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Economies of scale, density and scope in Swiss Post's Mail Delivery[1]

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1. INTRODUCTION

Delivery of physical mail accounts for about 50 percent of total costs of postal operators. Hence, inefficiencies in mail delivery are of particular importance and face increasing management attention. New econometric approaches have the potential to serve the decision makers in several crucial issues: implementing internal benchmarking tools to promote internal competition between decision units, to determine the optimal size of delivery units, and to assess where mail and parcels services should be provided by joint or separate delivery units.

The empirical part of the paper assesses the two latter issues using an econometric approach. We analyze the cost structure of a sample of mail delivery units from Swiss Post. In 2004, Swiss Post organized these units in four regions. In every region, various mail delivery centers lead a small number of local delivery units. These delivery units are the main starting point for a total of 10,000 mail carriers that deliver letters six times a week to almost every household in Switzerland.

We estimate a quadratic cost function employing a cross-section data set from Swiss Post from 2004 with information on 327 postal units, most of them delivering parcels as well. The quadratic specification enables us to estimate measures of economies of scale and density as well as economies of scope between mail and parcels. The empirical results of this study could be used by management in order to define the optimal size of the service area for each delivery unit. The results are further useful for policy makers to

[1] The views expressed in this paper are those of the authors and do not necessarily reflect the opinion of the institutions they are affiliated with.

assess the impact of the letter market liberalization on the industry's cost structure.

The paper is organized as follows. Section 2 outlines the main contribution of the paper relative to the most important papers in the field. Section 3 presents the model specifications. Section 4 introduces the data, and Section 5 provides the estimation results. We compute the measures for economies of scale, density and scope in Section 6 and conclude in Section 7. We find empirical evidence for economies of scale, density, and scope.

2. BACKGROUND

In the literature, there are few published studies on the economies of scale and scope of postal services.[2] The most recent studies relevant for our study are those by Wada, et. al. (1997), Gazzei et al. (2002), Mizutani and Uranishi (2003), Cazals et al. (2005) and Filippini and Zola (2005).

Wada, Tsunoda and Nemoto (1997) estimate a multiproduct total cost function of the Japanese mail service by treating the delivery of letter mail and that of parcels as two independent outputs. In their study, they consider panel data covering 12 regional postal offices collected over a 15-year period from 1980 to 1994. Using a translog cost function they find evidence for the existence of overall economies of scale. Furthermore, the estimation of a generalized translog function highlights significant product-specific economies of scale for letter mail, but not for parcels.

Gazzei et al. (2002) apply a multiproduct cost function to analyze a database consisting of a cross-section of 9168 French post offices operating over the year 1999. The results of their empirical analysis, based on a log-log cost function, suggest the presence of economies of scale. In spite the fact that these authors estimate a multiproduct cost function, no estimation on the economies of scope is provided. The reason is that the log-log functional form does not allow the computation of the economies of scope.

Mizutani and Uranishi (2003) perform an econometric analysis of economies of scale using a single-output cost model, considering the public company (Post Office) and five other private carriers operating in Japan. Through the econometric estimation of a translog total cost function using a pooled data set over the period 1972-1998, they find no evidence for the hypothesis of the presence of economies of scale for this industry.

Cazals, Florens and Soteri (2005) assume a log-linear specification to analyze panel data of Royal Mail's delivery units. By estimating the cost elasticity for various sub-samples, they highlight the importance of the

[2] See NERA (2004) for an overview of the empirical literature in this field.

unobserved heterogeneity in the estimation of scale economies especially in the rural areas. They also point out that the economies of scale in delivery mainly originate from the key variable traffic per delivery point. The scope economies have not been estimated.

The paper by Filippini and Zola (2005) investigates scale and cost efficiency of a sample of Swiss postal offices. The paper considers estimation of a log-log multiproduct cost function employing a cross-section data set on small local post offices. The empirical evidence indicates the existence of economies of scale. Further, the outcome of this analysis shows that approximately 50% of the postal offices operate close to the regional standard for efficiency. Again, the authors do not provide empirical evidence on economies of scope because of the use of the log-log functional form.

