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The Appropriateness of the Poolability Assumption for Multiproduct Technologies

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Abstract. Empirical literature on the cost structure of multiproduct firms traditionally assumes a common technology across different products and stages of production, letting the issue of poolability unexplored. The appropriateness of this assumption is tested by using data from UK specialized and diversified water utilities and by estimating a General cost function. The hypothesis of common technological parameters is rejected, suggesting caution in pooling samples when studying multiproduct firms.

Keywords: Multiproduct technologies; Poolability; General cost function; Water utilities
JEL codes: C52; C81; D24; L95

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1. Introduction

The empirical literature studying the cost structure of firms initially focussed on single product-single stage technologies (Christensen and Greene, 1976, for electricity generation). In subsequent developments, the cost function was allowed to accommodate for multiple outputs (Shin and Ying, 1992), in order to investigate the presence and the extent of *multi-product* (or horizontal) scope economies, or for multiple production stages, with the aim of measuring *multi-stage* (or vertical) scope economies (Kaserman and Mayo, 1991). Finally, starting from the seminal work of Ivaldi and McCullough (2001), who estimated in the context of the US railways industry a cost function with three outputs at the downstream stage and one output at the upstream stage, scholars are now refining methodologies capable to infer simultaneously on the presence of both scope and vertical integration economies.

The above cited studies addressed important policy issues, such as the optimal organization of network industries (for example, suggesting the breakdown of State-owned monopolies in order to promote more competition, or the deverticalization of the industry to contrast the dominant position of incumbents). To that respect, the use of an integrated approach is very useful, but it relies on the assumption that a common technology exists across stage of production and, for each stage, across different products. Rather surprisingly, but similarly to what happens in other areas of empirical analysis, the issue of poolability has been largely unexplored in the literature. Electric utilities who are only active in the generation phase have been supposed to have the same production function of vertically integrated firms and pure distributors. Similarly, multi-utilities active in different combinations in the gas, electricity and water sectors have been have been hypothesized to share the same technology. In this paper we test the appropriateness of the poolability assumption by using a sample of data on the English and Welsh water and sewerage sector over the period 1995-2005, which includes both the ten large water and sewerage companies (WASCs) and all the smaller water only companies (WOCs). From a methodological point of view, we estimate the *General* specification of the *Composite* cost function model firstly introduced by Pulley and Braunstein (1992). The latter has been widely cited (but rarely used as yet) and recognized as particularly suitable for the analysis of multi-output firms (Piacenza and Vannoni, 2004).

2. Methodology

Let us assume the following *General* cost function specification (PB$_G$):

$$c(y;p)^{(\phi)} = \left\{ \exp\left[\begin{pmatrix} \alpha_{WA} + \alpha_{WO} + \sum_i \alpha_{i_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} + \sum_i \alpha_{i_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} + \frac{1}{2}\sum_i\sum_j \alpha_{ij_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} y_{j_{WA}}{}^{(\pi_{WA})} + \\ \frac{1}{2}\sum_i\sum_j \alpha_{ij_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} y_{j_{WO}}{}^{(\pi_{WO})} + \sum_i\sum_r \delta_{ir_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} \ln p_r + \sum_i\sum_r \delta_{ir_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} \ln p_r \end{pmatrix}^{(\tau)} \right] \right.$$

$$\left. \cdot \exp\left[\sum_r \beta_{r_{WA}} \ln p_{r_{WA}} + \sum_r \beta_{r_{WO}} \ln p_{r_{WO}} + \frac{1}{2}\sum_r\sum_l \beta_{rl_{WA}} \ln p_{r_{WA}} \ln p_{l_{WA}} + \frac{1}{2}\sum_r\sum_l \beta_{rl_{WO}} \ln p_{r_{WO}} \ln p_{l_{WO}} \right] \right\}^{(\phi)} \quad [1]$$

where $c(y;\, p)$ is the long-run cost of production, y_i and p_r refer to outputs and factor prices, *WA* and *WO* are two types of firms in which the sample has been partitioned ($y_{i_{WA}}$ and $p_{r_{WA}}$ record the values of the i^{th} output and of the price of the r^{th} input for WASCs and are zero for WOCs), and the superscripts in parentheses ϕ, π_{WA}, π_{WO} and τ represent Box-Cox transformations[1].

