
Mechanics	389	302	1540	337	197	146	354	218	17
Fleet Mean Age	8.30	6.50	7.69	9.79	7.17	9.90	11.4	11.4	6.41
Buses per Labour Unit	.387	.321	.279	.434	.447	.504	.380	.279	.456
Buses per Driver	.622	.506	.449	.639	.741	.798	.655	.508	.684
Buses per Mechanic	1.93	2.49	1.114	2.71	1.90	1.97	1.57	1.35	2.35
VKM per Labour['000]	16.71	16.44	10.77	20.93	17.95	17.03	15.44	13.38	21.73
VKM per Driver ['000]	26.80	25.88	17.32	30.83	29.80	26.95	26.65	24.35	32.59
VKM per Mech. ['000]	85.59	127.6	42.99	130.6	76.60	66.42	64.06	64.52	111.9
Pass.per Labour ['000]	26.85	25.03	30.96	24.24	24.59	35.05	28.14	20.10	11.62
Pass per Driver ['000]	43.37	39.42	49.77	35.70	40.85	55.45	48.54	36.61	17.41
Pass per Mechanic ['000]	132.6	194.9	123.6	151.3	105.2	136.8	116.4	96.97	59.70
Rev per Labour ['000]	10.30	10.37	12.46	10.20	10.77	8.135	12.87	9.287	8.331
Rev per Driver ['000]	16.72	16.31	20.01	15.02	17.85	12.87	22.21	16.87	12.58
Rev per Mechanic ['000]	51.50	80.72	49.81	63.61	45.81	31.75	53.30	44.77	42.24
Pass km per L ['000]	198.8	200.2	141.1	271.9	125.4	210.3	252.5	180.6	92.84
Pass km per Drv.['000]	320.6	315.4	226.8	400.4	208.3	332.7	435.5	328.9	139.3
Pass km per Mech ['000]	1019	1558	563.3	1697	536.3	820.7	1044	871.3	477.6
Cost per Pass km [$]	.1329	.1298	.1889	.0814	.1885	.1086	.0983	.1523	.417
Cost per Pass [$]	1.030	1.039	0.866	1.019	0.961	0.652	0.882	1.369	3.335
Cost per VKM [$]	1.656	1.569	2.475	1.176	1.311	1.340	1.612	2.043	1.724
Cost per Rev [$]	2.730	2.510	2.158	2.415	2.188	2.815	1.926	2.940	4.887
VKM per bus ['000]	53.43	56.54	50.05	50.17	49.91	47.31	49.18	55.33	68.95
Pass per VKM	1.701	1.524	2.859	1.159	1.370	2.059	1.834	1.503	0.533
Pass km per VKM	12.20	12.19	13.10	13.01	6.989	12.35	16.45	13.50	4.262
Rev per Pass [$]	.392	.415	.404	.421	.440	.233	.458	.465	.760
Rev per Pass km [$]	.0554	.0519	.0881	.0375	.0863	.0388	.0510	.0517	.0950
Pass km per Seat Km	206.8	199.9	224.3	220.5	122.6	216.7	288.5	270.0	74.77
Cost per Seat Km [$]	.0294	.0257	.0427	.0206	.0230	.0235	.0283	.0409	.0302
Prop Buses in Service	.820	.910	.780	.960	.810	.730	.830	.870	.700
Ave Trip Length [km]	7.202	8.000	4.560	11.00	5.100	6.000	8.971	8.986	8.000
Ave Price of L [$/hour]	8.483	7.118	9.956	8.131	7.742	7.025	7.323	8.480	12.08
Price of Fuel [$/lt]	.2886	.2851	.2999	.3034	.2226	.3225	.2433	.3405	.2915
Price of Maint [$/km]	.0902	.0971	.0948	.0461	.0649	.1009	.0595	.0826	.1753
Price of Cap [$/km]	.1694	.2695	.1827	.1220	.0488	.1139	.1453	.3059	.1667
Total Cost [mill $]	47.09	60.44	163.7	51.81	19.71	13.01	36.35	28.45	3.204
Passenger Kms [mill]	341.6	469.7	866.4	572.0	105.7	119.9	369.9	190.1	8.018
Passengers [mill]	51.11	58.71	189.1	51.01	20.72	19.99	41.24	21.15	1.002
Revenue [mill $]	20.65	24.34	76.44	21.45	9.02	4.642	18.87	9.71	0.723
Deficit per km [$/vkm]	.979	.956	1.192	.688	.747	.862	.662	1.353	1.370

