HOTELLING IN THE AIR?
FLIGHT DEPARTURES IN NORWAY[ψ]

by

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Abstract:
The purpose of this study is to test empirically the degree of departure-time differentiation in the Norwegian airline industry, where we observed both monopoly and duopoly routes following deregulation in 1994. By constructing a waiting cost index where we measure degree of clustering of departure times during a day on 12 different routes before and after deregulation, we can use an econometric panel data test to see whether there have been systematic changes in localisation of departures. We find that after deregulation the clustering of flights increases on duopoly routes as compared to monopoly routes. When we focus on the more narrowly defined business segment we find an even clearer pattern of flight clustering after deregulation.

Keywords: Competition on location, airlines, panel data models
J.E.L. codes:

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1. Introduction

According to the theory of location, it is ambiguous whether a firm should locate close to its rival or not. With a few exceptions, there are no empirical studies of location.[1] The purpose of this article is to test empirically the time location of flight departures in the Norwegian airline industry: have the firms located their flights close in time (clustering) or not? The Norwegian airline market was deregulated in April 1994, and we observed both monopoly and duopoly on individual routes after the deregulation. We use city-pair data for the 12 most important domestic routes in Norway from 1991 to 1997 to test for both intra-route changes and inter-route differences in time scheduling following deregulation.

Until April 1994 both prices and time location of flights were regulated in this particular industry, and on each route one carrier had a legal monopoly.[2] We find that on those routes where one carrier continued to be a monopolist even after deregulation, the deregulation did not lead to any significant changes in its departure-time differentiation. This suggests that a monopoly outcome concerning location was achieved in the regulated era. If so, what would we expect to happen on routes where we observe duopoly after deregulation? Predictions from theory are ambiguous. On the one hand, a firm locates close to its rival to steal customers. On the other hand, a firm locates far away from its rival to dampen price competition. The data we use are collected from 12 routes, including six duopoly routes and the six largest monopoly routes. We control for time varying factors such as demand growth by including control variables. Route-specific time-invariant effects are controlled for by estimating route specific

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[1]In Borenstein and Netz (1999), a study very much in the same spirit as ours, the time schedule of flights in US before and after the deregulation in 1978 is tested empirically. Netz and Taylor (1997) test empirically the location of petrol stations in Los Angeles Basin. See also Kalnins and Lafontaine (1997), which focuses on the incentives for vertical separation and tests empirically the location pattern for fast-food chains in Texas.
[2]In October 1987, a second carrier was allowed to have a maximum of four flights on some particular routes. However, both prices and time location continued to be regulated until April 1994.

fixed effect models. Our main question is the following: are there any changes in time location on monopoly and duopoly routes after deregulation? The change in time location is captured by a clustering index that increases if a flight is located closer to its nearest flight, and even more so the closer it is to its nearest flight initially.

When we examine only the incumbent carrier in a duopoly, we find no indication of clustering following deregulation. When we include the second carrier, our results significantly change. Then we find that monopoly results in less clustering than duopoly. We have also tested for a more narrow set of our data, by including only the business segment. We find even a stronger tendency of clustering following deregulation.

In the next section, we describe the Norwegian airline industry. Some theory for location is discussed in section 3. In section 4, the econometric models are specified, and we present the results in section 5. Section 6 concludes the paper, and we briefly discuss some public policy measures.

2. The Norwegian airline industry

The largest routes in Norway are of almost equal size as the routes between many specific airports inside Europe as well as inside United States.[3] Oslo, the capitol of Norway, is more than twice as large as the second largest city in Norway. All ministries, as well as other governmental activities and many of the head quarters for the largest private firms, are located in Oslo (or the surroundings). Therefore, we observe a large number of daily round trips to and from Oslo in connections with meetings and other business activities. Moreover, the other largest cities have direct flights to international hubs as

[3]Not surprisingly, the number of flights between city pairs as, for example, San Francisco-Los Angeles and London-Amsterdam, are much higher than between city pairs in Norway. However, when we take into account the fact that there are several airports in each of these large cities, then the number of flights between specific airports are at the same level as the number of flights on the largest routes in Norway [see Stra ndenes (1990)].