By applying the *Shephard's Lemma*, one can easily obtain the associated input cost-share equations:

$$S_r = \begin{bmatrix} \alpha_{WA} + \alpha_{WO} + \sum_i \alpha_{i_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} + \sum_i \alpha_{i_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} + \frac{1}{2}\sum_i\sum_j \alpha_{ij_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} y_{j_{WA}}{}^{(\pi_{WA})} + \\ \frac{1}{2}\sum_i\sum_j \alpha_{ij_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} y_{j_{WO}}{}^{(\pi_{WO})} + \sum_i\sum_r \delta_{ir_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} \ln p_r + \sum_i\sum_r \delta_{ir_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} \ln p_r \end{bmatrix}^{\tau-1} \quad [2]$$

$$\cdot \left(\sum_i \delta_{ir_{WA}} y_{i_{WA}}{}^{(\pi_{WA})} + \sum_i \delta_{ir_{WO}} y_{i_{WO}}{}^{(\pi_{WO})} \right) + \beta_{r_{WA}} + \beta_{r_{WO}} + \sum_l \beta_{rl_{WA}} \ln p_{l_{WA}} + \sum_l \beta_{rl_{WO}} \ln p_{l_{WO}}$$

Equation [1] embraces several of the most commonly used cost functions. The *Generalized Translog* (GT) and the *Standard Translog* (ST) models can be easily obtained by imposing the restrictions ϕ = 0 and τ = 1 (and $\pi_{WA} = \pi_{WO} = 0$ for the ST model). The *Composite* specification (PB$_C$) is a nested model in which $\pi_{WA} = \pi_{WO} = 1$ and $\tau = 0$, while the *Separable Quadratic* (SQ) functional form requires the further restrictions $\delta_{ir} = 0$ for all i and r.

In this paper we estimate the system [1]-[2] and carry out LR tests to select the model best fitting observed data.[2] More interestingly, for the preferred model, the null hypothesis

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[1] $y_i^{(\pi_{WA})} = (y_i^{\pi_{WA}} - 1)/\pi_{WA}$ for $\pi_{WA} \neq 0$ and $y_i^{(\pi_{WA})} \to \ln y_i$ for $\pi_{WA} \to 0$.

[2] For technical details relative to the Composite cost function and for the selection procedure, see Piacenza and Vannoni (2004).

that there is a common parameter vector for *WA* and *WO* firms is tested again the alternative hypothesis that the parameters differ across sub-samples, by carrying out an LR test between a pooled specification versus an unrestricted one.

3. Data and estimation

Total costs (c) are the sum of labor, capital[3] and other input costs, a residual category which includes materials, energy, services, etc. Outputs are the Megalitres/day of water delivered (y_w) and the equivalent sewerage population (y_s). Productive factors are labor (L), capital (K) and other inputs (O). The price of labor (p_L) is given by the ratio of total employment expenses to the number of employees. The price of other inputs (p_O) is obtained by dividing residual expenses by the sum of the km of sewerage and water mains. The price of capital (p_K) has been calculated as the sum of the depreciation rate and the weighted average cost of capital.

All the specifications of the multi-output cost function are estimated jointly with the input cost-share equations via a non-linear GLS estimation (NLSUR). In our three-inputs case, to avoid singularity of the covariance matrix of residuals, only the equations for labor (S_L) and capital (S_K) were retained in the system. Before estimation, all variables were standardized on their respective sample average values.

The estimated ϕ = 0.12 τ = 0.08, π_{WA} = 0.47 and π_{WO} = 0.30 are in favor of the General Composite model PB_G.[4] Moreover, the hypothesis that the parameters are invariant to the type of firm is rejected, as one can realize by a close inspection at the estimates reported in the first two columns of table 1. Indeed, the $\chi^2_{(11)}$ statistic for the LR test (65.982) leads to retain the GENERAL SPECIFICATION.

