Marginal Costs Pricing of Airport Operations in Norway

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Abstract

The article first reviews the charge scheme used to finance the airport infrastructure in Norway. Then an econometric approach is taken using empirical data for production and costs from 2007 to 2009 in order to derive long-run marginal costs for passengers and air traffic movements at Norwegian airports using panel data analysis. The marginal costs are then applied as the basis for a revised airport charge scheme designed to meet the principle of maximizing social benefits. The results suggest that there should be a shift towards a relatively higher charge for passengers compared to air traffic movements.

Keywords: Airport cost, panel data analysis, passengers, air traffic movements, marginal cost pricing, Ramsey pricing

JEL: D24, D40, L93

1. Introduction

Airport infrastructure is, in most countries, financed by airport charges put on the services produced at the airport, together with revenues from commercial activities (Losada et al., 2012). The international air transport organizations aim for standardization of airport charges (Martin-Cejas, 1997) and ICAO (2009) has a general policy stating that charges, amongst other things, should be based on costs and also be non-discriminatory. Most airports charge both passengers (*PAX*) and air traffic movements (*ATM*), but there are variations with respect to the distribution of charges between *PAX* and *ATM,* both between countries and type of airport ownership.

Most Norwegian airports are operated by the state-owned company Avinor (see e.g. Lian, 2010) according to commercial principles. The network does not in total require state subsidies, but there is quite substantial cross-subsidization between the largest airports and those located in rural areas. Total operating costs vary considerably between the airports, due to different size and amount of traffic, and so does their cost efficiency (see e.g. GAP, 2012).

Many earlier studies of costs in airport operations have focused on analyzing efficiency and economies of scale (e.g. Martín et al., 2011; Pels et al., 2003). However, the aim of this article is to analyze the Norwegian airports' costs structure, using panel data models and subsequently derive the marginal cost of serving passengers and airplanes. The new panel data estimates enable better estimates of long-run marginal costs which, according to the social-welfare maximization principles (see e.g. Button, 2010), should be used as the basis for the national fare scheme. Taking the marginal cost estimations as a starting point, the article suggests a revised scheme for aviation charges designed according to the principles of welfare economics. The study is, in contrast to most other analyses of costs carried out in the transport industry, not an efficiency study, but rather focuses on providing new and better estimates on the actual costs of producing the current transport services.

The article first provides a brief presentation of the Norwegian airport infrastructure with special focus on how it is currently financed in Section 2. Then, Section 3 presents an econometric model suitable for studying long-run marginal costs at Norwegian airports using panel data analysis. Next, Section 4 gives details about the data set, presents model results and derives marginal costs for *PAX* and *ATM*. The results are applied in new schemes for airport charges in Section 5 where the cost of raising public funds also is taken into account. Finally, possible implications for air transport companies, passengers and the authorities by implementing these airport charges are briefly discussed in Section 6.

2. Norwegian Airport Network and Airport Charges

2.1 The Norwegian Airport Structure

Today Norway is amongst the countries in Europe with the highest air transport dependence (Williams et al., 2007). While Norway in 2003 had a domestic air trip rate per capita of 2.27, most European countries had less than one third of this value. Moreover, Williams et al. (2007) show that Norway has the highest number of commercial airports with short runways (< 1 000 m) in Europe.[1] Many of these airports have low traffic and are located in areas which can be classified as peripheral (Kjærland and Mathisen, 2012).

Consequently, in order to maintain satisfying provision of routes, the Norwegian Ministry of Transport and Communications procures air transport services from many of these airports through a public service obligation (PSO) system. Norway is, according to the European Commission (2009), a dominating 'PSO-country' in Europe holding nearly 20 % of all restricted PSO-routes. In 2009 the government used about NOK 574 million to subsidize PSO-operations to and from these airports (St. prp. 42, 2008-2009). The subsidized contracts are awarded as net contracts using competitive tendering every fourth or fifth year.[2] The PSO regulations give the winning operator exclusive rights to operate the defined routes with a determined frequency, size of aircraft, maximum fare level, and social discounts. In 2013 almost all Norwegian PSO-routes are operated by Widerøes, the largest regional airline company in Scandinavia.

The state, through the wholly owned company Avinor, owns and operates 46 airports throughout Norway with a total annual traffic of about 44 million passengers (PAX) in 2012 (Avinor, 2013). Avinor organizes the airports into three groups in which the main airport of Norway (OSL), located near the capital city Oslo, makes up the first 'group', the three other large airports located near the cities of Bergen, Stavanger and Trondheim make up the second group and the remaining 42 airports make up the third group as illustrated in Figure 1. In 2012 OSL had 22 million terminal passengers, the second group an average of 4.7 million terminal passengers, and the third group an average of 0.26 million terminal passengers. The main section of the third group consists of 29 local airports characterized by particularly low traffic (68000 terminal passengers on average in 2012). At these airports virtually all passenger traffic is subject to PSO. The remaining regional airports are located in more densely populated areas and air traffic is based on routes operated on a commercial basis.