Copenhagen, London and Amsterdam. Due to this only a minor share of the passengers to and from Oslo are transfer flights passengers.

As in most countries, the Norwegian airline industry has been heavily regulated. For each route, one single firm was given the exclusive right to have flights. Both prices and time location were regulated. However, there are indications that the regulation was not a binding constraint on each firm's price setting.[4] In October 1987, a second airline was permitted to have a limited number of flights for some particular routes - four flights at a maximum on each route. However, both prices and time location continued to be regulated by the government.[5] In April 1994, all routes, except those between the smallest airports, were deregulated. Free entry for all Norwegian firms was permitted, and they were free to set prices as well as the departure times for their flights.

Competition on prices?

It turned out that the two incumbent firms for the routes in question, SAS and Braathens, became the only active firms in the deregulated system. Studies indicate no price reduction in the business travellers' segment following deregulation and only a minor increase in the share of discounted tickets.[6] However, we should keep in mind that these conclusions are drawn from observing descriptive statistics rather than from testing for whether deregulation actually resulted in price competition. Given that the conclusion

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[4]The regulation dates back to the 40s. At that time the Norwegian economy was heavily regulated, with no focus on anti-trust issues. Each firm had to apply to the civil aviation authorities concerning price changes. Then each firm could argue that they have had cost increases, an argument that the authorities would find difficult to disprove. Norman and Strandenes (1994) have calibrated the market equilibrium on the route Stockholm-Oslo prior to deregulation in 1993, and they conclude that '[i]nsofar our calibrated coefficients seem «reasonable», the regulatory constraint cannot be severe' (p. 96).

[5]Salvanes, Steen and Sørgard (1997) tests for whether this regulatory change had any effect on location of flight departures, and they find that the answer is no. Therefore, it is natural to focus on the deregulation that took place in 1994.

[6]This is shown in Lian (1996). He finds that the share of the discounted tickets increased with 2,5 %-point from 1992 to 1994-95. According to Lian (1996) this is no dramatic change: *'a 2-3 %-point increase in discount tickets in two-three years is in line with a long term trend and imply no sudden change in this trend'* [our translation] (p. 15). The

from the referred study is correct, there are four factors that can explain why the firms have succeeded in avoiding price competition.

First, there is a potential for collusive behaviour in this particular industry. There are only two active firms, and until April 1997 foreign firms were not permitted to serve domestic routes in Norway. Price changes will either be announced in the press or made through the travellers' bureau, which in both cases will quickly be observed by the rival. Hence, both firms can quickly respond to the rival's price changes. Furthermore, both firms have expanded their capacity significantly following deregulation. As a result, both firms are able to expand their sale in the business travellers' segment and thus cut prices significantly following any possible cartel breakdown.

Second, the two firms had initially almost equal market shares in the domestic market. Then it was natural to continue with the initial market sharing in the deregulated system. In fact, there were only rather minor changes in the market shares on each route as well as in the total market shares after deregulation.[7] At 24 out of the 32 city-pair routes, the initial monopoly carrier continued to be a monopolist. For the remaining eight routes, the pre-deregulation dominant firm continued to have a dominant position. On average, the dominant firm had a 13 %-points reduction in market share on these eight routes, and it had no less than 60% market share on any of the routes in the deregulated regime.[8]

Third, for those routes where both firms did have flights, there exists a system for co-ordinating prices. The firms are permitted to consult each other concerning price setting. To allow for late changes of flight schedules for normal (no discount) tickets, from one airline to another, the airlines have

increase in the share of discounted tickets are larger in the 'leisure' segment than in the business segment [see Lian (1996), tabell 4.4].

[7]Each firm's market share changed only modestly following deregulation; Braathens increased its market share from approximately 50% in 1993 to 52% in 1995 [see Lorentzen *et al*. (1996)].

[8]The exception is the route Bodø-Tromsø, where each had two non-stop flights both before and after April 1994.

«transferable» prices. To implement such a policy, the firms are permitted to meet regularly to inform each other concerning future prices on non-rebated tickets - labelled interline tickets. Hence, there exists an institutional pre-play communication system where each firm can inform its rival about its future prices on normal tickets.