Most of these studies have used a log-log or a translog functional form.[3] These functional forms have a drawback compared to other forms such as quadratic in that they do not provide a straightforward estimation method for economies of scope.[4]

The concept of scope economies (Baumol et al., 1982) can only be estimated if the cost function allows a zero value for outputs, which is not the case in any logarithmic form. There are few studies that have tried an estimation of scope economies in line with the classical definition. One exception is Wada et al. (1997), who have used a generalized translog form with Box-Cox transformation to overcome the problem of zero output. In this paper we are interested to analyze both economies of scale and economies of scope. For this reason, we follow Baumol et al. (1982) and use a quadratic functional form in which the scope economies can be directly identified.

The three major differences of this study in comparison to the studies discussed before are (1) the utilization of a quadratic functional form, (2) the use of an econometric procedure that takes into account the heteroscedasticity problem typical for a sample that contains small as well very large production units, and (3) the estimation of a cost function for the delivery units of Swiss Post.

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3 See for example Cazals et al. (2001), Mizutani and Uranishi (2003), Wada et al. (1997) and Gori et al. (2005).

4 A major shortcoming of the translog functional form is that, since the natural logarithm of zero is not defined, it can only be used for multiproduct producers that supply positive quantities in all outputs. This problem can be solved by incorporating a Box-Cox transformation of the output variables. However, the translog functional form incorporating this transformation is non-linear in its parameters and therefore harder to estimate.

3. MODEL SPECIFICATION AND ECONOMETRIC METHODS

The adopted model is based on a quadratic cost function with two outputs namely, mail (Y_1) and parcel (Y_2) and two input factors: labor and capital. The outputs are calculated as an adjusted sum of the number of letters (parcels) delivered. Letters, for which the postal carrier needs more time for delivery, are weighted more than ordinary letters. Labor price (P_L) is measured as the average annual salary of a full-time-equivalent employee engaged in delivery. Capital price (P_K) is measured as the ratio of the non-labor expenses to a measure of physical capital. This latter measure is taken is a weighted sum of the number of vehicles owned by the postal unit. This measure has its clear limitations, but is the only one available.

In addition to outputs and input prices, two output characteristics have been included: These variables include the number of delivery points in the service area (denoted by H) and the number of affiliated local delivery units (B), which is a positive value for the regional delivery centers that are usually linked to several local delivery units. It is set to zero for local units. In addition, three dummies (R_1, R_2, R_3) representing the north, east, west and southern regions are included.

The resulting specification of the cost function can be written as:

$$C = C(Y_1, Y_2, P_L, P_K, H, B, R_1, R_2, R_3) \qquad (1),$$

where C represents total cost and the explanatory variables are defined as above.

A quadratic functional form is used. As explained in the previous Section, this functional form provides a readily applicable expression for the economies of scope. Moreover, because of the presence of zero parcel output in some of the delivery units (about 12.5% of the sample) logarithmic forms like Cobb-Douglas and translog would require additional adjustments. The cost function can be written as:

$$\begin{aligned} C_i = {} & \beta_0 + \beta_1 Y_{1i} + \beta_2 Y_{2i} + \tfrac{\beta_{11}}{2}\left(Y_{1i}\right)^2 + \tfrac{\beta_{22}}{2}\left(Y_{2i}\right)^2 + \beta_{12} Y_{1i} Y_{2i} \\ & + \beta_K P_{Ki} + \beta_L P_{Li} + \beta_H H_i + \beta_B B_i + \delta_1 R_{1i} + \delta_2 R_{2i} + \delta_3 R_{3i} + \varepsilon_i \end{aligned} \qquad (2),$$

with $i = 1, 2, ..., N$, where subscript i denotes the delivery unit; N is the number of delivery units; and ε_i is the error term. All the explanatory variables are normalized, namely, they are replaced by their deviations from their respective median values. Four econometric specifications have been considered: The first model (Model *I*) is an Ordinary Least Squares (OLS) model in which the error term (ε_i) is assumed to be identically and independently distributed across the delivery units.