The estimates of cost elasticities with respect to the water output are 0.40 for WASCs and 0.86 for WOCs, while the cost elasticity with respect to the sewerage output is 0.41. The estimated cost shares are 0.04 for labor and 0.87 for capital for WASCs (0.09 and 0.80 for WOCs). For the average WASCs firm, global scale economies ($SE(y;p) = 1/\sum_i \varepsilon_{cy_i}$) are 1.23, while $SC(y;p) =$ -0.27, highlighting that costs of diversified firms are higher than the

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[3] Capital costs have been computed as the product of the capital stock (the Modern Equivalent Asset estimation of replacement costs of net tangible assets as reported in the regulatory accounts) and the price of capital, and deflated using the UK Construction Output Price Index.

[4] The LR statistics lead to the rejection of the (nested) PB_C, GT, ST and SQ models. Results are available upon request.

sum of costs of two utilities specialised in the water and in the sewerage sector, respectively.[5] Tables 1 and 2 show that the results of the restricted model are qualitatively similar and point towards the presence of diseconomies of scope and weak increasing returns to scale. However, there are non trivial differences as far as the estimated cost shares and the measures of scale and scope economies are concerned. We have run also separate regressions for WASCs and WOCs[6]. In order to compare our results with the ones coming from other studies, see, among others, Saal *et al.* (2007) and Bottasso and Conti (2007).[7]

4. Conclusions

This paper analyses the cost structure of a sample of utilities active in the English and Welsh water and sewerage industry. From a methodological standpoint, we use the Composite cost function model, on the one hand, and we test the hypothesis that WASCs and WOCs share the same technology, on the other hand. The results confirm the merits of the PB-type cost functions and show for the average firm the existence of both aggregate scale economies and scope diseconomies. More interestingly, the hypothesis that the two groups share the same parameters is rejected.

While the pooling of specialized and (horizontally and/or vertically) diversified firms is a common practice in empirical investigations on cost and efficiency measurement of multi-product utilities, our simple exercise suggests a cautious approach which duly takes into account the possibility to investigate different functional forms and, for the preferred specification, to have a separate set of parameters for different sub-samples.

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[5] $SC(y;p) = \left[c(y_w,0;p) + c(0,y_s;p) - c(y_w,y_s;p)\right]/\,c(y_w,y_s;p)$.

[6] Since WOCs firms are only active in the water sector and are smaller than WASCs, the point of approximation at which scale and scope economies are computed refer to utilities of a smaller size for the former and of a larger size for the latter.

[7] The models have also been estimated including, as it is common in the literature, a set of control variables taking into account the firms' different operating conditions: the average pumping head, the proportion of water abstracted from rivers, the proportion of large users, the fraction of population receiving at least secondary sewage treatment. Furthermore, we included quality adjusted outputs too.

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Table 1. NLSUR estimates of the *General* cost function [1] for pooled and separated samples