[1] Short Take-Off and Landing (STOL) planes such as Bombardier Dash-8 100 (or DHC-8) operate on local airports with runways as short as 800 meters. Local airports with sufficiently long runways are operated by jet planes.
[2] In the southern part of Norway the contract length is four years while it is five years in Northern Norway (see e.g. Kjærland and Mathisen, 2012).

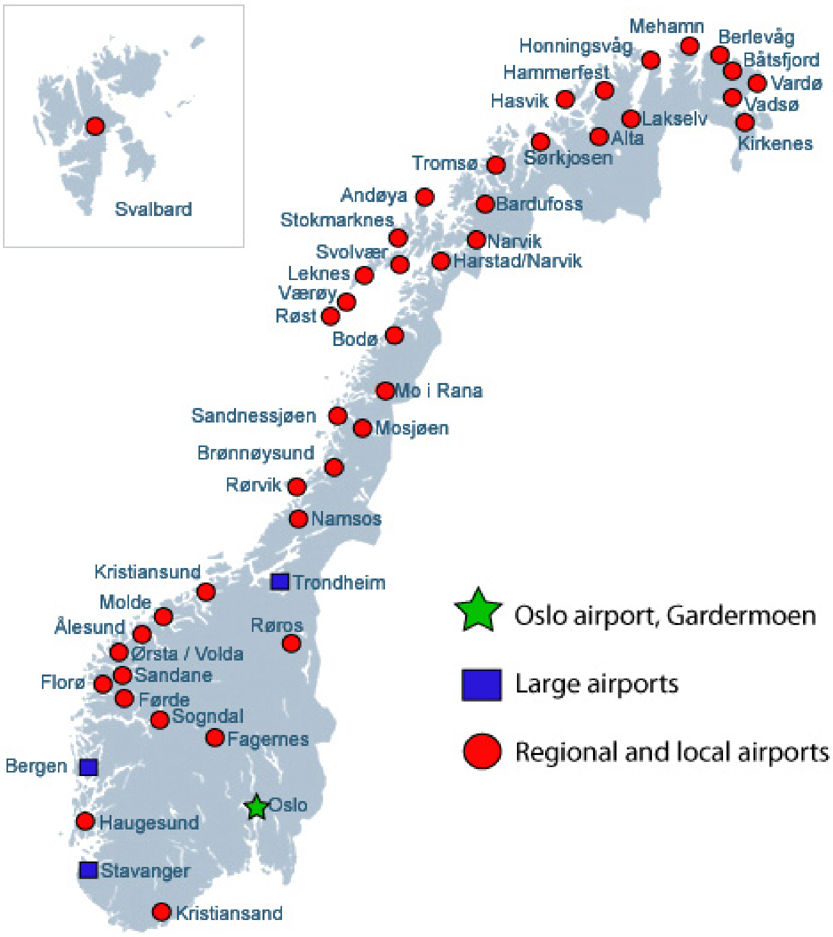

Figure 1. Norwegian airports owned by Avinor (Source: Avinor).

However, the road infrastructure has improved since the airports were built about 40 years ago (Mathisen and Solvoll, 2012), and there is an increasing leak of passengers to the larger airports in the network where commercial routes are operated by jet planes (Lian and Rønnevik, 2011). This development has revitalized the issue of reconsidering the whole structure of the regional airport network in Norway. For further details regarding the airport network in Norway see e.g. Lian (2010).

2.2 Current Airport Charges

The airport charges imposed on air traffic are made up of five elements;[3] take-off charge, passenger charge, security charge, TNC (Terminal Navigation Charge) and en-route charge. [4] Security charge, TNC and en-route charge are set to cover Avinors' costs. The two remaining categories, take-off charge and passenger charge, which are the focus of this study, are set by Avinor according to directions from The Norwegian Ministry of Transport and Communication. Avinor also generates revenues indirectly related to air transport from commercial activities such as rent from shops and tax-free sales and parking. Prices for commercial activities are determined by Avinor. Total revenues for all airports are almost evenly distributed between *PAX* and *ATM* charges, on the one hand, and commercial activities on the other hand.

The basis for this study is the airport charge system in 2009 forming the reference for all comparisons between new and old charges. Passengers were charged NOK 36 [5] and NOK 59 for domestic and international flights, respectively. Air traffic movements were charged at a rate of NOK 96 per tonne according to the aircrafts' maximum take-off weight (MTOW). For particularly large aircraft the charge is reduced to NOK 48 for each tonne exceeding 100. Consequently, an aircraft with a MTOW of 70 tonnes had to pay a take-off charge of about NOK 6700. According to the accounting figures for Avinor airports there was a total of 35.8 million *PAX* and 596 000 *ATM* in 2009 generating revenues of NOK 833 million and NOK 1280 million, respectively. This gives NOK 23 per *PAX* and NOK 2148 per *ATM* on average, (the figures can be doubled since a departure and arrival is charged only once). The charges were updated in 2010 to match the increase in costs and the entire scheme for *ATM* was then revised in 2011. The charges in NOK for the last three years are shown in Table 1. These figures do, however, not fully reflect the actual charges, since the airport owner in some situations introduces discounts in order to stimulate demand.[6]

[3] All taxes are charged once per trip. A trip (without transfer) includes two flight movements and visits at terminals both at departure and landing. It is however, uncommon to charge these services separately for the origin and destination airports.

