

Pricing of Airport Operations

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Abstract

It is demonstrated how an analysis of airports' cost structures and the calculation of long-run marginal costs (MC) of serving passengers and airplanes can be used as a basis for setting airport charges according to the principles of welfare economics. Based on Norwegian data, the MC for an extra passenger (PAX) and extra air traffic movement (ATM) are used to set airport charges under the assumption that the charges should be equal for all airports in the country. When adjusting the estimates to meet revenue restrictions and comparing the estimates to current charges, we observe that PAX should be charged more and ATM less. This finding is in line with recommendations from the International Air Transport Association (IATA). When allowing charges to vary between airports, we demonstrate how a Ramsey pricing approach can be applied to set differentiated PAX and ATM charges, considering both the supply side (the competitive conditions between the airlines operating at the airports) and the demand side (the passengers' price elasticity of demand).

Keywords: airports, air traffic movements, marginal cost pricing, aviation charges, Ramsey-style pricing

1. Introduction

Airport infrastructure is, in most countries, financed by airport charges for the services offered at the airport together with revenues from commercial activities (Losada et al., 2012). International air transport organizations that aim to standardize airport charges have a general policy stating that charges, amongst other things, should be based on costs and should be non-discriminatory (ICAO, 2009; Martin-Cejas, 1997). Most airports charge both passengers (PAX) and air traffic movement (ATM). However, there are variations with respect to the distribution of charges between PAX and ATM both between countries and based on type of airport ownership (e.g. Graham, 2013). The similarity in the charging structure has occurred because most countries have adopted the recommendations made by the International Civil Aviation Organisation (ICAO) and the International Air Transport Association (IATA) for the standardisation of airport charges.

Because of the influence that airport charges have on airport financing and the economics of airlines, the charging policy draws the attention of many stakeholders. From the airlines' viewpoint, the design of airport charges is important since they directly affect their operating costs. According to Doganis (2010), airport and en-route charges represent approximately 7 percent of total operating costs for ICAO member airlines on average. For low-cost operators flying short-haul operations, this share can be as high as 25 percent. Although the aeronautical charges constitute a small part of most airlines' total costs, a more competitive airline environment and falling yields have resulted in airlines giving their external costs, such as airport charges, greater attention (Graham, 2013).

From the airports' viewpoint, the income from airport charges must provide a secure basis for airport operations and future infrastructure investments. Hence, for many airports, it appears that the motivation in setting charges is financing concerns rather than economic efficiency concerns. Because the efficient allocation of airport resources necessitates that the charges reflect the costs that each flight imposes, the shortcomings of traditional pricing policies makes alternative pricing strategies, such as marginal cost pricing or Ramsey pricing, interesting. However, since marginal cost pricing does not cover total costs, the charges must be increased above the marginal costs when budget constraints exist. The Ramsey rule helps us to set charges in an economically optimal way (Button, (2010). A simple interpretation of this rule is that it is a form of price discrimination where charges are set based on the consumer's ability to pay.

Aviation charges based on a Ramsey pricing approach has been discussed both principally and empirically in the literature on airport pricing. Morrison (1983) developed a pricing model for uncongested airports by using the Ramsey rule with profit constraints. Based on a hypothetical 'representative' airport, Morrison (1983) found that the take-off charges increased too rapidly with the aircraft weight, and based on 'Ramsey thinking', he recommended to increase the charges for small planes on long flights and decrease the charges for large planes on short flights. A numerical example with the use of the Ramsey rule in setting aviation charges is given by Martin-Cejas (1997). He analyses the structure of landing charges at uncongested airports in Spain using the same model formulation as Morrison (1983). In Martin-Cejas (1997), the charges depend on the marginal costs of airport operations (differentiated by aircraft size and flight distance) and the price elasticity of demand (dependent on trip distance). The results from the analysis shows the same trend as found in Morrison's work. The model was further extended by including CO₂ emission costs (Martin-Cejas (2010). The analysis with emission costs imposes a penalty ranging from 70 percent to almost 100 percent for all planes and distances compared to the analysis without emission costs. Hakimov and Mueller (2014) present a list of landing charges for five uncongested German airports using Ramsey pricing. The calculated charges are compared to the actual weight-based charges at these airports. Unlike Morrison and Martin-Cejas, Hakimov and Mueller (2014) found that Ramsey prices increase with distance and aircraft weight faster than the real charges, especially in short-distance markets. However, they note that the difference between the theoretical optimum and practice needs to be better understood.

The aim of this chapter is to demonstrate how estimates of the marginal cost of serving passengers and airplanes can be used as a basis for setting airport charges according to the principles of welfare economics. Attention is also given to the effect of the pass-on rate and to what extent a change in charges is passed on to the passengers via the ticket price. The empirical evidence is based on a project initiated in 2010 by the Norwegian Ministry of Transport and Communications with the main objective of revising present airport charges based on principles of economic welfare under revenue

restrictions. Some results from this project are discussed by Jørgensen et al. (2011) and Mathisen et al. (2014).

The remaining of this chapter is organised as follows: Section 2 provides a brief presentation of the Norwegian airport network, the structure of the airport charges and marginal cost estimates for airport operations in Norway. In section 3 the marginal cost estimates are applied in new schemes for national airport charges, where the cost of raising public funds is also taken into consideration. In section 4, an example of how Ramsey thinking can be used to differentiate charges between airports is considered. Finally, in section 5, we present conclusions and implications from this study.

2. Norwegian airport network, airport charges and operating costs

Most Norwegian airports are operated by the state-owned company Avinor (see e.g. Lian, 2010) according to commercial principles. In total, the airport network in Norway does not require state subsidies, but there is substantial cross-subsidization between the largest airports and those located in rural areas. The total operating costs vary considerably between the airports due to the different sizes and amount of traffic, as does their cost efficiency (GAP, 2012). In this section, we will elaborate on the airport network in Norway, the way in which the infrastructure is financed through charges imposed on airlines, and show the results from an analysis of the cost structure.

2.1 Norwegian airport structure

Norway has some of the highest air transport dependence in Europe (Williams et al., 2007). While Norway had a domestic air trip rate per capita of 2.27 in 2003, most European countries had less than one-third of this value. The airports in the network represent a heterogeneous group. One part is characterised by airports with high traffic volume near the largest cities. A second part includes airports characterised by low traffic and a location in what can be classified as peripheral areas (Kjærland and Mathisen, 2012). These airports contribute to Norway having the highest number of commercial airports with short runways (<1000 m) in Europe (Williams et al. (2007).¹ Despite its low population level, several routes in Europe with the highest frequency and number of passengers are found domestically in Norway (<http://ec.europa.eu/eurostat>).

To maintain a satisfactory provision of the routes at the local airports, the Norwegian Ministry of Transport and Communications procures air transport services at 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 percent of all restricted PSO routes. In 2014, the government spent approximately NOK 677² million (€ 75 million) to subsidize PSO operations to and from these airports. The subsidized contracts are awarded as net contracts using competitive tendering every fourth year (in the southern part of Norway) and fifth year (in the northern part of Norway). The PSO regulations give the winning operator exclusive rights to operate the defined routes with a predetermined set of quality factors such as frequency, size of aircraft and maximum fare level. In 2017, the air transport company Widerøes, the largest regional airline company in Scandinavia, operates almost all Norwegian PSO routes.

¹ Short Take-Off and Landing (STOL) planes, such as the Bombardier Dash-8 100 (DHC-8), operates in local airports with runways as short as 800 m. Local airports with sufficiently long runways are, in some cases, operated by jet planes.