Fourth, the firms have signalled an aggressive response to any move by its rival. In particular, each firm matches the rival's offer. For example, prior to deregulation Braathens introduced a rebate ticket named *Billy* to match SAS' rebate ticket *Jackpot* and set a price NOK 5 below the *Jackpot* price. SAS responded immediately by reducing its *Jackpot* price by NOK 5. A statement by a representative for Braathens suggests that this is a deliberate policy for the firms in question:

> '*We will match any offer by SAS within an hour, and we can not accept that SAS has cheaper discount tickets than what we have' (our translation) [C. Fougli to Dagens Næringsliv, 20/1/94].*

Such an apparently aggressive behaviour is analogous to the introduction of a meet-competition clause. As shown in the literature, a meet-competition clause may have a dampening-of-competition effect [see Salop (1986)]. An explanation of this principle, that also may serve as an illustration of the companies' strategy, was provided by Audun Tjomsland, the public relation manager for Braathens:

> *'The two Norwegian firms on Norwegian routes, Braathens and SAS, are of equal size and can follow each other during a price war. The firm that starts a price war will quickly be followed by the rival firm, so that the firm that starts a war will have an advantage only a day or two. Accordingly, the firms are reluctant to trigger a price war.' (our translation) [Bergens Tidende, 31/7/95].*

Although the study we referred to suggests that there was no fierce price competition in the business travellers' segment following deregulation, casual observations as well as other studies suggest that it has been more price competition in the leisure segment, where the firms offer discounted tickets.[9] As mentioned above, the two firms competed on prices with identical kind of offers like Billy and Jackpot, respectively. These were discounted tickets with restrictions which made them unattractive for business travellers. There are numerous other examples of discounted tickets with restrictions, where the firms matched the rival firm's offer. For example, SAS and Braathens introduced both in the summer of 96 50th anniversary tickets, which also were discount tickets with restrictions.

Competition on location?

Prior to the deregulation in April 1994, the civil aviation authorities regulated the location pattern on each route. The authorities should approve any time schedule pattern on a particular route. Apparently, the authorities did not permit pairwise flights, *i.e.*, flights at almost the same point in time. The obvious argument was that a spread of flights would increase the consumers' freedom of choice concerning departure time and thereby increase welfare. After deregulation, the firms were free to set the time schedule on each route. However, the government continued to ban any departures between 11:00 pm and 7:00 am. Although the Norwegian civil aviation authorities still are responsible for the rights governing the slot allocation, both companies are now closely involved in this decision process [see Lorentzen *et al.* 1996)]. Such a way to organise the slot allocation may give the two firms, SAS and Braathens, a potential for co-ordinating their time scheduling of flight departures. Both before and after the deregulation time schedules were made for the fall/winter and spring/summer season, respectively. Although it was possible to make changes within each season, this institutional setting thus made it more difficult to re-schedule departure times than to change prices.

[9] In a recent study for 11 city-pair routes from fall 1993 to winter 1998, Risvold (2000) finds that the full-price tickets had increased more than the low-price. Of the eleven city-pairs she analyses, ten are included in our analysis. Only Bergen-Stavanger and Trondheim-Ålesund are excluded in Risvold's sample.

We have in Figure 1 and 2 shown the time scheduling on weekday non-stop flights on the route Oslo-Bodø and Oslo-Stavanger.

[Figures 1 and 2 approximately here]

First, deregulation seems to have no or only a limited effect on the time-scheduling pattern *within* each airline. In particular, the first carrier - the one with the largest number of flights - seems to spread its flights throughout the day both before and after deregulation. Second, the tendency towards pairwise flights seems to be more prevalent in the morning segment as well as in the afternoon segment than in general. This is especially the case if we look at the route Oslo-Stavanger. In these segments, 7:00-10:00 and 15:30-18:00, the typical passenger is a business traveller.

However, this is only two out of several routes. To conclude that there in fact is systematic clustering in the Norwegian airline industry, we have to check carefully for many routes, and control for other factors as well. But first, let discuss theory of location.

