Quantonomics

QUANTITATIVE ECONOMICS

Australia Post's Delivery Centre Cost Elasticities

Report prepared for Australia Post

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Executive Summary

Australia Post has requested Quantonomics to produce updated estimates of its cost elasticities for Delivery Centres (DCs). Cost elasticities measure the percentage change in costs in response to a one per cent change in output. They provide information on the likely effects of declining mail volumes and declining mail density on Australia Post's future costs.

Cost elasticities are estimated by the econometric analysis of costs. The methodology used in this report is consistent with that used in the last study of Australia Post's cost elasticities, by Economic Insights (2018). The present study is based on a considerable amount of additional data, which is combined with the data used by Economic Insights in the previous study. Whilst Economic Insights' 2018 study also separately estimated cost elasticities for Australia Post's Mail Centres (MCs), this report covers only DCs.

Economic Insights (2018) notes that delivery accounts for around 62 per cent of Australia Post's reserved service costs, so the likely effects of output trends on DC costs have a substantial bearing on Australia Post's overall reserved services costs.

The 2018 study of DC costs used 52 months of data, from July 2012 to October 2016, for each of 114 DCs; amounting to 5,928 observations in total. For this study, Australia Post provided additional data for the 56 months from November 2016 to June 2021. This data has complete records for 94 DCs and 5,264 additional observations overall. Combining this with the previous data, the full sample has 11,192 observations. This is an unbalanced panel because not all of the DCs in the first half of the sample period are present in the data for the second half of the period and vice versa. The main results we present are based on a subset of this data which is a balanced panel over the full nine-year period from July 2012 to June 2021. This balanced panel has 92 DCs and 9,936 observations.

DCs are taken to have three key outputs: the number of articles delivered, the number of delivery points serviced and the distance travelled on delivery rounds. The elasticity of *total* DC cost with respect to a proportionate increase in all three outputs is 0.67. The elasticity of *variable* DC cost with respect to a proportionate increase in all three outputs is 0.50. Despite the data sample used in this study being almost twice the size of that used in the 2018 study, these estimates for the elasticities of total cost and variable cost with respect to total output are very close to the estimates obtained in the previous study.

When the three outputs move in different directions—which has been the case for more than a decade—we need to look at the output elasticities individually. The total cost elasticity for articles delivered is estimated to be 0.10, for points serviced is 0.24 and for distance travelled on rounds is 0.33. The elasticity of variable cost with respect to articles delivered is estimated to be 0.08, for points serviced is 0.05 and for distance travelled on rounds is 0.36.

Over the last decade, the number of articles delivered has fallen rapidly, whereas the number of points and the aggregate distance travelled in delivering articles, have both increased steadily. Since the elasticities of total cost with respect to points serviced and distance travelled are larger than the cost elasticity of articles, the combination of these trends means that cost increases remain likely even with a decline in the number of articles delivered. The same point applies to variable costs. The elasticity estimates suggest that, for both variable cost and total cost functions, the effect on cost of decreases in the quantity of articles delivered is likely to be offset, or more than offset, by the effects of increases in delivery points and delivery distances (depending on the rates of decline and increase respectively).

1 Introduction

1.1 Scope and purpose

The Australian Competition and Consumer Commission (ACCC) currently has a price monitoring declaration covering certain core services of Australia Post, including reserved ordinary letters (eg, the basic postage rate) but not covering bulk business letter services. Although the ACCC does not have a role of approving price increases of reserved services, if Australia Post intends to increase the price of a covered letter service or introduce a new covered letter service, it must notify the ACCC in advance. The ACCC then indicates whether or not it objects to the proposed price increase. Australia Post intends to make a submission to the ACCC in 2022 for prices that would apply from January 2023.

Australia Post has requested Quantonomics to produce updated estimates of its cost elasticities for Delivery Centres (DCs). This analysis uses the same methodology as that developed previously by Economic Insights (2014, 2015, 2018), and builds on the data used in those studies. These previous studies also separately estimated cost elasticities for Australia Post's Mail Centres (MCs). This report covers only DCs.

Cost elasticities measure the percentage change in costs in response to a one per cent change in a given output, or the overall level of output. A cost elasticity of one indicates that costs change by the same percentage as output, while a cost elasticity of zero indicates that costs are independent of output changes. The elasticities of cost with respect to individual outputs provide important information on how a business's costs change as its outputs change. Australia Post's postal volumes, especially domestic letters, have been falling at a significant annual rate, whereas the number of delivery points it services is growing broadly in line with population. Cost elasticities provide a means for estimating the likely effect of movements in outputs on costs. As with the previous cost elasticity studies, this study estimates cost elasticities for both total cost and variable cost, which essentially correspond to long-run and short-run elasticities respectively.

When assessing the scope for cost reduction in the face of declining mail volumes, it is important to use cost elasticities that reflect the business's own characteristics and its current circumstances rather than drawing on overseas results that may bear little resemblance to the business's operating environment. Cost elasticities are likely to be influenced by the operating environment of the business. For example, in postal services population density is likely to be an important influence on the share of the business's fixed costs and, hence, on its ability to reduce costs as volumes decline. Postal services operating in countries with high population densities are more likely to be able to combine rounds and achieve other economies as volumes decline than postal services with lower population densities.

Economic Insights (2018) indicated that DCs accounted for approximately 62 per cent of Australia Post's operational costs. Hence, the results of this study are representative of a substantial part of Australia Post's direct costs.

1.2 Previous studies of Australia Post Cost Elasticities

Economic Insights carried out studies of Australia Post's cost elasticities in 2014 and 2015 and 2018. These studies estimated total cost and variable cost functions for monthly panel data on Australia Post's DCs (and, separately for MCs, although these are not covered in this study). They obtained estimates of total cost output elasticities and variable cost output elasticities. Elasticities for total cost are long-run cost elasticities, whereas elasticities for variable cost are short-run and partial (ie, only relating to a subset of all costs) elasticities. Table 1.1 presents a summary of the cost elasticity estimates for DCs obtained in those studies.

Over the series of studies, the data sample sizes increased considerably. In addition, there were structural changes within Australia Post between the studies. Consolidation of DC operations reduced the number of DCs for which comparable data were available from 125 in Economic Insights' 2014 and 2015 studies, to 114 in the 2018 study. Another relevant structural change is the secular decline in postal volumes starting in 2008. Between 2007–08 and 2020–21 the number of mail articles delivered fell by 50 per cent (Australia Post 2010, 2021). These sample changes and structural operational changes mean that cost elasticity estimates will vary between studies conducted at different times.