² For all conversions from the Norwegian kroner (NOK) to Euro (€), we have assumed that € 1 ≈ NOK 9.

The state-owned company Avinor owns and operates 45 airports and one helipad in Norway with a total annual traffic of approximately 51 million terminal passengers (PAX) in 2016. Avinor organizes the airports into three groups in which the main airport of Norway (OSL), located near the capital city Oslo, comprises the first 'group'. The three other large airports located near the cities of Bergen (BGO), Stavanger (SVG) and Trondheim (TRD) comprise the second group, and the remaining 41 airports comprise the third group, as illustrated in Figure 1.

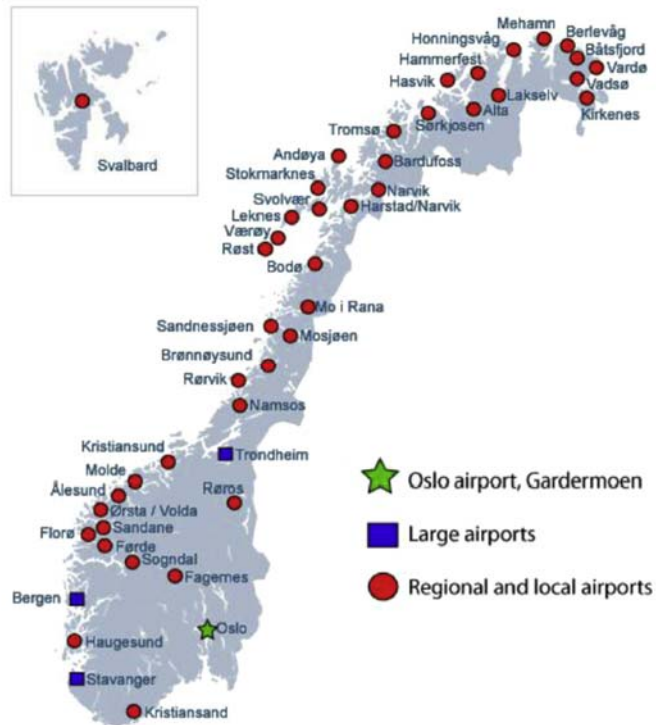


Figure 1: Norwegian airports owned by Avinor.

In 2016, OSL had 25.8 million terminal passengers, the airports in the second group had an average of 4.8 million terminal passengers, and the airports in the third group had an average of 0.26 million terminal passengers (Avinor, 2016). The main part of the third group consists of 28 local airports characterized by particularly low traffic (50,000 terminal passengers on average in 2016). At these airports, virtually all passenger traffic is subject to PSO. The remaining regional airports are in more densely populated areas, and air traffic is based on routes operated on a commercial basis. However, the road infrastructure has improved since most small airports were built approximately 45 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). Consequently, there is an ongoing debate on the future structure of the local airport network in Norway.

2.2 Current airport charges

The general purpose of Avinors' charging policy is to provide revenues that allow the company to accomplish the tasks that their owner has instructed them to complete. Primarily, this means that the charges should be considered compensation for services related to air navigation, the operation of airports and security. However, in addition, the aviation policy shall fulfil a number of other goals. The policy shall ensure operating efficiency and at the same time consider social considerations, such as the effects on settlement and economic development in rural areas, as well as environmental considerations. The aviation policy shall also aim to ensure competition between airlines and must comply with international rules in this area (The Norwegian Ministry of Transport and Communication, 2012).

The airport charges imposed on air traffic in Norway are composed of five elements³: the take-off charge, passenger charge, security charge, TNC (Terminal Navigation Charge) and en-route charge.⁴ The security charge, TNC and en-route charge are set to cover Avinors' costs of providing these services. Avinor sets the two remaining categories, the take-off charge and passenger charge — which are the focus in this article — according to guidelines from the Norwegian Ministry of Transport and Communication. The take-off charge is weight-based, and the passenger charge is levied per departing passenger. This is also the basic pricing structure for most airports from different countries (Graham, 2013; Martin-Cejas, 1997). Avinor also generates revenues from commercial activities, such as rent from shops, tax-free sales and parking. The authorities do not regulate prices for commercial activities. The total revenue for all airports operated by Avinor is almost evenly distributed between air transport charges and commercial activities.

The basis for the present study is the airport charge system and the airport charges in 2009.⁵ This forms a reference year for all comparisons between revised and present charges. The charges in NOK for 2009 and 2016 are shown in Table 1. In 2009, passenger charges were NOK 36 and NOK 59 for domestic and international flights, respectively. The take-off charge was NOK 96 per tonne based on the aircrafts' maximum take-off weight (MTOW). For particularly large aircrafts, the charge was reduced to NOK 48 per tonne exceeding 100 tonnes. Consequently, an aircraft with an MTOW of 70 tonnes was required to pay a take-off charge of approximately NOK 6,700. 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 1,280 million, respectively. This yields NOK 23 per PAX and NOK 2,150 per ATM on average (the figures can be doubled since a departure and arrival is charged only once). This implies that an average ATM in 2009 was approximately 45 tonnes. The entire ATM scheme was revised in 2011 when part of the take-off charge was collected as a Terminal Navigation Charge (TNC).

³ All taxes are charged to the airlines once per trip. Charges passed on to passengers are paid as part of the ticket price. A trip (without transfer) includes two air traffic movements (ATM) and visits at terminals at both departure and landing. It is, however, not typical for these services to be charged 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 centres of Avinor. The TNC was introduced in 2011 to cover the control tower operating costs and was designed as a concavely increasing function of airplane weight (MTOW). Before 2011, this charge was included in the take-off charge. The charges for security, tower services and en-route costs are changed when the costs or traffic amount changes.

⁵ The reason for using this reference year is that the analysis of the cost structure at Norwegian airports is based on a research project initiated by the Norwegian Ministry of Transport and Communications, where cost data for 2007, 2008 and 2009 for all airports owned by Avinor formed the basis of the analysis.

Table 1: Aviation charges of Norwegian airports owned by Avinor in 2009 and 2016. Numbers are in NOK.

Charge type		2009	2016
ATM charge (MTOW)	<75 tonnes	96	64
	75-100 tonnes		32
	100-150 tonnes	48	
	>151 tonnes		
PAX charge	Domestic flights	36	54
	International flights	59	54
	Security charges	60	56
Terminal navigation charge (TNC) ^a		0	1,251
En-route charge ^b		547	381

^a TNC per service unit. The number of service units is calculated based on the formula $(MTOW/50)^{0.7}$.

^b The en-route charge is a per-unit rate. The charges are set by Eurocontrol and vary between states (charging zones); see www.eurocontrol.int/articles/establishing-route-charges.

2.3 Costs at Norwegian airports

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. The most central output measures when studying airports are the number of passengers (PAX), the number of air traffic movements (ATM) and the amount of freight (FRT) handled (Graham, 2013). Since most airports handle both passengers and freight, an output measure that combines the two, such as work load units (WLU), can be used. The WLU uses a weight criteria for combining these two types of traffic; one WLU equals one PAX or 100 kg of FRT. This output measure has, however, been shown to be imprecise and vague and therefore has rarely been used in recent studies (see e.g. Martín and Voltes-Dorta, 2011). Ideally, the WLU-formula includes an ATM element. An example of such an output measure is the air throughput unit (ATU) (LeighFisher, 2012). This output measure implies that 1 tonne of freight counts the same as handling 10 passengers. Moreover, one additional ATM counts the same as handling 100 passengers. However, as freight handling at airports is very much an airline activity, it has little impact on an airport's economic performance, and the focus should be on PAX and ATM. Thus, we are left with the output measures PAX and ATM as the most relevant variables to use when analysing the cost structure at airports. However, a potential problem for econometric analyses is that these two explanatory variables are highly correlated; when PAX increases, the number of ATMs will also increase to meet the increased demand and vice versa. The use of ATM is also not ideal because it does not differentiate between aircrafts of different sizes.