3. Theory of location

The time-scheduling of flights can be interpreted as location on a line, where the line represents the time schedule during a day, say 7:00 to 23:00, or during a segment of the day.[10] Therefore, let us discuss the location of products on a line.[11]

Assuming collusion on prices, we have a simple time scheduling game. As a starting point, let us consider the monopolist's location choice. It can maximise the number of consumers it serves by

[10]By such a definition, we rule out that a flight tomorrow morning can be a substitute for a flight this evening. If we had regarded that as an important aspect in this particular market, we should have applied theory of location on a circle. Travellers in the business segment are typically making a round trip, for example between Bergen and Oslo, in one day rather than stay away from home by delaying the return from evening to next morning. This is possible in Norway, because ten out of twelve routes we study are flights with less than one hour duration. Therefore, we find it more natural to apply theory of location on a line than theory of location on a circle.

[11]For an overview of the literature on location, see Eaton and Lipsey (1989) or Gabszewics and Thisse (1992).

locating flights far away from each other (see Steiner [1952]). For the same reason, we expect that an industry acting as a cartel would like to differentiate its products to maximise the number of customers or to enable the firms to set a high price.

What happens if there is competition rather than collusion on location, but still collusion on prices? The seminal Hotelling article may be interpreted as location on a straight line with exogenously determined prices, *i.e.*, no price competition.[12] As is well known, in a duopoly with no price competition both firms locate in the middle and share the market equally. Put differently, there is a tendency to minimum differentiation. This is in line with the findings in Friedman and Thisse (1993), which allows for collusion on prices in a duopoly after location is chosen non-collusively.

Gabszewicz and Thisse (1986) analyse location on a straight line in a duopoly, where each firm is allowed to supply more than one product each.[13] For an identical number of products for each firm, they find that the firms differentiate their own products, but locate each of its products close to one of its rivals' products. As a result, the products are located pairwise. This can be interpreted as local clustering. However, as far as we know, there are no studies of two firms with an unequal number of products. It could be argued that the firm with the large number of products would try to squeeze the other firm by locating close to him on both sides. If so, the firm with the low number of products would regret its own choice given its rival's choice, so that would be no equilibrium in pure strategies.[14]

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[12]In Hotelling (1929), both prices and location are endogenously determined. As first pointed out in d'Aspremont, Gabszewicz and Thisse (1979), the Hotelling solution with both locating arbitrarely close is not a global equilibrium. The reason is that a firm then could capture all the rival's sale by lowering its price. As shown in Dasgupta and Maskin (1985), the equilibrium is in mixed strategies. However, for exogenously determined prices the Hotelling outcome is restored. For further elaborations concerning exogenously given prices and endogenously determined location, see Eaton and Lipsey (1975) and Denzau, Kats and Slutsky (1985).

[13]See also Bensaid and dePalma (1993) and Martinez-Giralt and Neven (1988), which also analyse a setting where each firm has more than one product each.

[14]In Salvanes, Steen and Sørgard (1997) it is shown that in a Hotelling type model with two firms, offering two and three products each respectively, there is no Nash equilibrium in pure strategies.

Let us now assume competition on prices. If the firms collude on location, we expect no clustering. This follows from the general results from the theory of location. Differentiation will typically increase the potential number of customers. In addition, differentiation typically dampens price competition. Hence, each firm should be better off with differentiation than with clustering: more customers and/or higher prices. The latter aspect is not present if the firms collude on both prices and location. All else equal, it suggests that one typically expects more differentiation in this case than the case where the firms collude along both dimensions.[15]

What happens if there is competition on both location and prices? Then there are two opposing forces. On the one hand, each firm should locate far away from its rival to dampen price competition. On the other hand, each firm should locate close to its rival to capture market shares. Whether there is clustering or not in the equilibrium outcome depends on, among others, the structure of the transportation costs and the consumer heterogeneity.[16]

Summing up, we see that there is not possible to make any clear-cut predictions from the theory of location. One cautious observation, thought, would be that in a setting with collusion on prices the theory suggests clustering of flights.

4. An econometric model of flight location

The construction of a clustering index

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[15] See, for example, Tirole (1988) who concludes that one important insight from spatial models is that firms want to differentiate their products from their rivals' products to soften price competition (p. 286-287).

[16] For example, d'Aspremont, Gabszewics and Thisse (1979) applies a model with quadratic transportation costs and find that maximum differentiation is obtained. On the other hand, DePalma *et al*. (1985) show that minimum differentiation is obtained if there is sufficient consumer heterogeneity.