[4] The en-route charge is set to meet the cost generated by the air space surveillance services provided by the control centrals of Avinor. The TNC was introduced in 2011 to cover the control tower operating costs and is designed as a concavely increasing function of airplane weight (MTOW). Earlier, this charge was included in the take-off charge. The charges for security, tower services and en-route can be changed, if costs or traffic amount changes.

[5] € 1 ≈ NOK 8.

[6] A number of smaller airports operate a 30% discount on the take-off charge. Additionally, there is a start-up discount for the first few years of operation for newly established routes.

Table 1. Aviation charges on Norwegian airports owned by Avinor.

Charges (in NOK)	2011	2012	2013
Take-off Charge per ton MTOW [a]			
- tons 4-75	69	70	67
- tons 76-150	34.5	35	33,5
- tons > 151	14	14	13,4
Passenger charge domestic flights	44	46	47
Passenger charge international flights	59	60	61
Security charge	58	47	55
Terminal Navigation Charge (TNC per service unit) [b]	1912	1857	1609
En-route charge [c]	530.04	475.06	430.28

[a] From 2011, take-off charge is not payable for the first 6 tons of aircraft weight of more than 8 tons, with the exception of cargo flights who pay 70 NOK/ton for the first 6 tons of aircraft weight.

[b] The number of service units for terminal charge is calculated according to the following formula: (MTOW in tons/50)^0.9).

[c] The en-route charge is billed and collected by Eurocontrol.

3. The Model

Airport charges are vital for the financing of airport infrastructure and make up a considerable part of operating costs for airliners. These charges to finance airport infrastructure should, from a welfare economic point of view, be set to reflect the costs imposed by the activities.

3.1 Previous Costs Studies

An important basis for the analysis of airports' costs is to define which services are provided by an airport and how they can be measured. Common production measures to assess the activity at an airport are the number of passengers (*PAX*), air traffic movements (*ATM*), work load units (*WLU*) and commercial revenues, while the size (or capacity) is often measured by runway length, number of runways, terminal area (square meters), number of gates, etc. (see e.g. Martín and Voltes-Dorta, 2011). Moreover, Link et al. (2009) successfully applied labour as input in cost analyses of airport operations.

One should, however, be aware that the choice of production measure and model formulation will influence the cost estimates. A comparison of cost estimates using different production measures is given by Martín and Voltes-Dorta (2008) revealing large differences in the estimated marginal costs, depending on model specification. External costs of air transport such as noise, pollution and delays can be internalized in order to make estimations of social marginal costs (see e.g. Santos and Robin, 2010).

The most central production measures when studying airports are *PAX* and *ATM*. However, a potential problem for econometric analyses is that these two explanatory factors are highly correlated; when *PAX* increases the number of *ATM* will also increase in order to meet the increased demand, and vice versa. A way to avoid this problem is to use the above mentioned *WLU*-measure in which each passenger is for example assumed as weighing 100 kg. This production measure has, however, shown to be imprecise and vague, and is therefore rarely used in recent studies (Martín and Voltes-Dorta, 2011).

An example of marginal cost estimation in Scandinavia was carried out by Carlsson (2003) using an exponential model with the number of passengers as the only independent variable, explaining about 96% of the variation in costs between airports. Mathisen et al. (2012) used both *PAX* and *ATM* in a model estimating the marginal costs of airport operations in Norway. Morgado and Macao (2012) estimated marginal costs at Portuguese airports and used these to suggest new charges. The importance of distinguishing between long-run and short-run marginal costs was addressed by Morrison (1983) who concluded that investment levels at a number of US airports were inefficient when considering capacity problems. When aiming to meet revenue restrictions, the Ramsey-rule has been applied by Martin-Cejas (1997) and Hakimov and Scholz (2010) to design charge schemes based on marginal cost estimates for Spanish and German airports, respectively.

3.2 The Applied Cost Model

The cost function applied in this study is an additive multiproduct specification relatively similar to the linear function presented by Mathisen et al. (2012). As mentioned in Section 3.1, a potential problem is that the number of passengers (*PAX*) and air traffic movements (*ATM*) are closely correlated. In order to reduce multi-correlation the independent variable *ATM* is processed both by the use of deviation from mean transformation and logarithmic transformation. This function was chosen after having assessed a number of specifications and transformations of the variables. Following the principle of parsimony (see. e.g. Link et al., 2009), the chosen model has properties in accordance with reasonable a-priori assumptions regarding the cost structure at Norwegian airports. For example, this type of specification implies that the marginal cost for an *ATM* is independent of *PAX* at the airport and vice versa.

In a review of econometric analyses of costs at airports, Martín and Voltes-Dorta (2011) show that Cobb-Douglas and translog specifications have been frequently used. Even if a linear specification is less flexible than it often provides a good approximation for more advanced models (see e.g. Pels and Rietveld, 2008). Moreover, the results from linear models are easy to interpret and are well-suited for the purpose of the article since they can be applied directly as marginal cost estimates.