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, accounting for approximately 96 percent of the variation in costs between airports. Morgado and Macario (2012) estimated the marginal costs at Portuguese airports and used these to suggest new charges. Our demonstration of Ramsey-style pricing is based on a cost study by Mathisen et al. (2014) using both PAX and ATM in a model estimating the marginal costs of airport operations in Norway.

The panel data model applied by Mathisen et al. (2014) is presented in Equation (1) and argued to have properties in accordance with reasonable a priori assumptions regarding the cost structure at Norwegian airports. It is clear from Equation (1) that the marginal cost with respect to $PAX = X_1$ is

$\partial C/\partial PAX = \beta_1$. To reduce multicollinearity, the independent variable ATM is processed using a deviation from both a mean transformation and logarithmic transformation. Since it is reasonable to consider the mean value, $\ln\overline{ATM}_t$, to be a relatively constant variable, the marginal cost for ATM is $\partial C/\partial ATM \approx \beta_2/ATM$.

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

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

The cost function in Equation (1) estimates the total operating costs measured in Norwegian kroner (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 the airport. The independent variables, X_{1it} and X_{2it} are observable time-varying factors. Moreover, X_{2it} is represented by a deviation from the annual mean for 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 $D_{1i} = 1$.⁶ 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 regional and local airports defined in Section 2.1. This separation is important, since runways shorter than 1199 meters are not suited for jet planes. Since D_{1i} is an imprecise and weak indication of capacity, the estimates can be interpreted as long-run.⁷ The dummy variable D_{2i} is defined as 1 if the observation relates to the main national airport OSL (Oslo airport, Gardermoen), 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 airports and time and can be thought of as the usual disturbance term in the regression (see e.g. Wooldridge, 2006).

The data set analysed by Mathisen et al. (2014) consists of annual observations of production and accounting figures for all 45 airports owned by Avinor for the years 2007, 2008, and 2009. 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 (2016). All airports have reported the figures for all three years, and this is consequently a balanced data set without missing values. Consequently, the selection in the data set is a complete representation of

⁶ 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 the investments and operation costs. The difference between the categories is most easily seen by the runway length and safety zones.

⁷ Although the cost function assumes airports minimize long run costs, there are some costs required by aviation authorities that are relatively independent of the number of passengers or the size of the airport.

the population since all Avinor airports are included, and the three years with 45 airports comprise a total of 135 observations. The mean values for the variables *PAX* and *ATM* are 860,410 and 13,625, respectively. 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 approximately NOK 40 million.

The cost estimations derived by Mathisen et al. (2014) are presented in Table 2. The random effects model, using both within and between variations, is argued by Mathisen et al. (2014) as consistently providing the best unbiased estimates. The unobserved individual effects (ρ) explain about half of the variation in operating costs, which can be properties such as quality and organisational structure.

Table 2: Estimation results.

Variable		Random effects (GLS)		
		Coefficient	Std. dev.	t-value
β_0	Constant	1.98×10^7	1,604,496	12.3
β_1	X_1 (<i>PAX</i>)	34	1.71	19.7
β_2	X_2 ($\ln \text{ATM}$)	5,974,870	1,709,082	3.5
β_3	D_1 (Category)	1.54×10^7	2,493,248	6.2
β_4	D_2 (OSL)	8.01×10^8	2.75×10^7	29.1
Rho		0.52		
R ² (Overall)		0.9988		

The results in Table 2 indicate that the long-run marginal costs for handling an extra passenger (*PAX*) are rounded to NOK 34. According to the derivative presented in Section 2, the costs for an extra air traffic movement (*ATM*) amount to approximately NOK 439 and is an average value independent of the weight of the plane.⁸ Fixed costs amount to approximately NOK 20 million per year, with an additional element of NOK 15.4 million if the airport is large (qualifies for category 3 or 4). Finally, for the main airport OSL, the total costs shift positively by approximately NOK 800 million.

3. Marginal cost-based airport charges

The Norwegian Ministry of Transport and Communications have decided that airport charges at airports owned by Avinor should be based on three main objectives of the Directive 2009/12/EC of the European Parliament (2009). This implies:

- Improving the transparency of the costs and related charges: Avinor must present the allocation of their costs to their users and thus justify the calculation of airport charges.
- Prohibiting discrimination between users: airlines receiving the same service at a given airport must pay the same charge. A differentiation of charges should be based on clear and transparent criteria.
- Establishing consultation mechanisms: Avinor must consult their users before setting charges.

⁸ If $\beta_2 = 5,974,870$ and average $ATM = 13,625$, 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.

In addition to the bullet points, the above charges should, as much as possible, be based on the principles of welfare economics. Changes in charges should generate approximately the same revenues as the current charge (revenue neutrality), and the charges should be equal for all airports throughout the country.

3.1 Price equal to long-run marginal cost

Estimates of long-run marginal costs (MC) were discussed in relation to Equation (1). MC-values are valid for both departure and arrival, implying that estimated values are multiplied by 2 if charged only once per trip. Hence, in 2009, the prices of the marginal cost-based airport charges imposed on air transport companies should amount to NOK 68 (34×2) for each passenger and by a fixed element of NOK 878 (439×2) for each air traffic movement. 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, when using these figures and assuming a load factor of 80 percent, a 'landing and take-off' procedure with a Boeing 737-800 (186 seats) and a Dash 8 100 (39 seats) will be charged NOK 10,996 and NOK 3,000, respectively.

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 Equation (1), the marginal cost-based ATM charge will depend on the number of ATMs independent of the size of the aircraft. The derivative with respect to ATM implies that airports with high traffic should have a lower ATM charge, with the opposite applying to smaller airports. While marginal cost based pricing suggests lower ATM charge at larger airports, setting charges based on this rule is problematic in meeting the Norwegian Ministry of Transport and Communications' directive that charges should be equal for all airports. Moreover, it is difficult from a regional policy perspective because 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. However, it is possible to differentiate the ATM charge with respect to the size of the aircraft by taking into account that an average ATM has an MTOW of 45 tonnes. If it is assumed that the marginal cost of an ATM increases linearly with tonnage, an ATM could be charged 20 NOK per tonne ($878/45$), instead of a flat rate per movement. With this approach, a Boeing 737-800 (79 tonnes) and a Dash 8 100 (16 tonnes) would be charged NOK 1,580 and NOK 320, respectively.

A comparison between these marginal cost-based charges and charges in 2009 shows that, on average for domestic and international flights, the ATM charges are reduced from NOK 4,300 to NOK 878 for the average ATM, and PAX charges are increased from NOK 46 to NOK 68 (see average values in Table 3, which compares ATM and PAX charges under various charge schemes). This corresponds to an average charge reduction of 80 percent for ATM and an increase of 48 percent for PAX. Consequently, marginal cost pricing implies a significant shift in taxation from ATM to PAX. This indicates that even though both elements should still be taxed, the PAX charge should be increased and the ATM charge reduced.