Table 5. The Relationship Between TFPg and Partial Performance Measures

Variable	**Acronymn**	**Estimate**	**t-Ratio**
Constant		-0.32577	-6.87
Log (Route Kms)	LRKM	0.06239	14.50
Deficit per passenger	DEFPASS	-0.03221	-3.73
Buses per Employee	BUSPL	-0.23878	-7.53
Passgr.Kms per Veh Km	PASKMVKM	0.003282	3.14

R-squared 0.949
Sample Size 48 (excludes the first year of each firm)
Sum of squared residuals 0.00989

The set of significant indicators does not include any of the evaluated marker indicators of Fielding et.al. (1985). Individually the only marker indicator which was statistically significant was the number of peak vehicles per maintenance and support service employees. We found that it was collinear with buses per employee (BUSPL) and that the latter provided an improved contribution to the overall explanation of variation in TFPg. Two of the partial indicators are based on information on both the supply-side and the demand-side, reinforcing the importance of evaluating productivity in the context of the demand for the bus services and hence the need to treat the calculation of productivity in the context of a market equilibrium setting in which service effectiveness has a significant influence on cost efficiency. This suggests a need to generalise the Fielding "triangle" to consider a more comprehensive set of relationships as proposed in Figure 2. The deficit per passenger indicator is the single preferred indicator promoted by Talley (1982). Given the objective of the firm is to maximise passengers subject to a deficit constraint. Talley identifies the lagrange multiplier of an appropriately specified objective function as a measure of passengers per deficit (and hence its inverse which is operationally more appealing). Variations in deficit per passenger "explains" by itself fifty-five percent of the variation in TFPg.

The relationship established in Table 5 has assumed that the four explanatory variables are exogenous to the operator. In the context of identifying an expanded set of operational instruments which do not have a direct influence on TFPg, but which are underlying sources of influence on the direct effects, we have investigated a "second layer" of relationships. Three stage least squares (3SLS) is used to obtain parameter estimates because of the endogeneity of a number of right hand side variables. The four direct influences on TFPg are the dependent variables in the additional four equations in a system of 5 simultaneous equations. The results are given in Table 6.

Within the limitations of available data, we have identified seven additional underlying sources of variation which via the four direct effects can contribute to the identification of operational opportunities for securing an improvement in overall productivity. Together with total route kilometres, passenger kilometres per revenue capacity seat kilometres (LOAD) and the proportion of patronage which is school children (PSCHPASS) have a statistically significant negative relationship with the annual deficit per passenger. The higher incidence of school passengers as a means of reducing the deficit per passenger reflects the generous nature of concession reimbursements to public operators in Australia. In a sense it is an artificial guide to sources of productivity improvement since it can act as a disincentive to improve performance overall through actions associated with in-house efficiency programs.

The number of buses per unit of labour is related to variations in LOAD and total annual vehicle kilometres (ANNVKM). Both have negative parameters suggesting that an improvement in the utilisation of each revenue capacity seat kilometre will reduce the bus requirements per employee, which is further reinforced the more kilometres one can get out of the bus fleet each year. Operators throughout the period of our empirical study who had higher load factors were able to establish a lower vehicle:labour ratio in comparison to operators with lower load factors. A lower ratio implies a higher TFPg (from Table 6 (i)).