In the remaining models, the error term has a more general structure that allows for heteroscedasticity. Three cases have been considered: Model *II* is a Weighted Least Squares (WLS) in which variances are assumed to be proportional to the square of the mean of the dependent variable as predicted by the OLS model (denoted by C_i^{OLS}). Model *III* is also a WLS model but with variances proportional to the square of the total deliveries (Y) including mail and parcel outputs. Finally Model *IV* is a Multiplicative Heteroscedastic (MH) regression model in which the variance is assumed to be an exponential function of total deliveries (Y) and a binary indicator (D) distinguishing the delivery centers from the regional delivery units. The latter model has been estimated by the full-information maximum likelihood method, which requires the assumption of normality. The specification of variances in the adopted models can be summarized as:

$$\begin{aligned}
&\text{Model } I \text{ (OLS): } \varepsilon_i \sim iid(0,\sigma^2) \\
&\text{Model } II \text{ (WLS): } \varepsilon_i \sim iid(0,\sigma_i^2),\ \sigma_i^2 = \sigma^2 (C_i^{OLS})^2 \\
&\text{Model } III \text{ (WLS): } \varepsilon_i \sim iid(0,\sigma_i^2),\ \sigma_i^2 = \sigma^2 \left(Y_i\right)^2 \\
&\text{Model } IV \text{ (MH): } \varepsilon_i \sim N(0,\sigma_i^2),\ \sigma_i^2 = \sigma^2 \exp\left(\gamma_1 Y_i + \gamma_2 D_i\right)
\end{aligned} \qquad (3).$$

4. DATA

The data consist of a cross section of 328 mail delivery units operated by Swiss Post’s letter section. These units are organized as 241 local delivery units and 87 regional centers. The operation of each local unit is monitored by the corresponding regional delivery center. All the regional centers have also local delivery tasks. The number of delivery units attached to a regional delivery center varies considerably and averages about three units per center. The final regression sample consists of 327 observations including 86 regional centers[5] and 241 local delivery units. The various units cover a wide range of output and costs, varying from 1.3 to over 50 million deliveries.

Most of the studied mail delivery units also provide parcels deliveries in rural areas. In about 16 percent of the delivery units the number of delivered parcels is very small (less than 100 for the entire one-year period). The number of delivery points varies quite considerably across the delivery units.

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[5] We had to exclude one of the regional delivery centers from the sample because of missing values for costs.

As the operation of delivery centers includes the additional responsibility of monitoring the local units within their regional zone, one could argue that these centers should be analyzed separately. However, our preliminary regressions using the OLS specification in (2), and with the appropriate interaction terms indicated that the differences between the coefficients across local units and regional centers are not statistically significant. Therefore, we consider both categories in a single sample. It should be noted that although the regional centers are on average significantly larger than the local units, this is not a general rule. The t-tests show that while both mail output and number of delivery points are on average significantly larger in regional offices, the parcel output volume is not significantly different across the two categories.

5. ESTIMATION RESULTS

The models explained in Equations (2) and (3) have been estimated for the sample. The regression results are listed in Table 1. The first observation is that most of the explanatory variables show statistically significant effects with the expected signs. An exception is the input factor prices. The coefficients of both labor and capital prices are insignificant, suggesting that cost differences across companies are not driven by differences in input prices.[6]

Secondly, the results of Model *I* that does not consider the heteroscedasticity are significantly different from the other three models. In particular, according to this model, the parcel output does not have a significant effect on costs (at 5% significance level), whereas unlike other models, the output interaction term (Y_1Y_2) has a positive and significant effect on costs. These differences suggest that ignoring heteroscedasticity might cause misleading results not only regarding standard errors and significance but for the coefficients as well. Another interesting observation is that all region dummies are highly significant suggesting that postal networks in different areas depend on certain unobserved region-specific characteristics.