Table 1.1 DC Cost Elasticity Estimates of Previous Studies

Year of study	*Total cost*	*Var. cost*	*Obs.*
2014	0.76	0.58	2,000
2015	0.51	0.36	3,625
2018	0.66	0.53	5,928

1.3 Data used in this study

The data used in this study covers delivery activities, delivery centre costs and assets. The specific variables used are described in section 2. In preparing this update to the analysis of cost elasticities for DCs in Economic Insights (2018), Australia Post was able to supply us with monthly data for the period after that included in the previous study. The data sample used in the 2018 study was from July 2012 to October 2016 for 114 DCs and with 5,928 observations (as indicated in Table 1.1). For this study, Australia Post provided additional data for the 56 months from November 2016 to June 2021. This data has complete records for 94 DCs and 5,264 additional observations overall. The full unbalanced sample has 11,192 observations. The main results we present are based on a subset of this data which is a balanced panel over the full nine-year period from July 2012 to June 2021. This balanced panel has 92 DCs and 9,936 observations. The DCs included in each of the two sub-samples, and overall, are listed in Appendix A.

1.4 Outline

Section 2 describes the data compiled, and the definitions of the variables used in this study. It also explains the econometric cost function methodologies used in this study. Section 3 presents econometric cost function estimates for Australia Post's delivery centres. Section 4 discusses the main findings.

1.5 Quantonomics' experience

Quantonomics provides consulting services in the fields of economic and regulatory policy, quantitative economic analysis and pricing in infrastructure industries, especially the water, energy, telecommunications and transport industries, and quantitative analysis in competition law applications. Quantonomics was established in 2013 to provide high quality and robust quantitative analysis to support decision-making by Australia's infrastructure regulators, regulated infrastructure businesses and competition authorities.

2 Measurement and Methodology

This section explains the methods used to estimate cost elasticities in this report. Section 2.1 describes the data provided by Australia Post for this study. Section 2.2 discusses the outputs and inputs and the associated costs and their calculation. Section 2.3 sets out formally the specifications of the cost functions estimated using econometric methods in this study. Lastly, section 2.4 explains how the cost elasticities obtained from the econometric models can be used to forecast DC costs over the short-run and the long-run, given forecasts for the rates of change of DC outputs.

For the preceding study (Economic Insights 2018), Australia Post provided monthly data for 125 urban DCs for the period July 2012 to October 2016. Given that some of the DCs were amalgamated or otherwise restructured during this period, it was only possible to compile data for 114 of the DCs. The resulting dataset comprised a total of 5,928 observations. The study did not use data for the period from November 2016 to December 2017, as this period was affected by certain structural changes, in particular, more processing was done at MCs. In the current study we use data extending over a longer period to explicitly allow for structural changes within the econometric analysis, an approach made feasible by the longer time series.

2.1 Delivery Centre Data

For this study, Australia Post provided detailed monthly output and cost data by DC facility for:

- Rounds, points serviced, and articles delivered by facility,
- Trading expenditure and staff costs per facility,
- Full-time equivalents (FTE) by facility, and
- Assets by facility and by asset.

All of this data was available over the period November 2016 to June 2021. This data was used in conjunction with data previously collected by Economic Insights.

Rural and remote DCs were excluded from the analysis, as they tend to have quite different characteristics from urban DCs. Rural and remote DCs are typically smaller, run in conjunction with post offices and more dependent on use of contractors. Compared to urban DCs, they deliver fewer items over longer distances. The urban DCs included in the analysis cover approximately 80 per cent of delivery activity nationally. The smaller number of DCs available for the period from November 2016 to June 2021 partly reflects some consolidation of operations into fewer DCs. The 114 DCs included for the period up to October 2016, and the 94 DCs included for the period from November 2016, are listed in Appendix A.

The output and cost data used in the analysis excludes deliveries by contractors. Instead, it focuses on mail delivery on daily rounds, generally undertaken by motorbike, cycle or on foot. Small parcels and non-reserved letters delivered on normal rounds are included in the analysis. Delivery costs account for approximately 60 per cent of overall reserved service operational costs. The results from the analysis will thus be representative of reserved service delivery costs.

Extensive data validation and cleaning has been carried out prior to model estimation. Output data has required few corrections and some labour cost observations appeared to be outliers requiring correction. More outliers were found for Other Non-capital costs and these have generally been adjusted by averaging of values on either side of the outlier observation.

2.2 Outputs and Inputs

2.2.1 Outputs

While Australia Post is not paid per delivery point or kilometre, the inclusion of the number of delivery points and distance covered as output variables captures an important function Australia Post is required to perform. There are numerous precedents in econometric analyses of other network industries, such as electricity, gas and water distribution, where volume supplied, number of customers and distance covered are often the first three output variables specified to capture the range of functional outputs and also differences in density across firms (or data points). In this case, differences in density relate to both mail density (ie, articles per customer) and customer density (ie, customers per round kilometre). The Australian Energy Regulator (AER 2021) uses a broadly analogous output specification to measure electricity distribution performance.

This study follows the specifications and methodologies in Economic Insights (2018). There are three outputs for which data is collected monthly by DC:

(a) Number of articles delivered,

(b) Number of points serviced,

(c) Distance travelled on rounds (km).

Australia Post's output reporting is generally on an average per work day basis. We converted this to monthly totals based on the number of working days per month for our analysis.

2.2.2 Non-capital Input Costs

Non-capital input costs of DCs are labour costs and other non-capital costs. Nominal labour cost includes directly employed staff labour costs (including oncosts), contract labour and staff-associated costs. Other non-capital costs of DC are the remaining non-capital costs making up trading expenditure (excluding notional expenses). They include carriage of mails and parcels, accommodation, goods and services for expenses, franchising expenses, and other non-labour expenses. Notional expenses (such as depreciation) are excluded to avoid double counting with capital costs.

A price index for non-capital inputs was constructed using separate price indexes for labour and other non-capital inputs. An Australia Post-specific labour price index was formed based on scheduled wage increases included in Australia Post's Enterprise Bargaining Agreements (EBA). Following Economic Insights (2018), the consumer price index (CPI) is used as the price index associated with other costs.

2.2.3 Capital Input Costs

Detailed data was provided by Australia Post for individual assets relating to each DC. These were classified into 13 asset groups and, under them, more detailed asset classes. The asset groups include 12 categories of plant and equipment (P&E) and buildings. Asset data supplied for each asset included:

- Asset code,
- Acquisition date (ie, date of capitalisation),
- Acquisition value,
- Accumulated depreciation, and
- Book value.

This data was provided based on asset registers at the end of each financial year from 2017 to 2021. Duplicate asset records were removed so that only the earliest record was kept for each asset.

For each asset class there is an expected asset life, based on those used by Economic Insights (2018), supplemented as needed. These expected lives are mapped onto the assets within each asset class. Together with the acquisition date, the expected asset life is used to determine the relevant period for calculating the annualised cost of each asset over its life. Real annuities are calculated for each asset, for each period, in accordance with the method set out below. In the final analysis, these real annuities are aggregated into a single capital input measure for each DC.