An econometric approach using a model including the metric production measures number of passengers (*PAX*) and air traffic movements (*ATM*)[7] as independent variables is applied to study the costs structure at Norwegian airports. The applied model, which is the basis for the panel data study, is presented in equation (1) to estimate costs at airport *i* in year t. It is clear from (1) that the marginal cost with respect to $PAX = X_1$ is $\partial C/\partial PAX = \beta_1$. Since it is reasonable to consider the mean value, $ln\overline{ATM}_t$, as a relatively constant variable, the marginal cost for ATM is $\partial C/\partial ATM \approx \beta_2/ATM$. Since D_{1i} is an imprecise and weak indication of capacity, the estimates can be interpreted as long-run. [8]

(1) $$C_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 D_{1i} + \beta_4 D_{2i} + v_{it}$$

where $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4 > 0$ and $X_{2it} = lnATM_{it} - ln\overline{ATM}_t$

The cost function in (1) estimates the total operating costs measured in Norwegian currency (NOK) at the 2009 price level for airport i at time t, (C_{it}) where the subscript i denotes the cross-section dimension and t denotes the time-series dimension. The intercept term β_0 is fixed and thereby independent of both time and airport. The accounting figures are reported by Avinor and include all costs at the airport except security which is an outsourced service and covered by a separate charge. Regarding the independent variables, X_{1it} and X_{2it} are observable time-varying factors represented by deviation from annual mean for PAX and ATM as defined in (1). *PAX* is defined as the number of terminal passengers (sum of arrival and departure and transfer) at both route and charter flights and *ATM* is the sum of arrival and departure flights, including both route and charter categories. The dummy variable D_{1i} is defined as 0 if the airport is classified as category 1 or 2, else $D_{1i} = 1$.[9] This follows the BSL E 3-2 categorization which mainly separates airports with runways shorter than 1199 meters ($D_{1i} = 0$) from larger airports and, broadly speaking, corresponds with the group of local airports defined in Section 2.1. This separation is important since runways shorter than 1199 meters

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[7] There are strong indications that the part of the charge scheme related to *ATM* should be separated in one part depending on airplane weight with another part being independent of airplane weight (see e.g. Graham, 2008). This is considered by Martín and Voltes-Dorta (2008) by introducing a ln-transformed measure of *ATM* adjusted for average maximum take-off weight (MTOW) for the planes using the airport. This measure is, however, not applied in (1).

[8] See the literature dating back to e.g. Walters (1965) for a further discussion of the application of marginal cost concepts with different time-horizons in transport.

[9] This refers to the size of the airport according to the categories ranging from 1 (small) to 4 (large) following the regulations on the design of large airports (BSL E 3-2) defined by The Norwegian Ministry of Transport and Communication (2006). Generally, the infrastructure requirements increase substantially for higher categories which again increase both investments and operation costs. The difference between the categories is most easily seen by the runway length and safety zones.

are not suited for jet planes. The dummy variable D_{2i} is defined as 1 if the observation relates to the main national airport OSL which is considerably larger than all other airports in the network, otherwise $D_{2i} = 0$. Both dummy variables are observable time-invariant factors.

A-priori assumptions are that all β-parameters are positive, implying that all factors are positively correlated with costs. Furthermore, the disturbance term $v_{it} = u_i + \varepsilon_{it}$ is divided between the unobservable airport-specific effect, u_i, and the remainder of the disturbance, ε_{it}. u_i is time-invariant and accounts for the airports' unobserved characteristics, whereas the remainder of the disturbance, ε_{it}, varies with companies and time and can be thought of as the usual disturbance term in the regression (see e.g. Wooldridge, 2006).

3.3 Panel Data Analysis

A pooled regression of equation (1) could offer unbiased results if the unobserved effects, u_i are uncorrelated with the regressors, but would not make best use of the data. In the analysis, attention will be directed at how the panel data model can make better use of the data compared to pooled regression. When considering both within-, and between-group variation, the best unbiased estimation of equation (1) can be derived using random effects estimation with basis in the Generalized Least Squares (GLS) model. The random effects (GLS) model assumes the properties of data being sampled randomly to construct a more efficient estimator, i.e. individual effects are uncorrelated with the regressors in all time periods, $Cov(PAX_{1it}, u_i) = 0$. In the random effects model derived in equation (2), the weight given to between-group variation is defined by theta, $\theta = 1 - \sqrt{\frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + T\sigma_u^2}}$ where $\sigma_\varepsilon^2 = var(\varepsilon_{it})$, $\sigma_u^2 = var(u_i)$ and T is time periods (e.g. Adkins and Hill, 2011). Theta (θ) is defined to be a value between 0 and 1. If theta is close to 0, the unobserved effect is relatively unimportant and the within and between variation should be given equal weight. This makes random effects estimates equal to pooled OLS estimates. A theta value close to 1 indicates that the random effects estimates are equal to the within-group estimates (Wooldridge, 2006).