Passenger kilometres per vehicle kilometre (PASKMVKM) are positively influenced by the average fare level (LAVFAREI) and the number of vehicles in service (SVEHS), and higher PASKMVKM has a positive effect on productivity. The statistically significant positive relationship between PASKMVKM and LAVFAREI is curious, and may be attributable in part to the nature of the section fares. Finally the "size" of the network as proxied by route kilometres is influenced by the requirements of the service area population and the extent of school passengers. Both of these variables have a positive relationship with route kilometres provided which itself has a positive relationship with TFPg.

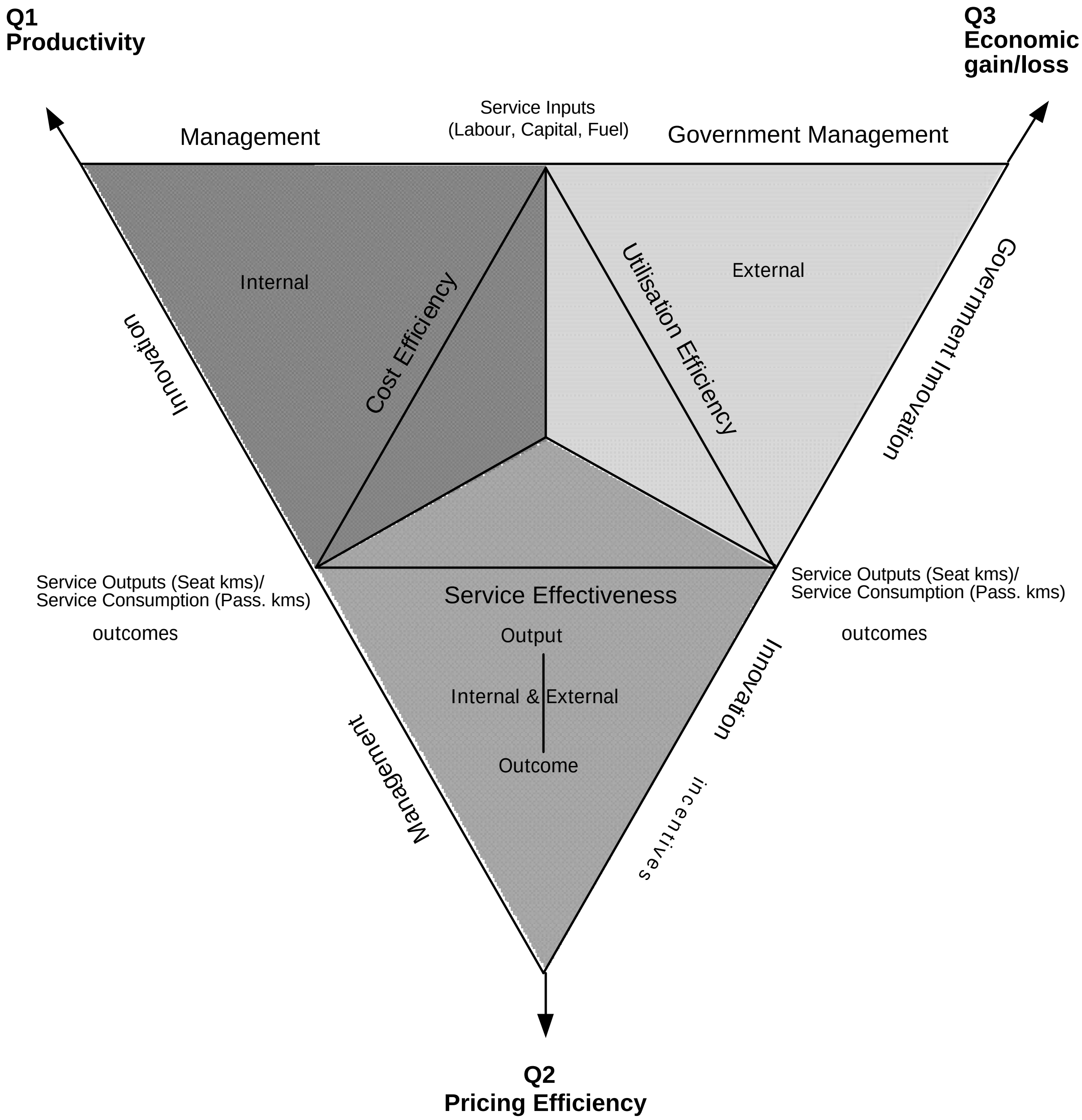


Figure 2. A Generalised and Extended Fielding Triangle

Table 6. The Relationship Between TFPg and Partial Performance Measures: Three-Stage Least Squares System Linkaging

(i) Dependent variable = Total Factor Productivity Growth

Variable	**Acronymn**	**Estimate**	**t-Ratio**
Constant		-0.44315	-9.69
Log (Route Kms)	LRKM	0.07243	17.75
Deficit per passenger	DEFPASS	-0.01662	-1.98
Buses per Employee	BUSPL	-0.20250	-6.89
Passgr.Kms per Veh Km	PASKMVKM	0.005288	5.41

R-squared	0.935
Sample Size	48 (excludes the first year of each firm)
Sum of squared residuals	0.01026

(ii) Dependent variable = Deficit per passenger (DEFPASS)

Variable	**Acronymn**	**Estimate**	**t-Ratio**
Constant		3.8091	10.31
Log (Route Kms)	LRKM	-0.35576	-6.99
Pass. kms per seat km	LOAD	-2.6645	-4.08
Propn. school passgrs	PSCHPASS	-1.0630	-2.98

R-squared	0.580
Sample Size	48 (excludes the first year of each firm)
Sum of squared residuals	0.02661

(iii) Dependent variable = Buses per Employee (BUSPL)

Variable	**Acronymn**	**Estimate**	**t-Ratio**
Constant		0.5813	17.24
Pass. kms per seat km	LOAD	-0.6700	-4.49
Annual vehicle kms	ANNVKM	-0.000002	-4.25

R-squared	0.410
Sample Size	48 (excludes the first year of each firm)
Sum of squared residuals	0.1737