However, if marginal cost pricing is implemented, there would be large reductions in total revenues. Appendix 1 provides an estimate of the reduction in revenues that would occur with marginal cost pricing under reasonable assumptions. For example, if we assume that 50 percent of the change in

charges is transferred to the passengers⁹ and an average price elasticity of demand of -1.0, setting PAX and ATM charges according to MC will reduce the annual revenues for Avinor by NOK 602 million. The corresponding reduction in ticket prices increases the number of passengers, which both raise commercial revenues and impose increased operating costs on Avinor. Bearing this in mind, the total profit change for Avinor is estimated to be NOK 571 million. See the details in Appendix 1, which form the basis for the figures in Table 4.

Thus, a consequence of MC pricing is that the total revenues are reduced from the present level. This is because the existing ATM charge is far above MC. Recall, however, that the Norwegian Ministry of Transport and Communications' directive states that changes in charges should be revenue neutral. Several approaches can be chosen to meet the revenue neutrality restriction. The first is to assume that a constant mark-up can be applied to PAX and ATM to keep total revenues at current levels without affecting the number of passengers. A second, more realistic approach, is to consider the costs of raising public funds and changes in the number of passengers resulting from the change in prices. These approaches are highlighted in the following sections, along with estimates of the PAX and ATM charges that would ensue (Table 3), the consequences for the airport owner (Table 4), and the overall welfare effects (Table 5). Details regarding estimated impacts of these approaches are discussed in the following sections and in Appendices 1 and 2.

3.2 Charges adjusted to meet revenue restrictions (revenue adjusted MC)

One way to secure that total revenues from the revised charging system will meet the target level of 2009 is to apply constant mark-ups to both PAX and ATM. Since total revenues remains unchanged, we assume that the number of PAX and ATMs does not change. However, it could be argued that a given percentage increase in the ATM charge will have a relative larger impact on the number of ATMs than a corresponding change in the PAX charge will have on the number of passengers. This is because an increased ATM charge directly influence the airlines' costs by operating at an airport, and thereby leads to supply changes that could influence demand. Consequently, in practice it is likely that the number of PAX and ATMs would change somehow. However, we do not have any unambiguous information on the impact on demand. Therefore, the calculations forming the basis for the figures presented in Table 4 and Table 5 assume unchanged demand and supply.

Following the tradition of setting airport charges (AC) equal for all airports, a reasonable approach is to raise all long-run marginal costs (MC) by the same factor (f) as indicated in Equation (2) — that is, adjusting the marginal costs to be sufficiently high to match the revenues generated by the current charge scheme.

$$(2) \quad AC = MC \times f$$

⁹ The extent to which a change in charges is passed on to passengers is discussed by Jørgensen and Santos (2014). They show that this pass-on rate is always 50 percent in the case of linear demand and supply curves under monopoly. In a situation with a duopoly, the pass-on rate will exceed 50 percent. However, for subsidized PSO routes, the situation would depend on whether the authorities change the maximum fares accordingly and compensate the operator. If reduced charges lead to an equal (or no) reduction in the regulated maximum fares, then all (or no) changes in charges will be passed 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.

In Equation (2), f is the relative mark-up on MC to meet the revenue restriction. Such an adjustment would raise the airport charges above MC by approximately 43 percent ($f = 1.43$) to NOK 97 for PAX and NOK 1,249 for an average ATM.¹⁰

3.3 Charges when considering the cost of raising public funds

If the deficit arising from MC pricing must be financed by the state, the question of whether the raising of public funds to finance the revenue loss has any welfare economic consequences should be addressed. The costs for general taxation have been studied empirically, and the Norwegian Ministry of Finance (2014) recommends a mark-up factor of 20 percent as a rule of thumb. The welfare optimal airport charges (AC^*), given that all loss of revenue is financed by the state, can be derived by the maximization of social surplus under budget constraint as in Equation (3 **Feil! Fant ikke referansekinden.**). Welfare optimal charges is obtained at the point where the impact on social welfare from increasing the amount raised through the charge is the same as the impact from raising it through taxes; see Appendix 2.

$$(3) \quad AC^* = MC \times f^* \text{ where } f^* = \frac{1}{1+\frac{\alpha}{e}} \text{ and } \alpha = \frac{\lambda}{1+\lambda} \leq 1 \text{ and } 0 \leq \alpha \leq 1$$

In Equation (3), e is the price elasticity of demand. The adjustment factor considering the costs of raising public funds, f^* , includes the parameter λ , representing the reduction in social surplus when the requirement for profit is increased by NOK 1. Hence, λ can be interpreted as welfare loss by taxation. If $\lambda = 0$, then $\alpha = 0$ and the optimal charge will, according to Equation (3 **Feil! Fant ikke referansekinden.**), be equal to MC.

From Equation (3 **Feil! Fant ikke referansekinden.**), it can be derived that f increases with λ (higher taxation costs) and decreases when $|e|$ increases (more price elastic demand). For example, 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 (2014) recommendations of the cost of raising public funds, the optimal charges based on MC are a PAX charge of NOK 82 and an ATM charge of NOK 1,054. As demonstrated in Table 4, these charges imply a revenue loss for Avinor of approximately NOK 295 million.

3.4 Consequences of long-run marginal cost pricing – a numerical example

Table 3 summarizes the results from the different marginal cost pricing strategies. It is clear from Table 3 that PAX should be charged more and ATM less. By comparing charges of equal revenue-adjusted MC with the PAX and ATM charges in 2009, we can calculate that the PAX charge increases by approximately 110 percent and the ATM charge decreases by approximately 71 percent (for an airplane weighing 45 tonnes). The benefits relate to improved accountability for passengers and lower risk for airline companies. More specifically, such a change will make a higher proportion of the operators' costs variable and thereby reduce the cabin factor required to establish new routes. Moreover, a higher emphasis on PAX charges ensures that large and heavy aircrafts are charged more than small and light aircrafts even though the ATM charge is independent of the aircraft size.

¹⁰ In the remainder of the chapter, all references to charges per PAX and ATM assume that only one charge applies per trip (i.e. twice the charge that would apply per departure and arrival).

Table 3: Charge schemes based on MC pricing and average revenues (2009 prices). Numbers are in NOK.

	PAX charge	ATM charge ^a
MC (no cost of raising public funds, $\lambda=0.0$)	68	878
MC (cost of raising public funds is 20%, $\lambda=0.2$)	82	1,054
MC (revenue adjusted)	97	1,249
Actual average charge in 2009	46	4,300

^a Using an average ATM in Norway in 2009 of 45 MTOW.

In the following discussion, we will study the consequences for different actors in the air transport market if MC pricing is implemented in greater detail.

3.4.1 Consequences for the airport owner (Avinor)

In Table 4, the consequences for the number of passengers, income and operating costs for all 45 airports owned by Avinor are summarized.

Table 4: Consequences for the airport owner Avinor of long-run marginal cost pricing. Numbers are in million NOK.

	2009 Actual	Setting price equal to MC	
		Cost of raising public funds	
		$\lambda = 0.0$	$\lambda = 0.2$
Number of passengers	35.8	36.4	35.9
Income from PAX and ATM charges	2,113	1,511	1,790
Income from commercial activities	3,016	3,069	3,044
Change in number of passengers	-	0.6	0.2
Change in charge income	-	-602	-323
Change in commercial income	-	53	28
Change in total income	-	-549	-295
Change in operating costs	-	22	15
Change in profit	-	-571	-310

The reference year is 2009, and the calculations are based on an average price elasticity of -1.0, an average ticket price one-way (in 2009) of NOK 1,000, and an average pass-on rate of 50 percent (the proportion of the change in charges passed on to passengers). This is, of course, a significant simplification since the airline companies are actively practising revenue management. The calculations are carried out assuming that the cost of raising public funds (λ) is either 0 percent or 20 percent. The calculation is shown in Appendix 1.