(2) $$C_{it} - \theta\bar{C}_t = \beta_0(1-\theta) + \beta_1(X_{1it} - \theta\bar{X}_{1t}) + \beta_2(X_{2it} - \theta\bar{X}_{2t}) + \beta_3(1-\theta)D_{1i} + \beta_4(1-\theta)D_{2i} + (v_{it} - \theta\bar{v}_{it})$$

The relatively strict assumptions imply that the model should be thoroughly tested to assess whether the random effects (GLS) can be applied. The Breusch-Pagan Lagrange multiplier test is designed to test if the random effects method is suited for analysing the data set. If the null hypothesis of zero variance in the groups is not rejected, the pooled regression model is more appropriate than the random effects model. Whether the random effects estimators are unbiased is most commonly assessed using the Hausman test comparing the estimated coefficients of the within-group with the random effects models. Random effects is consistent and should be used only if the two models do not differ significantly (Baltagi, 2005).

4. Estimation results

4.1 Available Data

All airports are obliged to report detailed accounting and traffic information to the fully state-owned company Avinor. Accounting figures are adjusted to a 2009 price level using the consumer price index provided by Statistics Norway (2013). The cost variable includes depreciation and excludes security and rents paid by commercial activity at the airport. The traffic statistics are publicly available on the website of the airport owner Avinor (2013). The data set consists of annual observations of production and accounting figures for all 46 airports owned by Avinor for the years 2007, 2008, and 2009. However, the heliport (purely a landing site for helicopters) at Værøy (VRY) has been omitted since its cost structure deviates somewhat from regular airports. Moreover, it should be noted that OSL is large compared to the other Norwegian airports and accounts for 40% of all airports' costs and 30% of *ATM*s and is, thus, an extreme outlier for all variables.

The two panel data dimensions relate to 1) an airport specific identifier and 2) the time period indicated by waves. The airport identifier is a unique number. The waves consider time periods of one year and the data set should be regarded as a short panel since it only includes three waves. The fact that this is a short panel makes it relevant to compare analyses of panel data models using ordinary regression on pooled data. All airports have reported the figures for all waves and this is consequently a balanced data set without missing values. Hence, the data set avoids survivorship bias and the loss of sample size (see e.g. Baum, 2006). Survivorship bias would not be a problem in this analysis because survival of the highly regulated airports in Norway is politically conditioned and uninfluenced by airport specific abilities. Moreover, the selection in the data set is a complete representation of the population since all Avinor airports are included. Consequently, three waves of 45 airports make up a total of 135 observations. Descriptive statistics for the pooled data set are presented in Table 2.

Table 2. Annual descriptive statistics for the airports (N=135).

Variable		Mean	Std. Dev.	Min.	Max.	Observations
(Costs)	Overall	7.27×10^7	2.19×10^8	1.04×10^7	1.54×10^9	N = 135
	Between		2.20×10^8	1.14×10^7	1.49×10^9	n = 45
	Within		6316915	3.19×10^7	1.21×10^8	T = 3
(*PAX*)	Overall	860410	2884354	5615	1.93×10^7	N = 135
	Between		2904934	6989	1.88×10^7	n = 45
	Within		82483	124103	1369903	T = 3
(*ATM*)	Overall	13625	33131	711	220514	N = 135
	Between		33357	870	211718	n = 45
	Within		1258	3095	22422	T = 3
D_1 (Category)	Overall	0.40	0.49	0	1	N = 135
	Between		0.49	0	1	n = 45
	Within		0	0.4	0.4	T = 3
D_2 (Main airport, OSL)	Overall	0.22	0.15	0	1	N = 135
	Between		0.15	0	1	n = 45
	Within		0	0.22	0.22	T = 3

For all variables in Table 2 the within variation is considerably lower compared to the between variation indicating large differences between airports and relatively stable characteristics over the years. A comparison of the minimum and maximum values with the mean values indicates that the data set is “right skewed” with a few large airports. All metric variables in Table 2 are right skewed due to the presence of few airports with high traffic and many small airports with low traffic in the data set. The average airport in the data set has annual operating costs of NOK 72.7 million. If OSL is excluded, the average costs would decrease to about NOK 40 million. The number of terminal passengers, which includes counting passengers both on departure and arrival, is 860000. This makes the actual number of people travelling about 430000. The average number of air traffic movements is about 13600.

Table 3. Correlation matrix.

Variable	C	X_1	lnX_2	D_1	D_2
C (Costs)	1				
X_1 (PAX)	.987*	1			
X_2 (*ln*ATM)	.625*	.698*	1		
D_1 (Category)	.306*	.346*	.570*	1	
D_2 (OSL)	.981*	.942*	.487*	.185*	1

* Significantly correlated at 1% level (2-tailed).

The matrix in Table 3 shows that correlations between the costs and the independent variables are very high. This can be expected keeping in mind earlier studies of this industry (e.g. Hakimov and Scholz, 2010). However, the correlation between *PAX* and *ATM* is considerably reduced by the transformation. Without transformation the correlation between *PAX* and *ATM* is 0.993.

4.2 Estimation Results

Estimation results by applying the empirical data in the panel data cost function in equation (2) are presented in Table 4 along with the results from the pooled data model in equation (1). The proportion of variance explained, indicated by R^2, is generally high and the F-test indicates a good model fit. All estimated parameters have signs in accordance with the a-priori assumptions and are significantly positive at 1% level (2-tailed).