Among the models, starting from OLS model that does not account for heteroscedasticity, there is a specific order across the remaining three models. Model *II* accounts for heteroscedasticity through the existing variables in the mode. Model *III* goes one step further in that the variations

[6] This result could be related to the measurement errors incurred in the estimation of prices. However, it is not surprising as we consider decision units from the same company.

are adjusted using an additional variable (total deliveries). Finally, Model *IV* defines a structure for heteroscedasticity based on two additional variables (total deliveries and regional unit dummy). As Table 1 indicates, the pattern of variation of the estimated coefficients across different models confirms the existence of heteroscedasticity bias. We contend that Model *IV* results should be considered as the best estimates among the presented models. According to this model, the output coefficient of mail is on average about 0.19. Each customer (delivery point) has a marginal cost of 70 Francs and each additional branch has a cost burden of about CHF 100,000 for a regional unit.

Table 1: Regression results (Dependent variable: total costs in CHF)

	Model I			***Model II***			***Model III***			***Model IV***		
Variable	**Coeff.**		**t-stat**	**Coeff.**		**t-stat**	**Coeff.**		**t-stat**	**Coeff.**		**z-stat**
Mail output (Y_1)	0.155	**	6.03	0.181	**	6.97	0.194	**	7.29	0.190	**	7.74
Parcel output (Y_2)	1.130		1.92	1.121	**	3.23	1.008	**	2.95	0.880	**	2.74
$(Y_1 Y_1)/2$	1.36E-09	**	2.59	2.41E-09	*	2.14	1.82E-09		1.74	5.57E-09	*	2.15
$(Y_2 Y_2)/2$	-5.04E-07		-0.18	3.55E-07		0.16	1.13E-06		0.56	1.28E-06		0.63
$Y_1 Y_2$	2.51E-07	*	2.34	-6.15E-08		-0.59	-7.93E-08		-0.79	-3.18E-08		-0.35
Labor price (P_L)	-1.92		-1.09	-0.95		-1.40	-0.88		-1.16	-1.30		-1.60
Capital price (P_K)	2.01		1.29	-0.40		-0.60	-0.22		-0.33	0.15		0.22
# of customers (H)	102.95	**	4.86	72.70	**	3.17	70.48	**	3.08	70.53	**	3.41
# of branches (B)	1.25E+05	**	6.39	1.19E+05	**	6.56	1.05E+05	**	6.56	1.05E+05	**	6.09
Region 1	-4.98E+05	**	-2.61	-3.16E+05	*	-2.30	-2.53E+05	**	-2.84	-2.35E+05	*	-2.53
Region 2	-7.00E+05	**	-3.75	-3.64E+05	**	-2.68	-3.10E+05	**	-3.53	-3.21E+05	**	-3.52
Region 3	-6.68E+05	**	-3.59	-3.66E+05	**	-2.69	-3.17E+05	**	-3.61	-3.37E+05	**	-3.69
Constant	1.99E+06	**	10.87	1.71E+06	**	12.61	1.67E+06	**	19.15	1.66E+06	**	18.35
Adjusted R-square	0.9598			0.8758			0.8875			0.8731		
log (variance):												
Regional unit (D)										0.919	**	4.54
Total deliveries (Y)										1.78E-07	**	14.38
Constant										23.57	**	210.5

***** significant at .05; ****** significant at .01; Model ***I*** *:* OLS; Model ***II*** : WLS with weights being the OLS predictions; Model ***III*** : WLS with weights being the total deliveries; Model ***IV*** : Multiplicative heteroscedastic regression.

6. ECONOMIES OF SCALE AND SCOPE

The inclusion in the cost function (3) of the number of delivery points allows for the distinction of economies of scale (*ES*), economies of density (*ED*), and economies of scope (*ESS*).

In a multiproduct setting, economies of scale are defined as those reductions in ray average cost when all outputs and number of delivery points are increased proportionally, holding all input prices fixed. E.g., merging two local units would save money when *ES* are positive. Economies of density exist if simultaneously increasing the production of all outputs, holding the number of delivery points fixed, lowers ray average cost. Thus, positive *ED* would mean that Swiss Post’s unit costs would increase in case mail demand where to be shrinking (e.g. because of E-Substitution or shrinking market shares). Economies of scope are present when there are cost efficiencies to be gained by joint production of multiple outputs. If *ESS* between mail and parcels are locally present, it makes sense to provide the two services with the same carrier.