Under these assumptions, it is demonstrated in Table 4 that income from PAX and ATM charges are reduced, while income from commercial activities increases. However, for the airport owner, total revenues will decrease and profit will decrease more due to the growth in operating costs because of

the increased number of passengers. The yearly profit decreases by NOK 571 million and NOK 310 million when the charges based on MC are implemented when $\lambda = 0.0$ and $\lambda = 0.2$.

3.4.2 Consequences for the State

The consequences for the State will be the fiscal effects of the change in profits for Avinor. Assuming that the income in the reference year is necessary for Avinor to operate the airports and meet investment obligations, the company will need capital injection if the charges equal MC. This capital can be obtained by reduced dividends to shareholders (the State), borrowing or increased general taxation. If the capital is raised through general taxation, and the welfare loss through taxation is 20 percent, a capital injection of NOK 310 million implies a tax cost of NOK 62 million; see Table 5. See Appendix 1 for details regarding the calculation.

A reduction in aviation charges also implies that the transport authorities may experience reduced subsidy requirements to PSO routes, at least in the short run (partially offsetting the need for raising capital through taxation). This is due to reduced costs for the airline companies operating these routes. However, in a situation where aviation charges are based on our numerical example with a Ramsey approach, see Table 7; the charges at the 'inelastic' PSO airports (category VIII-airports) will increase substantially. The Norwegian Ministry of Transport and Communications must compensate the increased costs for operators of the PSO routes.

3.4.3 Consequences for the airline companies and passengers

For the airline companies, any change in airport charges leads to a change in operating costs. The consequences for the airlines' profit depends on the structure of the charge system and the extent to which the airline companies will pass on changes in charges to the passengers' ticket prices. Since we assume a 50 percent pass-on rate, the charge change will be evenly distributed between a reduction in the airline companies' profits and an increased ticket price for passengers.

As suggested in Table 3, more of the aviation charge should be based on the number of passengers (PAX charge) and less on the number of air transport movements (ATM charge). This favours airline companies with the lowest load factors and the highest ticket prices. In Norway, this gives some advantage to Scandinavian Airlines (SAS) and the regional carrier Widerøe and some disadvantages for the low-cost carrier Norwegian. Furthermore, if the ATM charge does not consider the weight of the plane, the operators of small aircrafts are disadvantaged relative to companies operating large aircrafts. Thus, this change will be a significant disadvantage for Widerøe in Norway.

A central question is how much the airline companies will raise/lower ticket prices when aviation charges increase/decrease. With a decrease in charges, the answer to this question determines who enjoys the largest benefit — the airline companies or the passengers. The competitive situation, the airline companies' cost structure and the travellers' price elasticity of demand will affect the impact that changes in the charges have on the ticket prices. It is likely that increased charges equal the increase in price of the most expensive tickets, while the price of the cheapest tickets remain unchanged, at least in the short term. This is due to different price elasticities of demand for passengers buying from different ticket categories. Considering that the airline companies practise yield pricing, it is difficult to have a firm opinion about the degree of pass-on for a specific charge change.

3.4.4 Welfare considerations

The welfare effects of a new fare system based on MC pricing will be the sum of the consequences for the passengers (change in consumer surplus), for Avinor (change in profit), for the airline companies (change in profit) and for the State through the tax effect. These effects are summarized in Table 5. The calculation details are given in Appendix 2.

Table 5: Welfare effects of changing the airport charges according to long-run marginal costs. Numbers in million NOK (2009 prices).

	<i>MC pricing with</i>	
	$\lambda = 0.0$	$\lambda = 0.2$
Benefit to passengers (consumer surplus)	315	166
Change in profit for airport owner	-571	-310
Change in profit for airline companies	315	166
Economic effects before tax costs	60	22
Tax costs	-	62
Economic effects after tax costs	60	-40

As can be seen from Table 5, passengers will be better off due to a reduction in ticket prices. The benefit for the passengers increases with price sensitivity and pass-on rate. Due to the assumption of an average pass-on rate of 0.5, the benefits for the passengers equal the change in profit for the airline companies. Using a pass-on rate of 0.7, the consumer surplus will increase to NOK 442 million and NOK 233 million, and the profit for the airline companies will decrease to NOK 190 million and NOK 100 million because λ equals 0.0 and 0.2, respectively. The airport owner will also benefit from lower ticket prices due to increased traffic compared to a situation with a lower pass-on rate and thereby a higher fare level. However, the airline companies will be facing a lower increase in profit the more of the charge reduction they must ‘give away’ to the passengers. Nevertheless, a higher pass-on rate has a positive effect on the net welfare effects of a reduction in aviation charges.

When we take into account the costs of raising public funds, Table 5 demonstrates that the total welfare effect of implementing marginal cost pricing is negative. It is, however, worth noting that a tax cost of 20 percent implies a welfare loss if the entire revenue loss is financed through general taxation. The latter is a strict condition because it is reasonable to assume that Avinor can compensate for reduced revenues through different efficiency measures related to the operation of the airports.

4. Ramsey pricing approach under budget constraints

If the transport authorities allow airport charges to vary between airports, welfare optimal charges can be derived by the Ramsey approach. This rule provides guidelines on how to find the second-best charges — that is, how the charges of different airports should deviate from marginal costs when aiming to maximize the total surplus subject to a financial constraint. Assuming that the cross-elasticities of demand between different airports are negligible, Equation (3) can be rephrased as follows:

$$(4) \quad AC_i^R = MC_i \times f_i \text{ where } f_i = \frac{1}{1 + \frac{\alpha}{e_i}} \text{ and } 0 \leq \alpha \leq 1$$

In Equation (4), AC_i^R are the Ramsey charges at airport i , MC_i are the long-run marginal costs at airport i , f_i is the mark-up factor and e_i is the price elasticity of demand. The parameter α is dependent upon available subsidy funds and has a value of between 0 and 1; the less public funds are available the higher the value of α and, hence, the higher the value of f_i . When $\alpha = 0$, no binding financial constraints are present, and the value of $f_i = 1$ and charges can be set equal to MC_i (best charges). The Ramsey rule implies that the relative deviation between marginal costs and charges should be largest at airports where the price elasticities of demand are lowest, regardless of the available funds. It can also be deduced from Equation (4) that the value of e_i influences f_i more the higher the value of α is. This means that the less available funds are, the more will demand conditions at different airports influence the second-best charges. For a thorough review of Ramsey pricing, we refer to Brown and Sibley (1986) and Hensher and Brewer (2001).

An increase or decrease in airport charges will totally or partially be passed on to the ticket price that the passengers must pay. According to Jørgensen and Santos (2014), the pass-on rate will vary depending on the competitive conditions at the airports and the shape of the airlines' demand functions at the various airports, together with the shape of the airlines' cost functions. This implies that the Ramsey rule should be adjusted when taking into account that the effect the changes in charges will have on the demand for flights from various airports can be different even if the price elasticity of demand at the airports are equal.

One way that Equation (4) can be adapted to take into account different pass-on rates, defined by the variable φ , is shown in Equation (5).

$$(5) \quad AC_i^P = MC_i \times f_i^P \text{ where } f_i^P = \frac{1}{1 + \frac{\alpha}{e_i \times \varphi_i}} \text{ and } \alpha < |e_i \times \varphi_i|$$

In Equation (5) AC_i^P is the pass-on rate-adjusted Ramsey-charges at airport i where φ_i is the pass-on rate at airport i . According to Equation (5), the value of f_i^P increases when $|e_i \times \varphi_i|$ decreases. This implies that the relative deviation between MC and AC should be largest at airports where the price elasticity of demand is the most price inelastic and the pass-on rate is lowest, regardless of available funds.