Further tests of the statistical properties of the pooled analysis indicate near extreme multicollinearity, with a mean VIF value of 12.6. This is an expected consequence of the close relationship existing between the independent variables presented in Table 3. This leads to high standard errors but is not a violation of OSL regression assumptions (e.g. Wooldridge, 2006). A study of the residuals shows a mean value of about 0 and a peaked distribution. The error term is not significantly correlated to any of the independent variables. Hence, the statistical properties are generally good and indicate that the estimation results from the OLS regression can be trusted.

Table 4. Estimation results for pooled OLS and random effects (GLS)

Variable		*Pooled OLS*			*Random effects (GLS)*		
		Coefficient	Std. dev.	t-value	Coefficient	Std. dev.	t-value
β_0	Constant	2.06×10^7	1084468	19.0	1.98×10^7	1604496	12.3
β_1	X_1 (*PAX*)	31.95	1.18	27.0	33.61	1.71	19.7
β_2	X_2 (ln*ATM*)	7234523	1178193	6.1	5974870	1709082	3.5
β_3	D_1 (Category)	1.57×10^7	1667474	9.4	1.54×10^7	2493248	6.2
β_4	D_2 (OSL)	8.26×10^8	1.90×10^7	43.5	8.01×10^8	2.75×10^7	29.1
Rho		N.A.			0.52		
R^2 (Overall)		0.9988			0.9988		

Both pooled OLS and Random effects GLS returned quite similar coefficients for the estimated parameters. In the following the panel data estimates are used. The estimation in Table 4 indicates that the long-run marginal costs for handling an extra passenger (*PAX*) are NOK 34. According to the derivative presented in Section 2, the costs for an extra air traffic movement (*ATM*) amount to about NOK 439 and do not depend on the weight of the plane.[10] Values must be doubled if only departures are charged. Fixed costs amount to about NOK 20 million per year, with an additional element of NOK 15.4 million if the airport qualifies for category 3 or 4. Finally, for the main airport OSL, the total costs shift positively to the extent of about NOK 80 million. In comparison, Mathisen et al. (2012),

[10] If $\beta_2 = 5974870$ (see Table 4) and mean $ATM = 13625$ (see Table 2), then $\frac{\partial C}{\partial ATM} = \frac{\beta_2}{ATM} \approx 439$. The use of average ATM is a simplification implying that airports with more (less) traffic will have a lower (higher) value.

using untransformed variables only and excluding OSL, estimated the coefficients for *PAX* and *ATM* to be NOK 27 and NOK 604, respectively.

The fixed effects model (within-group) is not suited for this analysis since there is no variation over time for the dummy variables. Hence, D_1 and D_2 are excluded in the fixed effects analysis. The within-group estimation gives a correlation between the unobserved individual effects and the explanatory variables of 0.83. About half of the variation in operating costs is explained by the unobserved individual effects (rho) which can be properties such as quality and organisational structure. The random effects combination of between-group and within-group estimates give a median theta value of 0.515, thus lending some weight to the within estimator and indicating that the random effects method, using both within and between variations, will be optimal. However, some tests of the underlying assumptions must be carried out to determine whether the random effects model is appropriate.

The correlation between the error term, ε_{it}, and the explanatory variables is close to zero and not significant. Furthermore, the Breusch-Pagan Lagrange multiplier test, assessing whether random effects should be used instead of pooled data, strongly rejects the null hypothesis in favour of the random effects model. The Hausman test, checking whether regressors are uncorrelated with individual effects, satisfies the 5 % significance level and indicates that the random effects model is consistent and also provides the best unbiased estimates.

5. Marginal Cost Based Charge Schemes

The Norwegian Ministry of Transport and Communication has stated three main objectives for the revised charges for airports owned by Avinor. First, all requirements of the EU (2009) directive for airport charges must be met. Second, the new charges should to a larger extent than current charges be based on the principles of welfare economics. Finally, there are budget (revenue) restrictions stating that the new charging system should be revenue neutral. Additionally, it has been common practice that charges are equal for all airports throughout the country. This is regarded as fair since passengers in all parts of the country are treated equally. However, this condition must be relaxed if e.g. Ramsey pricing or peak-load pricing is to be implemented. Price differentiation between airports or between time periods is feasible, but this is ultimately a political decision and the principle of equality is strongly rooted in the Norwegian political system.

5.1 Charges Based on Marginal Costs Only

Marginal costs (MC) derived by using the parameter values $\beta_1 = 33.61, \beta_2 = 5974870$ and $ATM = 13625$ are presented in relation to Table 4. These values are valid for both departure and arrival, implying that estimated values are multiplied by 2 if charged only once per trip. Hence, the marginal cost based airport charges imposed on the air transport companies increase by NOK 67 (NOK 33.6×2) for each passenger and by a fixed element of NOK 878 (NOK 439×2). Hence, the model specification implies that the ATM charge is the same for aircrafts of all sizes. However, the increased importance of the PAX element indirectly ensures a differentiation in charges according to plane size. For example, a 39 seat Dash 8-100 and a 189 seat Boeing 737-800 would have charges of NOK 2861 and NOK 10526, respectively, assuming here 80% capacity utilization.