Following Baumol et al. (1982) economies of scale, density and scope in a multi-output setting are respectively defined as:

$$
\begin{aligned}
ES &\equiv \frac{C}{Y_1\frac{\partial C}{\partial Y_1}+Y_2\frac{\partial C}{\partial Y_2}+H\frac{\partial C}{\partial H}}=\frac{C}{\beta_1 Y_1+\beta_2 Y_2+\beta_{11}\left(Y_1\right)^2+\beta_{22}\left(Y_2\right)^2+2\beta_{12}Y_1Y_2+\beta_H H} \\
ED &\equiv \frac{C}{Y_1\frac{\partial C}{\partial Y_1}+Y_2\frac{\partial C}{\partial Y_2}}=\frac{C}{\beta_1 Y_1+\beta_2 Y_2+\beta_{11}\left(Y_1\right)^2+\beta_{22}\left(Y_2\right)^2+2\beta_{12}Y_1Y_2} \\
ESS &\equiv \frac{C(Y_1,0)+C(0,Y_2)-C(Y_1,Y_2)}{C(Y_1,Y_2)}
\end{aligned}
\quad (4).
$$

The estimated values of economies of scale, density and scope are given in Table 2. These values have been estimated based on equations (4) for each one of the delivery units in the sample. Taking into account the experiences from other countries, the levels of the variables should be treated with caution because of the lack of panel data. However, the relative altitudes are important. The results indicate that virtually in all companies and across all models, the scope economies are positive. Similarly, the constant of density economies is higher than 1 in almost all companies suggesting the existence of density economies in a large majority of the cases.[7] The constants of scale economies are also higher than 1 in a small majority of the observations. However, in about 20 to 25 percent of the cases, this constant is either less than 1 or very close to 1, suggesting that scale economies are not considerable in many cases.

The results suggest that scope economies are considerable across mail and parcel services especially in regions with low mail and parcels volume (negative correlation with *Y*). This supports Swiss Post's policy to combine the two services in rural areas. According to Model *IV*, combining parcel and mail can save a considerable amount of the total costs compared to a case, in which two delivery units operate mail and parcel separately. The estimated density economies suggest that an increase of mail demand, that goes not together with increasing the number of delivery points (extending network) reduces average costs per piece of mail and vice versa. On the other hand, the estimated scale economies suggest that in many cases, if such an increase involves an extension in the network or an increase in the number of customers, the economies will not be considerable. However, the results

[7] There is only one unit that according to the OLS model, has negative scope economies and diseconomies of density and scope. Model *IV* predicts diseconomies of density only for 5 units.

suggest that at least about half of the units included in the sample do not fully exploit the potential scale economies. The significant negative correlation with the output suggests that the scale economies are lower for large delivery units. In other words, the figures indicate that there is some potential for Swiss Post in merging some of the smaller delivery units. However, geographical reasons may restrict the potential of such a merger program.

Table 2: Economies of scope, scale and density

	Model I	***Model II***	***Model III***	***Model IV***
Scope economies:				
1st quartile	0.389	0.346	0.305	0.341
Median	0.455	0.378	0.334	0.372
3rd quartile	0.519	0.417	0.377	0.410
Correlation with *Y*	NS	-0.173	NS	-0.374
Scale economies:				
1st quartile	1.033	1.084	1.057	1.036
Median	1.109	1.147	1.102	1.112
3rd quartile	1.207	1.216	1.162	1.187
Correlation with *Y*	-0.267	-0.463	-0.387	-0.575
Density economies:				
1st quartile	1.594	1.477	1.401	1.390
Median	1.794	1.542	1.457	1.477
3rd quartile	2.021	1.645	1.556	1.587
Correlation with *Y*	-0.164	-0.389	-0.264	-0.570

NS: Not significant; Model ***I*** *:* OLS; Model ***II*** : WLS with weights being the OLS predictions; Model ***III*** : WLS with weights being the total deliveries; Model ***IV*** : Multiplicative heteroscedastic regression.

7. DISCUSSION

The purpose of this study was to analyze the cost structure of Swiss Post's delivery units in order to assess economies of scale, economies of density and economies of scope. In particular, policy-makers are interested in cost information of this industry in order to determine the desirability of competition in the postal delivery sector. Moreover, from a company point of view, the management of Swiss Post can be interested in having some information on the economies of scale and scope in order to define a policy on combining individual operating units.