4.2 Applying a Ramsey pricing approach at Norwegian airports: a calculation example

We will now apply the principle of Ramsey pricing in Equation (5) using Norwegian airports as an illustrative case. The assumption regarding the pass-on rate (φ_i) is based on a relatively rough assessment of the actual competitive situation at the airport. Three types of competitive environments were identified by Jørgensen et al. (2011). First, at several airports, the two major commercial airlines, SAS and Norwegian, compete in a duopoly. Assuming linear demand functions, cost functions and price competition, this situation corresponds to a pass-on rate above 0.5. The pass-on rate at these airports is set to 0.7. Second, many smaller airports are operated by only one operator due to the limited commercial potential. The pass-on rate in these 'monopoly' cases is set to 0.5. Third, airports without commercially attractive routes are served by PSO routes operated by one airline company only. These airlines operate at regulated maximum prices on the flexible tickets sold, and the state compensates the operator for any changes in airport charges.

Although the charges change, the maximum prices remain unchanged. On other tickets sold, the pass-on rate is likely to be close to 100 percent. Hence, a rough estimate gives us an average pass-on rate of 0.4. For a thorough discussion of reasonable values on the pass-on rate, see Jørgensen and Santos (2014) and the chapter in this book written by Mathisen et al. (2017).

The assumptions regarding the price elasticities of demand (e_i) are based on differences in alternative transport options to air transport for the inhabitants in the airport catchment area; see e.g. InterVISTAS (2007). The presence of alternatives is divided in four categories according to local knowledge and the best judgment of the authors. The larger cities are well connected by both coaches and railway (and fast-craft services in coastal areas) and have a well-developed road infrastructure for private vehicles. Hence, there are many alternatives, and the average price elasticity of demand is set to -1.2, which indicates high sensitivity to price. As a special case, alternatives are even more abundant at the main airport located near the capital of Norway, Oslo, and the price elasticity of demand is set to -1.4. Airports located far from the main airport, where travel alternatives are fewer, are assigned an elasticity of -1.0. Some local airports are rural, and people have few alternatives to air transport. The price elasticity of demand is relatively inelastic at these airports and is set to -0.8.

The above discussion of variations in the parameters produces eight airport categories. These are listed in Table 6. The assumptions regarding price elasticities and pass-on rates at different airports places most of the small PSO airports in category VIII, while the largest airport, OSL (Oslo airport, Gardermoen), ends up in category I.

Table 6: Airport categories classified by market structure, pass-on rate, transport alternatives and passengers price elasticities of demand.

<i>Airport category</i>	<i>Number of airports</i>	<i>Market structure</i>	<i>Pass-on rate</i>	<i>Transport alternatives</i>	<i>Price elasticity of demand</i>
I	1	Duopoly	0.7	Many	-1.4
II	3	Duopoly	0.7	Middle	-1.0
III	5	Duopoly	0.7	Many	-1.2
IV	7	Duopoly	0.7	Few	-0.8
V	2	PSO	0.4	Many	-1.2
VI	3	Monopoly	0.5	Middle	-1.0
VII	2	PSO	0.4	Middle	-1.0
VIII	22	PSO	0.4	Few	-0.8

Based on the parameters in Table 6, we are able to calculate the adjustment factor f_i^p to be used for deriving the Ramsey-charges for PAX and ATM following the use of Eq. (5); see Table 7. Calculations show that revenue restriction is met if $\alpha = 0.21$.¹¹ For a comparison, the uniform charges derived in section 4 are included in Table 7. When adjusting the charges to meet the revenue constraints, we have adjusted both the PAX charge and the ATM charge by the same factor. We have assumed that MC is equal for all airports. It should also be noted that long-run marginal cost estimates are applied

¹¹ The value of $\alpha = 0.21$ gives unchanged revenues from PAX and ATM charges when the 45 airports included in the calculation are given price elasticities of demand and pass-on-rates as shown in Table 6.

at all airports even though it can be argued that short-run estimates would be more appropriate at some smaller airports that are not operating on the capacity limit.

Table 7: Airport charges with revenue restrictions according to a Ramsey approach. All prices are in NOK at the 2009 price level.

<i>Airport category</i>	<i>Adjustment factors (f_i^p)</i>	<i>PAX charge</i>	<i>ATM charge</i>
I	1.27	87	1,117
II	1.43	97	1,254
III	1.33	91	1,171
IV	1.60	109	1,405
V	1.78	121	1,561
VI	1.72	117	1,514
VII	2.11	143	1,848
VIII	2.91	198	2,554
MC ($\lambda = 0$)	1.00	68	878
MC ($\lambda = 0.2$)	1.20	82	1,054
MC adjusted to meet revenue restrictions	1.43	97	1,249

As can be seen from Table 7 the PAX charge varies from NOK 87 to NOK 198, while the variation in the ATM charge ranges from NOK 1,117 to NOK 2,554, depending on airport category. It is therefore clear that the charges depend on departure airport, which may imply different charges on the same route depending on the travel direction. If we assume an average ATM charge per ton based on MTOW, based on the discussion in chapter 3.1, an aircraft of 16 tonnes (typically a Dash 8-100 with 39 seats) will have a take-off charge of NOK 397 $[(1,117/45) \times 16]$ at a category I airport and NOK 908 $[(2,554/45) \times 16]$ at a category VIII airport. If the cabin factor is 80 percent (31 passengers), the PAX charges will be NOK 2,697 (87×31) and NOK 6,138 (198×31) at category I and VIII airports, respectively. Thus, the total charges are NOK 3,952 higher (almost 128 percent) when the aircraft operates at a category VIII airport compared to a category I airport.

The diversity in airport locations, from rural areas to large cities, enables differentiation according to the presence of alternative transport options for passengers. The price elasticity will be less negative (less price sensitive) if there are few alternative transport options. Hence, according to Ramsey thinking, such airports should have a higher rise in marginal costs than airports located in regions with many transport alternatives. However, setting airport charges according to these criteria could be problematic from a regional policy perspective. Passengers with few travel alternatives (which would see the highest increase) are usually located in rural areas where the airport itself is regarded as an important means for further economic development (Halpern and Bråthen, 2011).

Another issue to consider is that small airports rarely meet the capacity limit. Since a marginal increase in traffic movements or passengers do not imply an extension of capacity, it is not appropriate to use long-run estimates as the basis for setting charges. Charges should rather be based on short-run marginal costs reflecting the increased use of the existing infrastructure only. See, for example, the discussion on the use of long- and short-run estimates by Viton (1981). The fact that short-run estimates are lower than long-run estimates implies that the differences addressed above are reduced.

5. Conclusions and implications

This paper investigates how an analysis of airports' marginal costs (MC) of serving passengers and airplanes can be used as the basis for setting airport charges according to the principles of economic welfare. The data are from 45 airports in Norway and are operated by the state-owned company Avinor. The analysis indicates that a revision of the Norwegian aviation charges towards MC pricing implies a shift towards relatively higher charges levied on passengers (PAX charge) compared to charges based on aircraft movements (ATM charge). This shift is in line with IATA (2010) recommendations that, wherever possible and practical, airports should transition to passenger-based charges. For 2009 prices, the marginal cost-based airport charges indicate charges of NOK 68 (7.6 €) for each passenger and NOK 878 (97.6 €) for an average air traffic movement.