It should be noted that this *ATM* charge is based on the average traffic volume for all airports in the network. Due to the ln-specification in (1), the marginal cost based *ATM* charge will depend on the number of *ATM*. The derivative with respect to *ATM* implies that airports with high traffic should have a lower *ATM* charge with the opposite applying for smaller airports. Setting charges according to this rule would be problematic from a regional policy perspective, in that the airports with low traffic are usually located in rural areas where the airport is regarded as an important mainstay for continued settlement and further economic development.

A comparison between these marginal cost charges and current charges shows that, on average for domestic and international flights, *ATM* charges are reduced from NOK 4296 to NOK 877 for an average aircraft and *PAX* charges are increased by NOK 21 (see average values in section 2.2). This corresponds to a reduction of 80% for *ATM* and an increase of 46% for *PAX*. Consequently, marginal cost pricing implies a significant transfer in taxation from *ATM* to *PAX*. This indicates that even though both elements should still be taxed, a considerable shift towards charging *PAX* should be implemented.

Seen in isolation, marginal cost pricing following the estimates above will reduce revenues by NOK 635 million. Hence, passengers will experience lower fares, thus stimulating increased demand for air transport. If we assume that 50% of the change in charges is transferred to the passengers[11] and a price elasticity of -1.0, then an average ticket price will be reduced by NOK 18. If we assume the

[11] To what extent a change in charges is passed on to passengers is discussed by Jørgensen and Santos (2011). They show that this proportion is always 50% in the case of linear curves under monopoly. However, for subsidized PSO routes the situation would depend on whether the authorities change the maximum fares accordingly and compensate the carrier. If reduced charges lead to an equal (or no) reduction in the regulated maximum fares, then all (or no) changes in charges will be transferred on to the passengers. On other discounted tickets, where prices are set freely in the market, it can be assumed that the normal market mechanism applies.

normal price to be NOK 1000, then the number of passengers will increase by about 1.8%. The increased number of passengers will not only impose an extra cost for the airports; they will also generate commercial revenues. Bearing in mind the increase in commercial revenues, the total revenue loss for Avinor is estimated at NOK 577 million.

5.2 Adjustment to meet the Revenue Restriction

A consequence of marginal cost pricing is that total revenues are reduced by about NOK 577 million compared to the current charge scheme for Norwegian airports. Several approaches can be chosen to meet the 2009 budget, or revenue, restriction. If total revenues generated from charges are kept at the same level, then the amount passed on from carriers to passengers can be assumed to equal those in the current charge scheme. Hence, for the purposes of simplicity, the number of *PAX* and *ATM* remains unchanged, as compared to that explained in Section 2.2. This is of course a debateable issue as a substantial amount of charges are charged on *PAX* instead of *ATM;* but we have no indications of the direction of any possible differentiations.

A simple measure would be to raise all marginal costs elements by the same factor, relatively speaking, that is sufficiently high to match the revenues generated by the current charge scheme. Such an adjustment would raise the airport charges above the marginal cost by 43% to NOK 96 for *PAX* and NOK 1255 for *ATM*.

Another well-recognized approach to meet revenue restrictions is to use the differences in air travellers' price elasticity throughout the country using the Ramsey-rule. Ramsey-pricing has, to our knowledge, not been used at Norwegian airports, but charges could, in principle, be differentiated at airport level. The diversity in airport location from rural areas to large cities enables differentiation according to the presence of alternative transport for passengers. The price elasticity will be less negative (less price sensitive), if there are few alternative transport forms. Hence, such airports should have a higher rise in marginal costs than airports located in regions with many transport alternatives. However, in the same way as for differentiation of the *ATM*-charge according to traffic volume, Ramsey pricing according to these criteria could also be problematic from a regional policy perspective since the group with few alternatives (which would get the highest raise) is usually located in rural areas where the airport itself is regarded as an important means for further economic development. An example of the implementation of the Ramsey-rule at Norwegian airports according to these criteria is given by Jørgensen et al. (2011) accompanied by airport specific assumptions of elasticities and to what extent a change in charges is transferred on to passengers.

Following the assumptions made by Jørgensen et al. (2011), the charges vary from NOK 82 to NOK 245 for *PAX* and NOK 1068 to NOK 3211 for *ATM* when using Ramsey pricing to meet the revenue restriction. However, if one considers that smaller airports rarely meet the capacity limit, then charges should be set according to short-run marginal costs. The fact that short-run estimates are lower than long-run estimates implies that the differences addressed above are reduced. This study addresses only long-run marginal costs, and we are thereby unable to carry out these calculations.

5.3 Taking into Account the Costs of Raising Public Funds

The deficit arising from marginal cost pricing must be financed by the state. Hence, it needs to be addressed whether the raising of public funds to finance revenue loss has any welfare economic consequences. The costs for general taxation have been studied empirically and The Norwegian Ministry of Finance (2005) has concluded that an add-on factor of 20% should be used as a rule.

The welfare optimal charges, given that the loss of revenues must be financed by the state, can be derived by maximization of social surplus under budget constraint. When solving the Lagrange function, the expression for optimal price, *P**, can be rephrased as in equation (3).