2.2.4 Capital annuity calculation

Capital input in each period is measured by a real annuity calculated separately for individual assets within each DC. The quantity of capital input in each year, as measured by the real annuity value, is then aggregated over relevant asset categories to obtain a capital input measure for each DC.

The key input data for a given asset category are:

(a) Acquisition value (*AcVal*),

(b) Acquisition date (*AcDate*),

(c) Average expected asset life (*ExpLife*).[1]

Acquisition value is converted into real terms (*RealAcVal*):

$$RealAcVal_s = AcVal_s \div CPI_{AcDate_s}, \tag{2.1}$$

where $CPI = 1.0$ in March 2022. The CPI index value is linked to the acquisition date of the asset, rather than to period *s*.

The monthly real annuity is then calculated for each asset category in each period, *s*, using an assumed depreciation rate equal to the real interest rate of $r = 0.07$. The annuity formula is:

$$RealAnnuity_s = RealAcVal_s \times \left[\frac{r}{1-(1+r)^{-ExpLife}}\right] \div 12 \tag{2.2}$$

The term in parentheses is constant within each asset category. After the period of the assets' assumed life, defined by the assets' *AcDate* + *ExpLife*, the annuity cost ceases (ie, is zero). For each monthly period, the real annuities are aggregated over the relevant asset categories and the result represents the real user cost of capital, which is the measure of capital input for that period.

2.2.5 Total cost and variable cost

As discussed in section 2.3, there are two kinds of cost function total cost (TC) and variable cost (VC). In each case the cost is measured in real terms, so that input prices are not explicitly included as explanatory variables.

Total cost is defined as:

$$TC = (LabourCost + OtherCost + RealAnnuity \times CPI) \div TIPI, \tag{2.3}$$

where $LabourCost$ refers to nominal labour cost, $OtherCost$ is other non-capital costs, and *RealAnnuity* is defined in equation (2.2). *TIPI* refers to the total input price index, which comprises the Australia Post-specific labour price index, with a weight of 0.78, and the CPI with a. weight of 0.22.

Variable cost is defined as:

$$VC = (LabourCost + OtherCost) \div VIPI, \tag{2.4}$$

[1] Expected lives were calculated as weighted averages of the expected lives of more detailed asset types within each of the 13 asset categories.

where *VIPI* refers to the variable input price index, which comprises the Australia Post-specific labour price index, with a weight of 0.80, and the CPI with a weight of 0.20. These weights are those previously used by Economic Insights (2018).

2.3 Econometric method

The primary econometric specification uses a translog (TL) functional form for the cost function and includes fixed effects (or indicator variables) for months to control for seasonal effects in the data. The estimation method is adjusted for serial correlation and standard errors are panel-corrected.

TC is a function of the three outputs. VC is a function of the three and also a single aggregate capital stock measure for each DC in each period. Treating capital inputs as fixed, and hence as exogenous, is suitable for examining the short-run effects of a change in outputs on variable costs.

An important aspect of the method is that, rather than including input prices within the econometric specification, an input price index is first calculated. This input index is based on fixed weights representing sample mean cost shares of each input, and the measure of cost is divided by this index. This simplifies the translog cost functions considerably. The specifications of these input price indexes have been explained.

The specification of the TC model is as follows. Denote the log of real total cost as rtc, and the log outputs as y_m for outputs $m = (1 \dots 3)$.[2] Subscript $i = (1 \dots I)$ denotes the panel categories (ie, the DCs); and subscript $s = (1 \dots S)$ indicates the (monthly) periods. Let variable z represent the year, and D_k are dummy variables $k = (1 \dots K)$ used to introduce fixed effects. There are 11 dummy variables for fixed monthly effects (hence, $K = 11$). Using this notation, the translog TC model is represented by:

$$rtc_{(is)} = \alpha_0 + \sum_{m=1}^{M} \beta_m y_{m(is)} + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{M} \beta_{mn} y_{m(is)} y_{n(is)} + \lambda_0 z_s \qquad (2.5)$$

$$+0.5\lambda_1 z_s^2 + \sum_{m=1}^{M} \phi_m y_{m(is)} z_i + \sum_{k=1}^{K} \psi_k D_{k(is)} + v_{(is)}$$

where $v_{(is)}$ is a random disturbance, and remaining Greek letters represent parameters to be estimated.

[2] Note that all log output variables are centred (by subtracting their mean values) so that the coefficients on the main effects (i.e. β_m for output m) can be interpreted as the elasticity of cost with respect to that output at the sample mean values of the independent variables.

The translog VC model is specified as follows:

$$rvc_{(is)} = \alpha_0 + \sum_{m=1}^{M} \beta_m y_{m(is)} + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{M} \beta_{mn} y_{m(is)} y_{n(is)} + \lambda_0 z_s \tag{2.6}$$

$$+\lambda_1 z_s^2 + \sum_{m=1}^{M} \phi_m y_{m(is)} z_i + \theta_0 x_{(is)} + 0.5\theta_1 x_{(is)}^2 + \sum_{m=1}^{M} \mu_m y_{m(is)} x_{(is)}$$

$$+\theta_2 x_{(is)} z_i + \textstyle\sum_{k=1}^{K} \psi_k D_{k(is)} + v_{(is)},$$

where the log of real variable cost is denoted as rvc and the log capital input is x.

In estimating these models, the hypothesis that the coefficients on the higher-order terms which distinguish the translog from the Cobb-Douglas specification are jointly equal to zero is tested.

2.4 Using the Estimates

The model can be used to estimate the rate of change in real total cost outside the sample period under different assumptions (or forecasts) for the rates of change of the outputs. As a first approximation:[3]

$$\Delta rtc = \sum_{m=1}^{M} \hat{\beta}_m \, g_m + \hat{\lambda}_0, \tag{2.7}$$

where g_m is the growth rate of output m and $\hat{\lambda}_0$ is the negative of the average rate of technical change, and $\hat{\beta}_m$ is the estimated output elasticity of output m. If all outputs increased common rate, g, then equation (2.11) can be simplified to: $\Delta rtc = \hat{\eta} g + \hat{\lambda}_0$, where $\hat{\eta} = \sum_{m=1}^{M} \hat{\beta}_m$ is the total of the output elasticities. This calculation was carried out in the previous study.

To forecast nominal total cost it is necessary to take into account movements in the input price index which was used to derive real total cost. The rate of change in the input price index (Δipi) is equal to the weighted average of the rates of change of the labour price index (Δlpi) and the CPI (Δcpi), where the fixed weights representing average cost shares mentioned above. Hence, $\Delta ipi = cs_L \Delta lpi + (1 - cs_L) \Delta cpi$, where cs_L is the fixed cost share of labour. It follows that forecast changes in total cost are given by:

$$\Delta tc = \Delta rtc + \Delta ipi \tag{2.8}$$

[3] Δ represents the difference between two successive time periods. For variables that are in logs, the difference between periods represents the growth rate.

$$= \sum_{m=1}^{M} \hat{\beta}_m \, g_m + \hat{\lambda}_0 + cs_L \Delta lpi + (1 - cs_L) \Delta cpi$$

This formula can be used to forecast total DC cost in response to forecast rates of change in outputs, the CPI and the labour price index. The same approach can used to forecast the rate of change in nominal variable costs in response to the same cost drivers (but with a different sum of output elasticities and different cost share weights).