(iv) Dependent variable = Passenger Kilometres per Vehicle Km. (PASKMVKM)

Variable	**Acronymn**	**Estimate**	**t-Ratio**
Constant		4.9772	3.50
Log(Average Fare)	LAVFAREI	4.7135	4.49
Vehicles in Service	SVEHS	0.00187	1.99

R-squared	0.151
Sample Size	48 (excludes the first year of each firm)
Sum of squared residuals	0.00031

(v) Dependent variable = Log (Route Kilometres), (LRKM)

Variable	**Acronymn**	**Estimate**	**t-Ratio**
Constant		5.7915	42.50
Service area population	SAPOP	0.00102	6.50
Annual school passengers	SCHPASS	0.000026	1.80

R-squared	0.321
Sample Size	48 (excludes the first year of each firm)
Sum of squared residuals	0.00145

6. Conclusion

This paper has highlighted the potential value of the establishment of a reference benchmark to assist bus operators in the selection of partial measures of performance which have a systematic link with the overall level of productivity. In addition we have argued for a need in all future studies of total factor productivity to treat the demand side endogenously, and to recognise the appropriate link between costs, a supply-side measure of output and a demand-side measure of output.

There is scope for both refinements in the theoretical approach to the study of productivity as well as in the development of a bottom-up data strategy within all firms in the bus industry so that we can increase our confidence in the results of productivity measurement studies There is much still to be achieved in the ongoing research agenda. Future studies should make appropriate allowance for minimum levels of service imposed by governments, deviations from marginal cost pricing and other regulatory influences such as a ceiling on fare increases. The framework presented in this paper can be easily extended to accommodate these further issues, but until suitable data become available (particularly in Australia), the empirical gains May be somewhat illusory.

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