(3) $$P^* = \frac{\partial C/\partial X}{1+\frac{\tau}{EL_P X}} \text{ where } 0 \leq \tau = \frac{\lambda}{1+\lambda}$$

In (3) P^* is optimal price, $\partial C/\partial X$ denotes marginal costs, *X* is the demand for airport services, $EL_P X$ is the price elasticity and λ is the Lagrange multiplier. Since $EL_P X$ has a negative value, it is required that $|EL_P X| > \tau$ to ensure that $P^* > 0$. The factor λ represents the reduction in social surplus when the requirement for profit is increased by NOK 1. Hence, λ can be interpreted as the welfare loss occurring due to taxation. If $\lambda = 0$ then $\tau = 0$ and the optimal charge will, according to (3), be equal to the marginal cost. A rephrasing of (3) can be made in order to show more clearly the adjustment factor, *F*, for marginal costs under the revenue restrictions presented in (4).

(4) $$P^* = \frac{\partial C}{\partial X} \times F \text{ where } F = \frac{1}{1+\frac{\tau}{EL_P X}},\ 0 \leq \tau = \frac{\lambda}{1+\lambda} \text{ and } |EL_P X| > \tau$$

It is evident from (4) that *F* increases when λ increases (higher taxation costs) and when $|EL_P X|$ is reduced (lower price sensitivity). It can be derived from (4) that the value of *F* is 1.26, 1.20 and 1.16 for price elasticities of -0.8, -1.0 and -1.2, respectively, given a welfare loss by taxation of $\lambda = 0.2$. Hence, assuming a price elasticity of -1.0 and The Norwegian Ministry of Finance (2005) recommendations of taxation costs, the optimal charges based on long-run marginal costs when considering cost of raising public funds are NOK 80 for *PAX* and NOK 1054 for *ATM*. These charges make a loss for Avinor of about NOK 332 million.

6. Conclusions and implications

This article presents the results from a project initiated by the Norwegian Ministry of Transport and Communication aiming to derive airport charges more in line with the principles of welfare economics. A multiple regression model using panel data analysis is applied to derive marginal costs for passengers (*PAX*) and air traffic movements (*ATM*), these being the two main production measures at airports. The empirical data consists of accounting and production figures for all 46 Norwegian publicly owned airports for the years 2007 to 2009.

When disregarding the social cost of raising public funds, it is well recognized that marginal cost pricing produces the highest social surplus and is therefore desirable from the perspective of welfare economics. Under reasonable assumptions regarding travellers' price elasticity and using the Ministry's recommendations for the costs of raising public funds, airport charges should be raised by about 20% above marginal costs when aiming to maximize airports' social surplus. If the charges aim to generate the same revenues as the current charge scheme, the values should be raised by an even higher factor.

The derived values for the three different marginal cost based charge schemes discussed above are summarized in Table 5 along with the current charge scheme. For all marginal cost based charge schemes using raised values the adjustment factor is similar for *PAX* and *ATM*. This simplification is made because there is no empirical evidence of how the adjustment factor should be differentiated. Table 5 also shows the consequences of changing the charges for total revenues.

Table 5. Charge schemes based on long-run marginal costs (MC) and current charges (NOK).

	PAX	*ATM*	*ΔRevenue*
Marginal cost (MC) pricing	67	877	-577 million
MC pricing adjusted for welfare loss	80	1054	-332 million
MC pricing adjusted to 2009 revenue	96	1255	0
Average charges in 2009	46	4296	0

Some changes can be suggested if using marginal cost based charges as compared to the current scheme. There should be a shift towards a relatively higher charge put on *PAX* compared to *ATM.* For example, if revenues are to be held at the 2009 level but based on marginal costs, the *ATM* charge is NOK 1255 compared to NOK 4296 based on the current charge scheme. This is in accordance with

IATA's (2010) recommendations that, wherever possible and practical, airports should move over to passenger-based charges. The benefits are related to improved accountability for passengers and a lower risk for airline companies. In isolation, such a change will make a higher proportion of the carriers' costs variable and, thereby, reduce the cabin factor required to establish new routes. Moreover, more emphasis on PAX charges ensures that larger and heavier aircraft are charged more greatly than small planes even though the ATM charge is independent of the maximum take-off weight (MTOW).

A well-recognized means of meeting budget restrictions using marginal costs is to utilize the differences in price elasticity (Ramsey pricing). An application of this method implies imposing the highest adjustment factor on the regional airports where demand is inelastic due to few alternatives to air transport. This is not an acceptable solution from a regional policy perspective where airports are used as a means of maintaining settlement and providing economic development for rural areas. However, since there is considerable spare capacity at regional airports, it is reasonable that these charges should be set on the basis of short-run marginal costs. Based on such an argument, the charges set should be quite low. However, the use of Ramsey pricing and different marginal cost concepts is not possible in the current uniform charge system since this implies that the authorities would have to allow charges to vary between airports.

Even though the data set contains objective information which is considered reliable, there is a potential for further improvements in the analysis should a more detailed data set be made available. This particularly applies to separating costs related to the inside area (e.g. terminal) and the airside area (e.g. runway system). Such data would enable us to run econometric regressions on inside costs using *PAX* as an independent variable and on airside costs using *ATM* as an independent variable. Analyses would then be even more accurate and multi-correlation problems could be avoided.

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