3 Econometric Results

This section presents econometric results using a balanced panel of 92 DCs for the nine-year period from July 2012 to June 2021. There are 108 monthly observations for each DC and, and 9,936 observations overall.

Appendix B presents estimates derived using a slightly larger unbalanced panel of DCs over the same period. It also shows models using the balanced panel, but after correcting for the most severe outliers on the assumption that they are erroneous data points. The results presented in Appendix B under slightly different samples or treatment of outliers assist in interpreting the main results presented in this section.

The estimation method used for all of the models is generalised least squares (GLS).[4] The variance is assumed to differ for each panel (ie, each DC); that is, heteroscedasticity across panels. It is also assumed that there is first-order autocorrelation of disturbances within panels. The serial correlation parameter is common across all panels. The assumptions relating to the stochastic structure of the model are similar to those used by Economic Insights (2018).

3.1 Econometric results for the total cost function for DCs

This section presents estimation results for the model defined in equation (2.5). In addition to the full model, a simpler version is also estimated which does not include the time trend effects incorporated in the variable representing years. This simpler model was Economic Insights' preferred specification in its 2018 study.

The econometric results for the total cost function are reported in Table 3.1, where we observe that the majority of estimated coefficients have t-ratios in excess of 1.96, indicating that they are statistically different from zero at the five percent level of significance. The first three rows of the table show the estimated main effects of each of the three outputs on total cost. Since the dependent variable is the log of total cost, and the output variables are also in log form, and because the output variables have been centred about their sample mean values, the coefficients on the output variables represent the elasticity of total cost with respect to each output, evaluated at the sample mean.

Table 3.1 also shows the sum of the three elasticities of total cost with respect to the individual outputs, and the associated standard error and t-statistic. This represents the elasticity of total cost with respect total output; that is, to a proportionate increase in all outputs. In the model without trend variables, the elasticity of total cost to total output is estimated to be 0.67. In the model with time trend variables, the elasticity is also 0.67. The elasticity of total cost to total output is a long-run elasticity, because it includes the full adjustment of capital costs, which are fixed in the short-run.

[4] The Stata *xtgls* routine is used (Stata 2009:153–162).

Table 3.1: Econometric results for the DC total cost function (full balanced panel)

	TL model without trend variables			*TL model with trend variables*		
Variable	**Coef.**	**SE**	**t-stat**	**Coef.**	**SE**	**t-stat**
ART	0.099	0.006	16.220	0.099	0.007	14.250
PTS	0.238	0.011	22.590	0.232	0.011	21.440
DIS	0.328	0.009	37.500	0.335	0.009	37.900
MO1	-0.107	0.003	-33.890	-0.105	0.003	-32.130
MO2	-0.119	0.004	-29.130	-0.116	0.004	-27.530
MO3	-0.070	0.005	-15.560	-0.069	0.005	-14.950
MO4	-0.095	0.005	-19.590	-0.094	0.005	-18.940
MO5	-0.071	0.005	-13.940	-0.067	0.005	-13.170
MO6	-0.079	0.005	-15.510	-0.078	0.005	-15.160
MO7	-0.082	0.005	-16.250	-0.080	0.005	-15.860
MO8	-0.081	0.005	-16.710	-0.080	0.005	-16.390
MO9	-0.090	0.005	-20.070	-0.089	0.004	-19.840
MO10	-0.069	0.004	-17.350	-0.067	0.004	-16.860
MO11	-0.077	0.003	-25.690	-0.075	0.003	-24.890
ART*ART	0.047	0.014	3.250	0.025	0.019	1.370
ART*PTS	0.096	0.019	5.080	0.044	0.023	1.920
ART*DIS	-0.103	0.014	-7.540	-0.057	0.016	-3.550
PTS*PTS	0.023	0.045	0.510	0.179	0.048	3.740
PTS*DIS	0.092	0.029	3.180	0.032	0.031	1.030
DIS*DIS	0.117	0.022	5.250	0.132	0.023	5.870
Y				0.048	0.015	3.180
Y*Y				-0.003	0.001	-3.230
Y*ART				-0.008	0.003	-2.810
Y*PTS				-0.031	0.004	-7.250
Y*DIS				0.023	0.004	6.530
CONSTANT	12.886	0.005	2442.270	13.275	0.122	108.380
Total output elasticity	0.665	0.006	110.250	0.666	0.006	110.430

We now discuss the first-order coefficients of the three output variables. In both of the TL models (with and without trend variables), all three output coefficients have the expected positive signs, implying that extra output incurs extra costs. The estimated coefficients on each output are similar between the two models, and it is sufficient to discuss the model without trend variables. The coefficient on the ART output is 0.10, implying that a 1 per cent increase in articles delivered will lead to a 0.1 per cent increase in costs (all else held constant), at the sample mean. The corresponding coefficients of PTS and DIS, are 0.24 and 0.33, respectively, implying that DC total costs are affected more by changes in the points and distance outputs than they are by changes in the articles output.[5] This finding is consistent with Economic Insights (2018).

The total elasticity measure of 0.099 + 0.238 + 0.328 = 0.665, implies that a 1 per cent increase in all outputs will lead to a 0.665 per cent increase in real costs. Equivalently, it implies that a 1 per cent *decrease* in all outputs should correspond to a 0.665 per cent *decrease* in real costs. This total elasticity estimate has an estimated standard error of 0.006, producing a 95 per cent confidence interval of (0.653, 0.676).

Although the data sample used to produce this estimate is almost twice the size of the sample used in the 2018 study, the estimated total cost elasticity is essentially the same as that found the previous study (0.66).

Since the number of articles handled by Australia Post has declined substantially over most of the period studied, whereas the number of delivery points and distance have been increasing, the three output elasticities really need to be considered individually. The findings show that a decline in articles delivered has a smaller effect on total cost than an increase of equivalent size in either network points or in delivery distances.

The number of articles delivered by Australia Post peaked in 2007-08 at 5.6 billion articles (Australia Post 2010:113) and has since declined to 2.8 billion articles in 2019-20 (Australia Post 2020:11). This translates to an average annual decline of 5.8 per cent. Combining this with the articles total cost elasticity of 0.10, the long-run impact on Australia Post's annual real delivery costs would have been around –0.6 per cent per year.

Over this same 12-year period, the number of delivery points Australia Post is required to serve increased from 10.5 million in 2007-08 (Australia Post 2010:113) to 12.3 million in 2019–20 (Australia Post 2020:11). This translates to an average annual increase of 1.3 per cent. Combining this with the points total cost elasticity of 0.24, the implied long-run impact on Australia Post's annual real delivery costs would have been 0.3 per cent.