Regressor[a]	POOLED SAMPLE (GENERAL SPECIFICATION)		POOLED SAMPLE (RESTRICTED SPECIFICATION)		WASC SAMPLE (WA)		WOC SAMPLE (WO)	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Box-Cox ϕ	0.119***	(0.024)	0.142***	(0.021)	-0.767***	(0.181)	0.009	(0.072)
Box-Cox π_{WA}	0.473	(1.144)	0.806***	(0.088)	0.800***	(0.097)		
Box-Cox π_{WO}	0.298**	(0.120)					-0.112**	(0.057)
Box-Cox τ	0.083	(0.111)	-0.155	(0.126)	-0.157	(1.652)	0.558***	(0.059)
Constant $_{WA}$	1.489***	(0.185)	1.334***	(0.057)	1.048***	(0.025)		
Constant $_{WO}$	1.746	(2.058)					1.008***	(0.024)
$y_{w\,WA}$	0.521**	(0.253)	0.650***	(0.121)	0.540***	(0.169)		
$y_{w\,WO}$	0.287***	(0.046)					0.963***	(0.032)
$y_{s\,WA}$	0.532***	(0.183)	0.593***	(0.080)	0.332**	(0.144)		
$y_w^2\,_{WA}$	0.071	(1.197)	0.035	(0.081)	-0.097	(0.677)		
$y_w^2\,_{WO}$	0.142***	(0.047)					0.463***	(0.032)
$y_s^2\,_{WA}$	-0.226	(0.833)	-0.308**	(0.150)	-0.475	(0.760)		
$y_w y_{s\,WA}$	0.252	(0.799)	0.284	(0.117)	0.312	(0.442)		
ln$p_{L\,WA}$	0.038***	(0.004)	0.039***	(0.002)	0.042***	(0.002)		
ln$p_{L\,WO}$	0.086***	(0.007)					0.074***	(0.002)
ln$p_{K\,WA}$	0.874***	(0.006)	0.875***	(0.003)	0.879***	(0.005)		
ln$p_{K\,WO}$	0.798***	(0.007)					0.794***	(0.002)
ln$p_L y_{w\,WA}$	0.008	(0.014)	0.007***	(0.001)	0.003	(0.007)		
ln$p_L y_{w\,WO}$	-0.001	(0.001)					-0.001*	(0.001)
ln$p_K y_{w\,WA}$	-0.025	(0.023)	-0.017***	(0.003)	-0.008	(0.018)		
ln$p_K y_{w\,WO}$	0.000	(0.001)					0.001	(0.001)
ln$p_L y_{s\,WA}$	-0.008	(0.014)	-0.008***	(0.001)	-0.006	(0.008)		
ln$p_K y_{s\,WA}$	0.026	(0.022)	0.018***	(0.003)	0.014	(0.016)		
lnp_Ll n$p_{K\,WA}$	-0.026**	(0.011)	-0.023***	(0.004)	-0.018*	(0.010)		
lnp_L ln$p_{K\,WO}$	-0.021***	(0.006)					-0.025***	(0.008)
lnp_L ln$p_{O\,WA}$	-0.003	(0.009)	-0.015***	(0.002)	-0.007	(0.008)		
lnp_L ln$p_{O\,WO}$	-0.028***	(0.003)					-0.028***	(0.004)
lnp_O ln $p_{K\,WA}$	-0.039***	(0.013)	-0.050***	(0.005)	-0.046**	(0.019)		
lnp_O ln$p_{K\,WO}$	-0.047***	(0.006)					-0.039***	(0.006)
Observations	240		240		96		144	
System Log-likelihood	1858.670		1825.679		754.931		1142.212	
McElroy system R^2	0.997		0.997		0.942		0.951	

[a] Dependent variable: c = total cost of production. Levels of significance:***1%;**5%;*10%.

Table 2. Cost properties estimates for pooled and separated samples (at the average values for outputs and input prices)

	POOLED SAMPLE (GENERAL SPECIFICATION)	POOLED SAMPLE (RESTRICTED SPECIFICATION)	WASC SAMPLE (WA)	WOC SAMPLE (WO)
Output elasticity				
$\varepsilon_{w\ WA}$	0.40	0.47	0.51	
$\varepsilon_{w\ WO}$	0.86			0.96
$\varepsilon_{s\ WA}$	0.41	0.42	0.31	
Economies of scale (SE) and scope (SC)				
$SE_{w,s\ WA}$	1.23	1.12	1.21	
$SE_{w\ WO}$	1.16			1.04
$SC_{w,s}$	-0.27	-0.34	-0.53	
Input cost-shares				
$S_{L\ WA}$	0.04	0.04	0.04	
$S_{L\ WO}$	0.09			0.07
$S_{K\ WA}$	0.87	0.88	0.88	
$S_{K\ WO}$	0.80			0.79