A quadratic total cost function was estimated using a cross section of 327 delivery units for the year 2004. The empirical results indicate the existence of economies of density, economies of scale and economies of scope especially for units with low mail volumes.

The results on economies of scale suggest that a considerable portion of the postal delivery units seem to operate at an inappropriately low scale. The service territory area of most of these units appear too small to produce at optimal scale. Therefore, if geographically feasible, mergers between two small units whose service territories are adjacent would improve the scale efficiency of these units.

The estimated economies of density can help to clarify the efficiency of side-by-side ("end-to-end") competition at all points of a given service territory versus monopolistic provision of delivery postal services. The finding shows that the cost of serving a market of size y over a municipal territory with one delivery unit is lower than the cost of serving the same market with n competitive delivery units that install parallel facilities everywhere. Therefore, side-by-side competition is less cost-efficient than the monopolistic distribution of postal services. Our findings offer some support to the policy of monopoly-based postal delivery regulations such as the US model "worksharing". In the US, a mandatory access-regime is in place, where access to the incumbent's network is not only possible, but also mandatory: It is not allowed to bypass the delivery network of the incumbent USPS. It is important to point out that such a system is not possible once end-to-end competition is introduced as it is the case in the UK. These results are in line with various market entry models.[8]

The presence of economies of scope shows that an unbundling of a multi-output company into single-output companies leads to higher costs in the market as the synergies in the joint (rural) production are no more exploited. This implies that the two postal delivery services, mail and parcels should be provided by the same delivery unit at least in rural areas. Again, the US

[8] Dietl et al. (2005) provides an assessment of the liberalization of the Swiss letter market.

system is economically supported: The USPS offers access for parcels. This product is utilized mainly for parcels destined to rural areas.

REFERENCES

Baumol, W. J., J. C. Panzar and R. D. Willig. 1982. *Contestable Markets and the Theory of Industry Structure*, Hartcourt Brace Jovanovich, Inc.

Cazals, C., J.-P. Florens and B. Roy. 2001. “An Analysis of Some Specific Cost Drivers in the Delivery Activity.” In *Future Directions in Postal Reform*, edited by M.A. Crew and P.R. Kleindorfer, Boston, MA: Kluwer Academic Publishers.

Cazals, C., J.-P. Florens, and S. Soteri. 2005. "Delivery Costs for Postal Services in the UK: Some Results on Scale Economies with Panel Data." In *Regulatory and Economic Challenges in the Postal and Delivery Sector*, edited by M.A. Crew and P.R. Kleindorfer. Boston, MA: Kluwer Academic Publishers.

Dietl, H. M., U. Trinkner, and R. Bleisch. 2005. "Liberalization and Regulation of the Swiss Letter Market." In *Regulatory and Economic Challenges in the Postal and Delivery Sector*, edited by M.A. Crew and P.R. Kleindorfer. Boston, MA: Kluwer Academic Publishers.

Filippini, M. and M. Zola. 2005. *Economies of scale and cost efficiency in the postal services: empirical evidence from Switzerland*. Applied Economics Letters, 12, 437-441.

Gori, S., E. Piccinijn, S. Romito and G. Scarfiglieri. 2006. “On the Use of Cost Functions in the Assessment of the Impact of Liberalization on Postal Universal Service Burden: Restricted versus Flexible Specifications.” In *Progress toward liberalization of the postal and delivery sector*, edited by M.A. Crew and P.R. Kleindorfer, Springer.

Mizutani, F. and S. Uranishi. 2003. *The Post Office vs. Parcel delivery Companies: Competition Effects on Costs and Productivity*. Journal of Regulatory Economics, 23 (3): 299-319.

NERA. 2004. *Economics of Postal Services: Final Report*, A report to the European Commission, NERA Economic Consulting, London.

Wada, T., C. Tsunoda and J. Nemoto.1997. *Empirical Analysis of Economies of Scale, Economies of Scope, and Cost subadditivity in japanese Mail Service*. IPTP paper series 1997-08.