For the 92 DCs included in our balanced sample, the total distance travelled on rounds increased from 33.0 million km in 2012-13 to 46.5 million km in 2020-21. This represents an annual average growth rate of 4.3 per cent over this 8-year period. Since this is based only on a sample of DCs, and over a shorter period than the other cited growth rates, it is not certain that this rate of increase in delivery distance is representative for Australia Post as a whole over the last 12 years. Nevertheless, when combining it with the distance total cost elasticity of 0.33, the long-run impact on Australia Post's annual real delivery costs would have been around 1.4 per cent.

If we assume that the foregoing output growth rates and impacts on cost are representative for a comparable period of about the last decade, then the estimated impacts of the average rates

[5] As noted in Economic Insights (2015), more weight can be placed on the sum of these coefficients than on the individual coefficients due to possible multicollinearity resulting from correlation between the output variables.

of change in the outputs on total costs can be added together to obtain a combined impact. This is –0.6 + 0.3 + 1.4 = 1.1 per cent per annum. The effect on total cost of decreases in articles delivered is more than offset by the effects of increases in delivery points and delivery distances.

3.2 Econometric results for the variable cost function for DCs

The variable cost model in equation (2.6) is estimated using the same econometric methods used in the previous section. The econometric results for the variable cost function are reported in table 3.2. In the variable cost function, capital input is treated as a fixed factor and is included among the explanatory variables. In addition to the full model of equation (2.6), a simpler version is also estimated which does not include the time trend effects incorporated in the variable representing years. This simpler model specification was preferred by Economic Insights in its 2018 study.

We again observe that the majority of estimated coefficients have t-ratios in excess of 1.96, indicating that they are statistically different from zero at the five percent level of significance. The main effects for all three outputs in the first three rows of the table have the expected positive signs, implying that extra output incurs extra costs. As previously discussed, since the variables are in log form and the outputs are centred at their sample means, these coefficients on the output variables represent the elasticity of variable cost with respect to each output, evaluated at the sample means.

Table 3.2 also shows the sum of the three elasticities of variable cost with respect to the individual outputs, and the associated standard error and t-statistic. This represents the elasticity of variable cost with respect to total output; that is, to a proportionate increase in all outputs. In the model without trend variables, the elasticity of variable cost to total output is estimated to be 0.50. In the model with time trend variables, the elasticity is also 0.51. The elasticity of variable cost to total output is a short-run elasticity because it only includes the adjustment of variable costs to output changes and assumes that capital costs are fixed in the short-run.

Although the data sample used to produce these estimates is almost twice the size of the sample used in the 2018 study, the estimated variable cost elasticity is very close to that found the previous study (0.53).

In terms of the estimated elasticities of variable cost with respect each individual output, we see that the estimates obtained from the simpler model are very close to those obtained from the model with time trends included. Using the simpler model, the estimated coefficient of the ART output is 0.081, implying that a 1 per cent increase in articles delivered will lead to a 0.08 per cent increase in costs (all else held constant), at the sample mean. The corresponding coefficients of PTS and DIS are 0.053 and 0.364, respectively. The elasticity of variable cost with respect to PTS is much smaller than the elasticity of total cost with respect to PTS, implying that the effect of changes in this output on costs occur mainly over the long-run. The elasticity of variable cost with respect to DIS is similar to the elasticity of total cost with respect to DIS, implying that the effect of changes in this output on costs occur mainly in the short-run.

Table 3.2: Econometric results for the DC variable cost function (full unbalanced panel)

	TL model without trend variables			*TL model with trend variables*		
Variable	**Coef.**	**SE**	**t-stat**	**Coef.**	**SE**	**t-stat**
ART	0.081	0.006	13.090	0.083	0.007	11.890
PTS	0.053	0.012	4.290	0.056	0.013	4.450
DIS	0.364	0.009	39.230	0.366	0.009	39.180
MO1	-0.114	0.003	-36.290	-0.111	0.003	-33.660
MO2	-0.123	0.004	-30.350	-0.120	0.004	-28.420
MO3	-0.074	0.005	-16.380	-0.072	0.005	-15.550
MO4	-0.098	0.005	-20.100	-0.095	0.005	-19.240
MO5	-0.075	0.005	-14.840	-0.072	0.005	-13.950
MO6	-0.082	0.005	-16.130	-0.080	0.005	-15.630
MO7	-0.084	0.005	-16.720	-0.082	0.005	-16.180
MO8	-0.085	0.005	-17.420	-0.083	0.005	-16.950
MO9	-0.092	0.004	-20.620	-0.091	0.004	-20.310
MO10	-0.070	0.004	-17.980	-0.069	0.004	-17.410
MO11	-0.079	0.003	-26.870	-0.077	0.003	-26.050
CAP	0.181	0.008	23.370	0.178	0.008	23.050
ART*ART	0.068	0.014	4.880	0.056	0.018	3.130
ART*PTS	0.084	0.019	4.450	0.042	0.023	1.880
ART*DIS	-0.148	0.015	-10.170	-0.108	0.018	-6.080
PTS*PTS	-0.204	0.050	-4.090	-0.093	0.053	-1.730
PTS*DIS	0.104	0.029	3.530	0.070	0.031	2.230
DIS*DIS	0.266	0.026	10.360	0.253	0.026	9.700
CAP*CAP	0.194	0.011	17.290	0.195	0.011	17.220
CAP*ART	0.046	0.011	4.290	0.034	0.011	3.160
CAP*PTS	0.136	0.020	6.930	0.126	0.020	6.330
CAP*DIS	-0.183	0.014	-13.450	-0.165	0.014	-11.730
Y				0.079	0.016	4.970
Y*Y				-0.005	0.001	-5.070
Y*ART				-0.007	0.003	-2.300
Y*PTS				-0.025	0.004	-5.560
Y*DIS				0.019	0.004	5.030
CONSTANT	12.860	0.006	2177.890	13.515	0.130	104.010
Total output elasticity	0.499	0.009	57.810	0.505	0.009	58.370

The overall variable cost elasticity measure of 0.081 + 0.053 + 0.364 = 0.499, implies that a 1 per cent increase in all outputs will lead to a 0.499 per cent increase in real non-capital costs. Equivalently, it implies that a 1 per cent *decrease* in all outputs should correspond to a 0.499 per cent *decrease* in real costs. This combined elasticity estimate has an estimated standard error of 0.009, producing a 95 per cent confidence interval of (0.482, 0.515).

The first-order coefficient of the CAP variable has a value of 0.181 in the simpler of the two specifications and 0.178 in the model with time trends included. The positive coefficient on capital implies that capital and non-capital inputs are complements rather than substitutes in postal delivery operations. It should also be noted that capital has only a small share of total DC costs.