To measure the effect of the number of firms on time location of flight departures, we need a measure of clustering. The clustering index we use is chosen in such a way that it can be interpreted as a total waiting time, given that the passengers' preferred departure time is uniformly distributed over the day. We normalise the number of passengers with preferred departure time to one for each minute. A passenger chooses always the flight that is located closest in time.[17] Let a_k denote the departure time for one flight k on a particular route, and a_{k-1} and a_{k+1} the flights located nearest in time before and after this flight k, respectively. If we for the moment rule out any end-points, *i.e*, do not investigate the first or the last flight during a day, then a uniform distribution of customers implies that the total waiting time for flight k, denoted CLU_k, is as follows:[18]

$$(1) \qquad CLU_k = \sum_{k=1}^{(a_k - a_{k-1})/2} k + \sum_{k=1}^{(a_{k+1} - a_k)/2} k$$

By summarising waiting time for all flights on a certain route, we have the total waiting time for that route. In Appendix *A* we have shown that this index, denoted *CLU*, has the expected properties. First, the *CLU* index is at its minimum when we have maximum differentiation (flights spread evenly out in time) and thus increases when we move one flight towards its nearest flight. Second, the *CLU* index is convex in departure time. It implies that a marginal change in departure time has a larger effect on the *CLU* index

[17]This is the case as long as the airlines' prices are identical. In the business travellers' segment, the full fare segment, the airliners' prices are identical. This is due to the interline ticket agreement. In the leisure segment, we observe that each airline matches the rival's price change within few hours or even quicker than that (see section 2).

[18] The formulation of (1) suggests that the consumer chooses the nearest flight in time regardless whether this flight leaves earlier than the "optimal" time or later. An argument against this symmetry is that consumers might have infinitively high transportation costs in one direction; a consumer that wants to leave say 9.15 will not consider a later flight if the cost of arriving to late on her destination is high. However, the large majority of customers book their flight at least a day in advance. This way one can schedule meetings according to departure times, and often also reschedule a meeting if a flight is full. Hence, this flexibility will reduce the problem of possible asymmetry in consumers' transportation costs.

the closer the flight is to another flight. Finally, we have also shown in Appendix A that the *CLU* index has the same properties if we allow for end points.

If the purpose had been to quantify how much the absolute level of total waiting time changes following deregulation, the uniform distribution assumption would be problematic.[19] In particular, we should then have taken into account the apparent non-uniformity in consumer tastes stemming from the peak and off-peak demand during a day; more passengers are travelling in the morning and the afternoon than mid-day and evening. However, we are *not* interested in the absolute level of waiting cost. Our main goal is to test whether there are more clustering in duopoly than in monopoly for an assumed fixed "peak-off-peak demand pattern" over the analysed time period. This implies that we are comparing the location of flights on a particular route observed on different time periods, as well as between routes on a particular point of time. Unless there is a structural change in the travelling pattern during the weekdays from 1991 to 1997, *i.e.*, the "peak-off-peak demand pattern" changes over time, we can compare the level of clustering before and after deregulation. Of course, the absolute level of waiting cost as measured with our clustering index is probably wrong. But as long as the possible bias in our measure following from our uniformity assumption is constant over time, we can measure the changes over time in clustering of flight due to deregulation.[20]

Another possible problem is structural difference between routes concerning the daily "peak-off-peak demand pattern" pattern. Since we have picked routes (see below) that are relatively homogenous in structure this problem is expected be limited. Furthermore, effects from possible structural route

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[19] By absolute level of waiting cost we think about exactly how many people that actually would like to leave during each minute, i.e., then we need to consider that there are more passengers wanting to travel per minute waiting time in the peak period then in the off-peak period. By assuming uniformity we disregard this difference.