However, charges based on MC do not cover the total costs of operating an airport, and the income from the PAX and ATM charges are reduced. If the loss of income is covered through general taxation and takes into consideration the costs of raising public funds, the charges should be set above MC. The higher the tax costs are, the higher the mark-up is from MC. With a revenue restriction stating that the new PAX and ATM charges should generate approximately the same revenues that the current ones do, our estimations show that MC-based charges must be set at approximately 43 percent above MC. The airport owner (the state) has decided that charges on all airports owned by Avinor should be equal. However, if charges are allowed to vary between airports, a Ramsey pricing approach indicates that the mark-up from MC should be highest at airports where the passenger price elasticity of demand is lowest (in absolute values) and where the pass-on rate (the proportion of a tax change passed on to passengers via the ticket price) is low.

By using our approach to Ramsey pricing on airports owned by Avinor, most local airports located in areas characterised by few transport alternatives to air transport will be given the maximum charge, while the main airport in Norway, where travel alternatives are numerous, will be assigned the minimum charges. Such distributional effects using our Ramsey pricing approach will be difficult to accept for policy makers, and it will conflict with Avinor's goal of promoting economic development in rural areas. Professionally speaking, it is legitimate to argue for lower charges at airports with significant spare capacity since optimal charges should then be set equal to short-run marginal costs. Then, however, the funding requirements increase considerably so that airports need additional funding from the state budget to cover operating costs and necessary investments.

Aviation charges based on MC pricing imply a reduction in the present charges and the income from these charges. From a welfare perspective, MC pricing is desirable when no financial bindings exist. However, as demonstrated in the calculation example, a change in MC pricing can imply a reduction in welfare for society if all losses of income for the airport owner are compensated by general taxation. In principle, the economic benefits of financing revenue loss with public funds increase with lower taxation costs and decrease the less price-sensitive the market in question is.

Our estimations of MC and the use of the estimated results in setting airport charges have weaknesses. First, it is technically difficult to estimate the marginal cost of both passengers and air transport movements in the same model due to the strong correlation between these production measures. This makes the estimates uncertain. Second, the estimations are based on a panel data set of 3 years, which we have treated as a pooled data set. Such a pooling approach is not unproblematic. The estimation results are calculated from the reported costs at Norwegian airports that are operated by the state-owned company Avinor. Therefore, the estimated marginal costs

indicate how efficiently Avinor runs these airports. If the airports are run inefficiently, the size of the marginal costs would reflect this. Thus, the actual parameter values cannot be directly transferred to airports in other countries, although it is corrected for factor price differences and differences in operating efficiency and other framework conditions that will influence costs. Nevertheless, the method used is transferable to countries that have organised their airports in the same way as in Norway and can thus be used to carry out similar analyses to the Norwegian case.

References

- Avinor (2016). Traffic statistics, from <http://www.avinor.no/en/avinor/traffic>.
- Button, K. (2010). *Transport Economics* (3rd ed.). Edward Elgar, Cheltenham, UK.
- Carlsson, F. (2003). Airport marginal cost pricing: Discussion and an application to Swedish airports. *International Journal of Transport Economics*, 30 (3), pp. 283-304.
- Doganis, R. (2010). *Flying off course : the economics of international airlines* (4th ed. ed.). Routledge, London.
- European Commission (2009). Public service obligations - list of routes concerned. Working document based on information from the Official Journal and on data delivered by Member States. Retrieved 11th January 2010, from http://ec.europa.eu/transport/air/internal_market/doc/2009_11_03_pso_inventory.pdf.
- European Union. (2009). Directive 2009/12/EC of the European Parliament and of the Council of 11 March 2009 on airport charges *Official Journal of the European Union*, 52.
- GAP. (2012). *Comparative study (benchmarking) on the efficiency of Avinor's airport operations*. Berlin.
- Graham, A. (2013). *Managing airports : an international perspective* (4th edition. ed.). Routledge, London.
- Hakimov, R. and Mueller, J. (2014). Charges of uncongested German airports: Do they follow ramsey pricing scheme? *Research in Transportation Economics*, 45, pp. 57-65.
- Halpern, N. and Bråthen, S. (2011). Impact of airports on regional accessibility and social development. *Journal of Transport Geography*, 19 (6), pp. 1145-1154.
- IATA (2010). Passenger Based Airport Charges, <http://www.iata.org/whatwedo/airports/charges/Documents/Passenger-based-airport-charges.pdf>.
- ICAO (2009). ICAO's Policies on Charges for Airports and Air Navigation Services. Doc 9082.
- InterVISTAS. (2007). *Estimating Air Travel Demand Elasticities*. Final Report.
- Jørgensen, F., Mathisen, T. and Solvoll, G. (2011). *Lufthavnavgifter i Norge - takstsystemets struktur og betydning for tilbud og etterspørsel* (Airport charges in Norway). SIB report 2/2011, Bodø Graduate School of Business, Norway. (In Norwegian).
- Jørgensen, F. and Santos, G. (2014). Charges on transport - To what extent are they passed on to users? *Transportation Research Part A: Policy and Practice*, 69, pp. 183-195.
- Kjærland, F. and Mathisen, T. A. (2012). Assessing the peripheral status of local airports. *Journal of Air Transport Studies*, 3 (2).
- LeighFisher. (2012). *Airport performance indicators 2012*. London.
- Lian, J. I. (2010). Network dependency and airline competition - Consequences for remote areas in Norway. *Journal of Air Transport Management*, 16 (3), pp. 137-143.
- Lian, J. I. and Rønnevik, J. (2011). Airport competition - Regional airports losing ground to main airports. *Journal of Transport Geography*, 19 (1), pp. 85-92.
- Losada, J. M. S., Eraso, J. C. and Garcia, P. D. (2012). Airport management: The survival of small airports. *International Journal of Transport Economics*, 39 (3), pp. 349-367.
- Martin-Cejas, R. R. (1997). Airport pricing systems in europe and an application of Ramsey pricing to Spanish airports. *Transportation Research Part E: Logistics and Transportation Review*, 33 (4), pp. 321-327.

- Martín-Cejas, R. R. (2010). Ramsey pricing including CO2 emission cost: An application to Spanish airports. *Journal of Air Transport Management*, 16 (1), pp. 45-47.
- Martín, J. C. and Voltes-Dorta, A. (2011). The econometric estimation of airports' cost function. *Transportation Research Part B: Methodological*, 45 (1), pp. 112-127.
- Mathisen, T. A., Jørgensen, F. and Solvoll, G. (2014). Marginal costs pricing of airport operations in Norway. *Research in Transportation Economics*, 45, pp. 49-56.
- Mathisen, T. A. and Solvoll, G. (2012). Reconsidering the regional airport network in Norway. *European Transport Research Review*, 4 (1), pp. 39-46.
- Morrison, S. A. (1983). Estimation of Long-Run Prices and Investment Levels for Airport Runways. In T. E. Keeler (Ed.), *Research in Transportation Economics*, Vol. 1, pp. 103-113. JAI Press.
- The Norwegian Ministry of Finance (2014). *Veileder i samfunnsøkonomiske analyser*.
- The Norwegian Ministry of Transport and Communication (2006). FOR 2006-07-06 nr 968: Forskrift om utforming av store flyplasser (BSL E 3-2). Oslo. (In Norwegian).
- The Norwegian Ministry of Transport and Communication. (2012). Verksamda til Avinor AS. Meld. St. 38 (2012-2013).
- Viton, P. A. (1981). A translog cost function for urban bus transit. *The Journal of Industrial Economics*, 29 (3), pp. 287-304.
- Walters, A. A. (1965). The long and the short of transport. *Bulletin of the Oxford University Institute of Economics and Statistics*, 27 (2), pp. 97-101.
- Williams, G., Fewings, R. and Fuglum, K. (2007). Airport provision and air transport dependence in European countries. *Journal of Airport Management*, 1 (4), pp. 398-412.
- Wooldridge, J. M. (2006). *Introductory econometrics: a modern approach* (3rd ed.). Thomson South-Western, Mason, OH.