Since Australia Post's outputs do not change over time at similar rates, it is useful to use trend average rates of change in outputs to determine the implied changes over time in variable costs. Previously we noted that the number of articles delivered by Australia Post declined at an average annual rate of 5.8 per cent over the last 12 years. Over the same period, the number of delivery points Australia Post is required to serve increased at an average annual increase of 1.3 per cent. These trends are based on data from Australia Post's annual reports. The aggregate delivery distance has been estimated from our sample of DCs over eight years, to have increased at an average annual rate of 2.7 per cent per year.

Combining these growth rates with the variable cost elasticities of 0.081, 0.053 and 0.364 for articles, points and distance respectively we see that, firstly, the effect of the decline of articles delivered on variable costs is approximately $0.081 \times -5.8 = -0.5$ per cent on variable costs on average per year. Secondly, the effect of the growth of delivery points is $0.053 \times 1.3 = 0.1$ per cent on average per year. Third, the effect of the growth of distance is $0.364 \times 2.7 = 1.0$ per cent per year. Hence the combined effect of output changes on variable costs is estimated to be approximately 0.6 per cent per annum. The effect on variable cost of decreases in articles delivered is more than offset by the effects of increases in delivery points and delivery distances.

4 Conclusions

The current study provides updated cost elasticity estimates for Australia Post's delivery centre operations. The econometric results update those developed in Economic Insights (2018), using a much larger data set covering nine years from 2012-13 to 2020-21. The dataset used in this study is approximately double the size of that used in the previous study, which allows for improved precision of statistical estimates, and is more relevant to the conditions Australia Post currently faces. Using this data, estimates of the parameters of the total and variable cost functions for DCs are obtained using flexible functional forms and a GLS estimation method.

Despite the substantial change in the size of the data sample, the estimated elasticities of both total and variable costs with respect to all outputs, when combined, are very similar to the estimates obtained in the 2018 study. The elasticity of *total* DC cost for a proportionate increase in all three outputs is 0.67. The elasticity of *variable* DC cost for a proportionate increase in all three outputs is 0.50. Despite the data sample used in this study being almost twice the size of that used in the 2018 study, these estimates for the elasticities of total cost and of variable cost in relation to total output are very close to the estimates obtained in the previous study.

The study shows the effects of the divergent trends in Australia Post's outputs on its rate of change of variable cost and total cost. The main output trends are a strong decline in the quantity of articles delivered, alongside ongoing growth of the number of delivery points and the length of delivery distances. The elasticity estimates show that, for both variable cost and total cost functions, the effect on cost of decreases in the quantity of articles delivered is more than offset by the effects of increases in delivery points and delivery distances.

Appendix A: Included Delivery Centres

DC code	Delivery centre	Jul 2012 – Oct 2016	Nov 2016 – Jun 2021	Balanced
4	Frenchs Forrest DF	✓	✓	✓
5	Hornsby DC	✓	✓	✓
6	Ingleburn DF	✓	✓	✓
7	Kingsgrove DF	✓	✓	✓
8	Kirrawee DC	✓	✓	✓
9	Leightonfield DF	✓	✓	✓
10	Mitchell DF	✓	✓	✓
11	Nepean DF	✓	✓	✓
15	Seven Hills DF	✓	✓	✓
16	St Leonards DF	✓	✓	✓
17	Strathfield DC	✓	✓	✓
18	Taren Point DC	✓	✓	✓
19	Tuggeranong DC	✓	✓	✓
29	Albion DC	✓	✗	✗
30	Arundel DC	✓	✓	✓
31	Beaudesert DC	✓	✗	✗
32	Brendale DC	✓	✓	✓
33	Brisbane Cty DC	✓	✗	✗
34	Bundall DC	✓	✓	✓
35	Burleigh DC	✓	✓	✓
36	Burpengary DC	✓	✓	✓
37	Caboolture DC	✓	✓	✓
38	Caloundra DC	✓	✗	✗
41	Clontarf DC	✓	✓	✓
42	Coorparoo DC	✓	✓	✓
43	Ferny Hills DC	✓	✓	✓
44	Gympie DC	✓	✗	✗
47	Kenmore DC	✓	✓	✓
48	Logan City DC	✓	✓	✓
50	Mansfield DC	✓	✓	✓
51	Murwillumbah DC	✓	✗	✗
52	Nambour DC	✓	✗	✗
54	Noosaville DC	✓	✓	✓
55	Sandgate DC	✓	✗	✗
56	Stafford DC	✓	✓	✓
57	Tingalpa DC	✓	✓	✓
58	Toowong DC	✓	✓	✓

DC code	Delivery centre	Jul 2012 – Oct 2016	Nov 2016 – Jun 2021	Balanced
59	Tweed Heads South DC	✓	✓	✓
60	Virginia DC	✓	✓	✓
61	Yatala DC	✓	✓	✓
68	Adelaide City DC	✓	✓	✓
69	Darwin DC	✓	✓	✓
70	Edinburgh North DC	✓	✓	✓
71	Gawler DC	✓	✓	✓
72	Glynde DC	✓	✓	✓
73	Kent Town DC	✓	✓	✓
74	Lonsdale DC	✓	✓	✓
75	Marleston DC	✓	✓	✓
77	Melrose Park DC	✓	✓	✓
78	Modbury North DC	✓	✓	✓
79	Palmerston DC	✗	✓	✗
80	Port Adelaide DC	✓	✓	✓
81	Regency Park DC	✓	✓	✓
83	Somerton Park DC	✓	✓	✓
91	Burnie DC	✓	✗	✗
92	Devonport DC	✓	✗	✗
94	Kingston DC	✓	✓	✓
95	Launceston DC	✓	✗	✗
96	Ulverstone DC	✓	✗	✗
97	Western Shore DC	✓	✓	✓
104	Airport West DC	✓	✓	✓
105	Bacchus Marsh DC	✓	✗	✗
106	Bayswater DC	✓	✓	✓
107	Belgrave DC	✓	✓	✓
108	Bentleigh East DC	✓	✓	✓
109	Braeside DC	✓	✓	✓
110	Brighton DC	✓	✓	✓
111	Bundoora DC	✓	✓	✓
112	Burwood DC	✓	✓	✓
113	Cranbourne DC	✓	✓	✓
114	Dandenong DC	✓	✓	✓
115	Deepdene DC	✓	✓	✓
117	Epping DC	✓	✓	✓
118	Ferntree Gully DC	✓	✓	✓
120	Hawthorn DC	✓	✓	✓
122	Heidelberg West DC	✓	✗	✗