[20] An alternative distribution assumption would be to have a consumer pattern with two normal distributions, with one centred around the morning traffic and one centred around the afternoon traffic.

differences will be partly remedied by using a route specific fixed effect model in the estimation, where each route is allowed to differ.[21]

The analysed routes

We use data for 12 domestic routes and consider only one-way traffic.[22] These include six duopoly routes, and the six largest monopoly routes. We only include the non-stop flights in the winter route between the city-pairs, and we only consider week-day flights that leave at least on four out of the five week-days.[23] The clustering index is calculated for each route for six years; 1991-93 and 1995-97. 1994 is not included since the deregulation took place in April that year. This leaves us with a panel of 72 observations.[24] A list of routes, data sources, and data definitions are provided in the Appendix B. The routes, the number of firms and market shares in winter 1996 are shown in Table 1B. The 12 routes and the market structure are shown in Figure 3.

[Figure 3 approximately here]

By defining a normal week-day starting at 06:30 a.m. and lasting until 11:00 p.m., we construct the index which adds up all passengers' waiting time for each flight. A problem when considering the total day-time period between 06:30 a.m. and 11:00 p.m. is as argued above that we implicitly neglect that there actually might be two market segments during the day: the business travellers' segment during

[21] Although we focus on relative rather than absolute waiting time, the difference in size between the routes can result in a bias in our results. All else equal, a route with ten flights will have a lower total waiting time than a route with, say, five flights. Even though we use control variables and different estimation techniques to take this into account (see below), we cannot rule out that such a bias is still to some extent present. Hence, we should be careful with the interpretation of a result where we find more clustering on small than on large routes. On the other hand, if we find the opposite pattern - more clustering on large routes - it can not be explained by a bias stemming from our way of measuring clustering.

[22] For all routes connected to Oslo (10 routes), we use the departures from Oslo to the other cities.

[23] For only two out of twelve routes, Oslo-Bodø and Oslo-Tromsø, other flights than non-stop is a realistic alternative.

[24] We could have extended the data set and thereby the number of observations, but we find it problematic to do so. First, we could have included more routes. However, routes not included are quite small routes with three or less departures one way. Second, we could have added the summer routes and thereby doubled our sample. However,

the two peaks, morning and afternoon, and the off-peak leisure segment otherwise. We test for the importance of different segments by splitting the day into one peak and one off-peak segment, and then undertake the clustering test. It is only the four largest duopoly routes that are large enough to have several flights in each of these segments. These four are also quite similar in size and travelling structure. Hence, the business travellers' segment estimations are based on more homogenous routes then when using the clustering index for the total day-time.[25] Obviously, peak hour demand could be a genuine reason for locating flights close to each other in this particular segment. Note, once again however, that we focus on *changes* over time. The tendency of clustering during peak hours (fixed "peak-off-peak demand pattern") should be present also before deregulation.

<u>The estimated models</u>

We estimate three pairs of models, one pair based on the full [A]ggregated dataset (1A and 2A), one for the [B]usiness traveller segments (1B and 2B), and one pair where we exclude the smallest firm on the routes and focus on the [D]ominant firm's clustering (1D and 2D):

(1A/1D)

$$\ln CLU_{i,t} = a + b_{DEP} \ln DEP_{i,t} + b_{DEP2} (\ln DEP_{i,t})^2 + b_{PASS} \ln PASS_{i,t} + b_{MON} MON_i + b_{REG94} REG94_{i,t} + e_{i,t}$$

(2A/2D)

$$\ln CLU_{i,t} = a + b_{DEP} \ln DEP_{i,t} + b_{DEP2} (\ln DEP_{i,t})^2 + b_{PASS} \ln PASS_{i,t} + b_{MON} MON_i + b_{DEP94} DEP94_{i,t} + e_{i,t}$$

(1B)

$$\ln CLU_{i,t} = a + b_{DEP} \ln DEP_{i,t} + b_{DEP2} (\ln DEP_{i,t})^2 + b_{PASS} \ln PASS_{i,t} + b_{REG94} REG94_{i,t} + b_{DA} DA + e_{i,t}$$

since we cannot split observations on passengers into 'winter' and 'summer', we would not properly be able to control for route size that way.

[25]The routes are FBU-TRD, FBU-BGO, FBU-STV and BGO-STV (see Table B1 for definitions). Note that by defining two peak periods for four routes with six years of observations we get (2x4x6) 48 observations.