Appendix 1

Below, we show how the consequences of MC pricing for the airport owner (Avinor) and for the society (welfare effects) are calculated. The central assumptions for the calculation are that we assume an average ticket price (P) of NOK 1,000 (one way), an average price elasticity of demand (e) of -1.0 and an average pass-on rate (φ) of 0.5. The following symbols are used:

ATM_{2009} = Number of air transport movements in 2009.

PAX_{2009} = Number of arriving and departing passengers in 2009.

PAX_{new} = Number of arriving and departing passengers with charges equal to MC .

AC_{2009}^{pax} = Passenger charge in 2009.

$\overline{AC}_{2009}^{atm}$ = Average ATM charge per passenger in 2009.

AC_{new}^{pax} = MC -based passenger charge.

AC_{new}^{atm} = MC -based ATM charge.

I_{new}^{AC} = Income from MC -based PAX and ATM charges.

I_{new}^{com} = Income from commercial activities when PAX and ATM charges are set equal to MC .

C = Operating costs.

Consequences for the airport owner (Avinor)

The number of passengers when PAX and ATM charges are set equal to MC are calculated using Equation (A1.1).¹²

$$(A1.1) \quad PAX_{new} = PAX_{2009} + e \times 0.5 \times \left(\frac{\Delta AC}{P} \times PAX_{2009} \right),$$

$$\text{where } \Delta AC = (AC_{2009}^{pax} + \overline{AC}_{2009}^{atm}) - \left(AC_{new}^{pax} + \frac{AC_{new}^{atm}}{PAX_{2009}} \times ATM_{2009} \right)$$

Income from MC -based PAX and ATM charges are calculated using Equation (A1.2).

$$(A 1.2) \quad I_{new}^{AC} = 0.5 \times \left(AC_{new}^{pax} + \frac{AC_{new}^{atm} \times ATM_{2009}}{PAX_{2009}} \right) \times PAX_{new}$$

The income from commercial activities when PAX and ATM charges are set equal to MC are calculated as follows:

$$(A 1.3) \quad I_{new}^{com} = I_{2009}^{com} + 0.5 \times \left[\frac{I_{2009}^{com}}{PAX_{2009}} \times (PAX_{new} - PAX_{2009}) \right]$$

The operating costs with an increased number of passengers due to MC pricing are calculated as follows:

$$(A 1.4) \quad \Delta C = MC_{2009}^{pax} \times \Delta PAX$$

¹² When using the number of arriving and departing passengers (PAX) as an analysis unit, the calculations of the impact that MC pricing has on the change in the number of passengers and the income from these components must be halved since a passenger contributes to two terminal visits, and the taxation is related to only one of these visits. The charges are set to $2 \times MC$.

Welfare effects

The welfare effects of implementing MC pricing are calculated as follows:

Change in consumer surplus (CS):

$$(A\ 1.5) \ \Delta CS = (0.5 \times PAX_{2009} \times \Delta AC^P) + (0.5 \times \Delta PAX \times \Delta AC^P) \times 0.5$$

Change in profit (π) for the airport owner ($\Delta\pi^{AO}$):

$$(A\ 1.6) \ \Delta\pi^{AO} = I_{2009}^{AC} - I_{new}^{AC} + I_{2009}^{com} - I_{new}^{com} + \Delta AC$$

Change in profit for airline companies ($\Delta\pi^{AC}$):

$$(A\ 1.7) \ \Delta\pi^{AC} = (0.5 \times PAX_{2009} \times \Delta AC^A) + (0.5 \times \Delta PAX \times \Delta AC^A) \times 0.5$$

Appendix 2

To analyse the problem of setting charges according to the principles of economic welfare, we use the condition for maximizing economic surplus under budget constraints (Ramsey pricing):

$$(A.2.1) \text{ Max } SO = \int_p^\infty X(P) + (P \times X(P)) - C(X(P)) \text{ given } P \times X(P) - C(X(P)) \leq \pi^*$$

where SO is economic surplus, P is the charge, $C(X)$ is the airport owner's cost function, $X(P)$ is the demand function for airport services and π^* is the surplus requirements ($\pi^* < 0$ implies deficit and $\pi^* > 0$ implies surplus). First order conditions for the maximisation of SO (Lagrangian) imply:

$$L(P) = \int_p^\infty X(P) + P \times X(P) - C(X(P)) + \lambda[P \times X(P) - C(X(P)) - \pi^*]$$

$$\frac{\partial L}{\partial P} = -X(P) + P \frac{\partial X}{\partial P} + X(P) - \frac{\partial C}{\partial X} \times \frac{\partial X}{\partial P} + \lambda \times P \frac{\partial X}{\partial P} + \lambda \times X(P) - \lambda \times \frac{\partial C}{\partial X} \times \frac{\partial X}{\partial P} = 0 \Rightarrow$$

$$(1 + \lambda) \times P \times \frac{\partial X}{\partial P} + \lambda \times X(P) = (1 + \lambda) \times \frac{\partial C}{\partial X} \times \frac{\partial X}{\partial P}$$

If the expression above is divided by $(1 + \lambda) \times \frac{\partial X}{\partial P}$ on both sides, we get:

$$P + \frac{\lambda \times X(P)}{(1 + \lambda) \times \frac{\partial X}{\partial P}} = \frac{\partial C}{\partial X} \Rightarrow$$

$$P \left(1 + \frac{\lambda \times X(P)}{(1 + \lambda) \times P \times \frac{\partial X}{\partial P}} \right) = \frac{\partial C}{\partial X} \Rightarrow$$

$$P \left(\frac{\frac{\partial C}{\partial X}}{1 + \frac{\lambda \times X(P)}{P \times \frac{\partial X}{\partial P}}} \right) = \frac{\frac{\partial C}{\partial X}}{1 + \frac{\lambda}{1 + \lambda} \times \frac{1}{e}} \Rightarrow$$

$$(A.2.2) P^* = \frac{\frac{\partial C}{\partial X}}{1 + \frac{\alpha}{e}} \text{ where } 0 \leq \alpha = \frac{\lambda}{1 + \lambda} \leq 1$$

where P^* is the optimal charge and e is the price elasticity of demand. Since e is negative, $|e| > \alpha$ if $P^* > 0$.

It can be shown that $\frac{\partial SO^*}{\partial \pi^*} = -\lambda$, where SO^* is the maximum economic surplus when the surplus requirement is π^* . This implies that λ indicates the reduction in economic surplus from the airport operation when the surplus requirement increases by NOK 1. Hence, λ can then be interpreted as the welfare loss by taxation. When $\lambda = 0$, $\alpha = 0$, and the optimal charge will, according to (A.2.2), equal the marginal costs.

The above helps us calculate how much optimal airport charges (AC) should deviate from MC ($\partial C / \partial X$) when the deficit is to be financed by general taxation.

$$(A.2.3) AC = P^* = MC \cdot f \text{ where } f = \frac{1}{1 + \frac{\alpha}{e}} \text{ and } 0 \leq \alpha = \frac{\lambda}{1 + \lambda} \leq 1 \text{ and } |e| > \alpha.$$

In (A.2.3), f is the in-percentage mark-up (in decimals) to be levied on MC to reach the surplus requirements.