DC code	Delivery centre	Jul 2012 – Oct 2016	Nov 2016 – Jun 2021	Balanced
123	Hoppers Crossing DC	✓	✓	✓
124	Melton DC	✓	✓	✓
125	Moorabbin DC	✓	✓	✓
126	Mooroolbark DC	✓	✓	✓
127	Mornington DC	✓	✓	✓
128	Mount Waverley DC	✓	✓	✓
129	Narre Warren DC	✓	✓	✓
130	Nunawading DC	✓	✓	✓
131	Port Melbourne DC	✗	✓	✗
132	Preston DC vic	✓	✓	✓
133	Research DC	✓	✓	✓
134	Richmond DC	✓	✗	✗
135	Rosebud DC	✓	✓	✓
136	Seaford DC	✓	✓	✓
137	Somerton DC	✓	✓	✓
138	St Albans DC	✓	✓	✓
139	St Kilda DC	✓	✓	✓
140	Sunbury DC	✓	✓	✓
141	Templestowe DC	✓	✓	✓
150	Bassendean DC	✓	✓	✓
151	Bentley DC	✓	✓	✓
152	Bibra Lake DC	✓	✓	✓
153	Canning Vale DC	✓	✓	✓
154	Clarkson DCA	✓	✗	✗
156	Gwelup DC	✓	✓	✓
157	Joondalup DC	✓	✓	✓
158	Kelmscott DC	✓	✓	✓
159	Malaga DC	✓	✓	✓
160	Mandurah DC	✓	✗	✗
161	Midland DC	✓	✓	✓
162	Mundaring DC	✓	✗	✗
163	Nedlands DC	✓	✓	✓
164	Northam DC	✓	✗	✗
165	Osborne Park DC	✓	✓	✓
166	Palmyra DC	✓	✓	✓
168	Rockingham DC	✓	✗	✗
169	Walliston DC	✓	✗	✗
170	Wangara DC	✓	✓	✓
171	Welshpool DC	✓	✓	✓

DC code	Delivery centre	Jul 2012 – Oct 2016	Nov 2016 – Jun 2021	Balanced
172	West Leederville DC	✓	✕	✕

Appendix B: Further econometric models

This appendix presents the results of alternative models estimates. The models in section B.1 were estimated using the full unbalanced panel of data which has 114 DCs in the first half of the sample period and 94 in the second half. The models in section B.1 were estimated by identifying extreme outliers and replacing the dependent variable in those cases with estimates.

B.1 Full unbalanced panel

The models in this section are estimated with an unbalanced panel of 11,192 observations.

Table B.1: Econometric results for the DC total cost function (full unbalanced panel)

	TL model without trend variables			*TL model with trend variables*		
Variable	**Coef.**	**SE**	**t-stat**	**Coef.**	**t-stat**	
	0.114	0.006	19.880	0.103	0.006	16.220
PTS	0.306	0.010	30.850	0.296	0.010	28.770
DIS	0.305	0.008	37.910	0.317	0.008	38.520
MO1	-0.105	0.003	-34.660	-0.105	0.003	-32.930
MO2	-0.120	0.004	-30.620	-0.117	0.004	-28.840
MO3	-0.070	0.004	-15.940	-0.069	0.004	-15.430
MO4	-0.095	0.005	-20.110	-0.093	0.005	-19.540
MO5	-0.070	0.005	-14.260	-0.067	0.005	-13.540
MO6	-0.080	0.005	-16.130	-0.078	0.005	-15.810
MO7	-0.081	0.005	-16.730	-0.079	0.005	-16.210
MO8	-0.082	0.005	-17.540	-0.080	0.005	-17.080
MO9	-0.091	0.004	-20.870	-0.089	0.004	-20.610
MO10	-0.071	0.004	-18.650	-0.068	0.004	-17.860
MO11	-0.079	0.003	-27.470	-0.077	0.003	-26.760
ART*ART	0.082	0.013	6.180	0.054	0.017	3.230
ART*PTS	0.019	0.012	1.610	0.031	0.013	2.390
ART*DIS	-0.095	0.010	-9.740	-0.096	0.012	-7.860
PTS*PTS	0.132	0.018	7.510	0.071	0.019	3.670
PTS*DIS	-0.057	0.019	-2.930	0.004	0.023	0.160
DIS*DIS	0.284	0.018	15.720	0.246	0.019	12.910
Y				0.034	0.015	2.260
Y*Y				-0.002	0.001	-2.320
Y*ART				-0.004	0.003	-1.510
Y*PTS				-0.036	0.004	-10.320
Y*DIS				0.020	0.003	6.280
CONSTANT	12.886	0.005	2529.820	13.175	0.123	107.460
Total output elasticity	0.725	0.005	135.190	0.716	0.006	129.110

Table B.2: Econometric results for the DC variable cost function (full unbalanced panel)

	TL model without trend variables			*TL model with trend variables*		
Variable	**Coef.**	**SE**	**t-stat**	**Coef.**	**t-stat**	
ART	0.093	0.006	15.950	0.086	0.006	13.740
PTS	0.095	0.012	7.950	0.099	0.012	8.190
DIS	0.342	0.009	39.110	0.347	0.009	39.390
MO1	-0.111	0.003	-37.530	-0.109	0.003	-34.140
MO2	-0.124	0.004	-32.350	-0.120	0.004	-29.690
MO3	-0.072	0.004	-16.900	-0.071	0.004	-15.900
MO4	-0.096	0.005	-20.680	-0.093	0.005	-19.670
MO5	-0.074	0.005	-15.240	-0.070	0.005	-14.190
MO6	-0.082	0.005	-16.780	-0.080	0.005	-16.240
MO7	-0.083	0.005	-17.210	-0.080	0.005	-16.470
MO8	-0.084	0.005	-18.090	-0.081	0.005	-17.470
MO9	-0.092	0.004	-21.600	-0.090	0.004	-21.180
MO10	-0.071	0.004	-19.110	-0.069	0.004	-18.220
MO11	-0.080	0.003	-28.820	-0.078	0.003	-27.790
CAP	0.229	0.007	31.340	0.226	0.007	31.240
ART*ART	0.072	0.014	5.310	0.059	0.017	3.400
ART*PTS	0.007	0.012	0.590	0.006	0.014	0.450
ART*DIS	-0.107	0.011	-10.000	-0.089	0.013	-6.870
PTS*PTS	-0.038	0.017	-2.300	-0.060	0.017	-3.510
PTS*DIS	0.090	0.021	4.250	0.102	0.023	4.400
DIS*DIS	0.244	0.021	11.530	0.229	0.021	10.730
CAP*CAP	0.208	0.010	20.850	0.211	0.010	20.990
CAP*ART	0.053	0.009	5.990	0.031	0.009	3.360
CAP*PTS	-0.051	0.013	-3.990	-0.010	0.014	-0.730
CAP*DIS	-0.139	0.011	-12.560	-0.148	0.011	-13.270
Y				0.073	0.016	4.620
Y*Y				-0.005	0.001	-4.770
Y*ART				-0.005	0.003	-1.950
Y*PTS				-0.031	0.004	-8.440
Y*DIS				0.021	0.003	6.550
CONSTANT	12.876	0.006	2145.300	13.490	0.129	104.330
Total output elasticity	0.529	0.008	64.390	0.532	0.008	65.080

B.2 Full balanced panel with outlier corrections

The models in this section are estimated with the full *balanced* panel of 9,936 observations. After estimating the models presented in section 3, the inter-quartile range (IQR) of the residuals is calculated; ie, the difference between the upper quartile (or 75th percentile) and the lower quartile (or 25th percentile). A residual more than 4.5 × IQR above the upper quartile or less than 4.5 × IQR below the lower quartile is assumed to be due to a spurious observation on the dependent variable. For that observation, the predicted value of the dependent variable, obtained from the corresponding model in section 3 is substituted for the spurious observation.