(2B)
$$\ln CLU_{i,t} = a + b_{DEP} \ln DEP_{i,t} + b_{DEP2}\left(\ln DEP_{i,t}\right)^2 + b_{PASS} \ln PASS_{i,t} + b_{DEP94} DEP94_{i,t} + b_{DA} DA + e_{i,t}$$

The variable $CLU_{i,t}$ is our clustering index, where the subscript *i* refers to route, and subscript *t* refers to year. The control variables $DEP_{i,t}$ and $PASS_{i,t}$ are the number of departures and the total number of passengers for each route in each year. All these variables are measured in logarithms. In Appendix A we show that departures enter not only as a linear term, but also as a quadratic term in CLU. We have therefore included the quadratic term $\left(DEP_{i,t}\right)^2$. The number of passengers is included to capture the growth in the market, and the departures are included to control for the increase in flights per day.[26] All else equal, an increase in the number of flights will have a non-positive effect on waiting costs. Hence, in line with the prediction from Appendix A, we expect the linear term to be negative (the first order effect) and the quadratic term to be positive (the second order effect). Since an increase in the number of passengers will be partly mirrored in the increase in the number of flights, also this control variable is expected to have a negative effect on waiting costs. If crowded routes reduce the carriers' incentive to cluster their flights, an increase in passengers should have a negative impact on clustering.

To measure the effect of servicing a monopoly route, we have included the dummy variable MON_i. The monopoly dummy takes the value *one* whenever we have a Braathens or *SAS* monopoly route that remains a monopoly route *throughout the period* 1991 to 1997. The regime shift dummy, $REG94_{i,t}$, is included to measure the duopoly effect of the 1994 deregulation. $REG94_{i,t}$ takes the

[26] There are two additional reasons for including both passengers and departures as control variables. First, there might be changes in the load factor across routes and time that should be accounted for. If so, passengers and departures are not perfectly correlated. Second, there are less incentives for carriers to locate close to their rivals' in order to steal customers if the flights are nearly full. As argued in Borenstein and Netz (1999), this should also be captured by the load factor. In our setting, this is captured by an increase in *PASS* without any corresponding increase in *DEP*.

value *one* for all six duopoly routes after deregulation in the three models A1,B1 and D1. The deregulation dummy, $REG94_{i,t}$, are capturing any possible *level* effects of the deregulation in the sense that the dummy is set equal to 1 for all duopoly routes. However, the transition from monopoly to duopoly may have had different effects on small than on large routes. To take this into account, we use terms which are the products of $DEP_{i,t}$ and $REG94_{i,t}$. The interaction term $DEP_{i,t} \cdot REG94_{i,t}$ weights the duopoly dummy with the size of the route in question, denoted $DEP94_{i,t}$ in models 2A, 2B and 2D. The MON_i, $REG94_{i,t}$ and $DEP94_{i,t}$ are all expected to capture any possible shift in location pattern following a transition from monopoly to duopoly. If we find that $b_{MON} < 0$, this is consistent with clustering following deregulation. Second, if the duopoly dummies are positive then this is also consistent with clustering following deregulation.

Models 1B and 2B is estimated for the business travellers' segment for the four largest duopoly routes. The morning segment is defined as the period between 06:30 and 10:30, and the afternoon segment is defined as the period between 15:00 and 18:30. [27] We include a dummy variable DA to capture any possible differences in the magnitude of our clustering index in those two segments.[28]

When measuring clustering for all flights by both carriers we are unable to detect whether possible clustering is driven by clustering *within* the firms rather than from clustering *between* the firms. To take this into account, we also estimate models where we only measure clustering *within* the firms. We construct an index that measures clustering for the incumbent, the *dominant* firm. Models 1D and 2D are therefore estimated for these within data.

[27]We have unequal length on the two periods to take into account the differences in the travelling pattern in the morning and the afternoon.

5. Empirical results

Heteroscedasticity is a potential problem since the variance may increase as a function of route size, *i.e.*, the number of departures or passengers. All models are therefore estimated using weighted least squares with size as weighting variable.[29] In Table 1 we present the results for the full sample for both carriers. Since the different routes may contain individual time-invariant characteristics not captured by our control variables, we also estimate route-specific fixed effect models, where possible route-specific differences are captured by route dummies. Note that the *MON* variable is excluded in the fixed effect models. This dummy is not identified with fixed effects since it is perfectly correlated with the fixed effects dummies representing the monopoly routes.