Table B.3: Econometric results, DC total cost function (balanced panel with outlier correction)

	TL model without trend variables			*TL model with trend variables*		
Variable	**Coef.**	**SE**	**t-stat**	**Coef.**	**t-stat**	
ART	0.096	0.006	16.530	0.100	0.007	15.290
PTS	0.243	0.010	23.690	0.239	0.011	22.620
DIS	0.333	0.008	39.980	0.345	0.008	40.720
MO1	-0.107	0.003	-36.070	-0.103	0.003	-33.500
MO2	-0.120	0.004	-31.110	-0.115	0.004	-29.050
MO3	-0.072	0.004	-16.780	-0.068	0.004	-15.720
MO4	-0.096	0.005	-20.930	-0.093	0.005	-19.900
MO5	-0.071	0.005	-14.730	-0.066	0.005	-13.750
MO6	-0.081	0.005	-16.720	-0.077	0.005	-16.030
MO7	-0.082	0.005	-17.290	-0.081	0.005	-16.880
MO8	-0.082	0.005	-17.920	-0.081	0.005	-17.610
MO9	-0.092	0.004	-21.530	-0.089	0.004	-21.090
MO10	-0.069	0.004	-18.510	-0.067	0.004	-18.050
MO11	-0.076	0.003	-27.140	-0.075	0.003	-26.710
ART*ART	0.038	0.013	2.870	0.009	0.015	0.580
ART*PTS	0.110	0.017	6.360	0.060	0.020	3.000
ART*DIS	-0.114	0.013	-8.820	-0.057	0.015	-3.780
PTS*PTS	0.004	0.042	0.090	0.185	0.045	4.080
PTS*DIS	0.107	0.027	3.990	0.033	0.029	1.150
DIS*DIS	0.115	0.020	5.630	0.117	0.020	5.810
Y				0.057	0.015	3.880
Y*Y				-0.004	0.001	-4.020
Y*ART				-0.011	0.003	-4.300
Y*PTS				-0.031	0.004	-7.640
Y*DIS				0.024	0.003	7.310
CONSTANT	12.885	0.005	2475.340	13.352	0.119	112.140
Total output elasticity	0.671	0.006	108.710	0.684	0.006	112.180

The criterion for identifying outliers (ie, 4.5 × IQR above the upper quartile or below the lower quartile) is extremely strict, designed to identify only the most severe outliers highly likely to be due to spurious data. In the total cost models, 23 to 25 observations are identified as extreme outliers, or 0.23 to 0.25 per cent of the sample. In the variable cost model, 12 to 14 observations are identified as extreme outliers, or 0.12 to 0.14 per cent of the observations in the sample.

Table B.4: Econometric results, DC variable cost function (balanced panel & outlier correction)

	TL model without trend variables			*TL model with trend variables*		
Variable	**Coef.**	**SE**	**t-stat**	**Coef.**	**t-stat**	
ART	0.081	0.006	13.330	0.083	0.007	12.400
PTS	0.053	0.012	4.340	0.058	0.012	4.670
DIS	0.370	0.009	40.740	0.377	0.009	41.310
MO1	-0.112	0.003	-36.960	-0.109	0.003	-34.230
MO2	-0.122	0.004	-30.990	-0.118	0.004	-29.150
MO3	-0.074	0.004	-16.960	-0.072	0.004	-16.110
MO4	-0.097	0.005	-20.500	-0.095	0.005	-19.860
MO5	-0.075	0.005	-15.200	-0.071	0.005	-14.370
MO6	-0.083	0.005	-16.660	-0.080	0.005	-16.190
MO7	-0.084	0.005	-17.160	-0.082	0.005	-16.780
MO8	-0.085	0.005	-18.060	-0.083	0.005	-17.720
MO9	-0.093	0.004	-21.290	-0.091	0.004	-21.150
MO10	-0.071	0.004	-18.700	-0.070	0.004	-18.410
MO11	-0.079	0.003	-27.690	-0.077	0.003	-27.290
CAP	0.178	0.008	23.160	0.162	0.007	22.830
ART*ART	0.069	0.014	5.040	0.054	0.017	3.120
ART*PTS	0.085	0.018	4.650	0.050	0.022	2.310
ART*DIS	-0.151	0.014	-10.650	-0.109	0.017	-6.400
PTS*PTS	-0.204	0.048	-4.220	-0.086	0.052	-1.660
PTS*DIS	0.119	0.028	4.210	0.062	0.030	2.080
DIS*DIS	0.253	0.024	10.490	0.239	0.024	9.910
CAP*CAP	0.188	0.011	17.020	0.158	0.009	16.830
CAP*ART	0.047	0.010	4.580	0.039	0.010	3.860
CAP*PTS	0.127	0.019	6.600	0.139	0.018	7.570
CAP*DIS	-0.186	0.013	-14.040	-0.164	0.014	-12.080
Y				0.075	0.016	4.780
Y*Y				-0.005	0.001	-4.910
Y*ART				-0.007	0.003	-2.380
Y*PTS				-0.026	0.004	-5.960
Y*DIS				0.019	0.004	5.250
CONSTANT	12.861	0.006	2154.990	13.489	0.128	105.200
Total output elasticity	0.505	0.009	58.340	0.518	0.008	61.740

B.3 Comments

The models in section B.1, which use the full unbalanced panel, have slightly higher elasticities of total cost with respect to total output, compared to the total cost models using a balanced panel presented in section 3. Here the estimated total cost elasticities are 0.725 and 0.716, compared to 0.665 and 0.666. The elasticities of variable cost to total output in the models of section B.1 are 0.529 and 0.532, which are only slightly higher than the estimates shown in section 3 from the balanced panel of 0.499 and 0.505. Although the models shown in section B.1 use a slightly larger sample than those presented in section 3, the unbalanced nature of the panel could possibly distort the elasticity estimates obtained. The balanced panel may produce more reliable estimates.

The models with outlier corrections in section B.2 produce results which are closely comparable to the main models in section 3. This suggests that, although there are extreme outliers in the dataset, the most extreme outliers do not have an undue effect on the estimated cost elasticities.

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