[Table 1 approximately here]

In all four models where the quadratic term $(DEP_{i,t})^2$ is included it comes out as insignificant, but with as predicted positive signs. Therefore, we also estimate four linear models where the quadratic term is excluded.

We note that the control variables - the number of departures and the number of passengers - come in negative and significant in all 8 models.[30] As departures and the number of passengers increase, the waiting cost decreases.

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[28] The dummy variable DA takes the value one for the afternoon observations. b_{DA} is expected to be negative as it accounts for a 30 minutes shorter time interval.

[29] We undertake two tests for heteroscedasticity for all models. The first test are the Breuch-Pagan/Godfrey (BPG) test (see e.g., Greene 2000), and the second test is a test for multiplicative heteroscedasticity designed by Harvey (1976, 1990). Both tests are asymptotically Chi-squared distributed with number of freedom according to the number of regressors used. Her we use the full $\boldsymbol{X}$ matrix except for the constant term as regressors in the tests.

[30] *Both* the passenger- and the departure variable are found to be significant in all eight models. This suggests that both changes in load factor across routes and time, as well as the PAS variable, might pick up the effect of crowded flights we have referred to above (an increase in the number of passengers reduces the clustering).

We use a Wald test to test for the importance of the fixed effects. For all the fixed route-specific effects models we cannot reject the null of *no route-specific fixed effects* (all route dummies equal to zero) on a 5% significance level. For three of the models we can reject the null of *no route-specific fixed effects* on a 10% level.

The change in clustering following deregulation can be measured in two ways. First, we can trace the monopoly effect of the six routes that remained monopoly routes throughout the period. Second, we can trace the duopoly effect on the six remaining routes. Concerning the duopoly effect, we see that for all models the variables $REG94_i$ and $DEP94_i$ have positive signs. In 5 out of 8 of the models the variable is significant at 5% and 10% significance levels. In the fixed effect models we find less significant results with significance levels between 10 and 20%.[31] Turning to the monopoly effect, we notice that the sign is as expected and clearly significant in all 8 models. When we use the data set covering the whole day and all flights, we thus find that our dummies clearly indicate a tendency of clustering on duopoly routes after deregulation. Our results for the business segment models, 1B and 2B, are shown in Table 2.

[Table 2 approximately here]

We included fixed effect models here as well. These did not perform better than the standard models, and the null of no fixed effect could not be rejected for any of the models. We found the quadratic term $(DEP_{i,t})^2$ to be insignificant, but with positive signs also here. Thus, suggesting that the linear models without fixed effects (column 2 and 6 in Table 2) can be preferred here. Our clustering hypothesis is

[31] It is common to get this difference in significance levels when introducing fixed effects. All variables are less precisely estimated in the fixed effect models. Partly this is due to fewer degrees of freedom, partly because the fixed effect dummies pick up some of the information that was attributed to the other variables when the fixed effect was excluded.

supported also within this more narrowly defined segment. In fact, we find even stronger support for clustering after 1994 in the business segment, where b_{DEP94} is now significant at a 2.5% in 4 models and 10% in 2, where both the linear models indicate a 2.5% level. This suggests that the shift in the degree of clustering is more prevalent in the business travellers' segment than in general. In Section 2 we argued that casual observations indicate that price competition is less intense in the business travellers' segment than in general.[32] If so, we have found more clustering in a segment where they compete less fierce on prices than in general. This is in line with the result in Borenstein and Netz (1999), which in a study of the US airline industry before and after deregulation in 1978 found that price competition results in less clustering.

Finally, we estimate models 1D and 2D where we include clustering and departures only for the dominant firm. This is to see if the driving force behind our results is clustering *within* rather than *between* the firms. The null of *no route-specific fixed effect* can be rejected for the two linear models at 5% level.[33] The results are presented in Table 3.

[Table 3 approximately here]

The control variables $DEP_{i,t}$ and $PAS_{i,t}$ have still the expected negative signs. The monopoly dummy is still negative and significant in all models. However, the regulation dummy is insignificant and negative in all the 8 *dominant firm* models. It suggests that the incumbent - the dominant firm – does not cluster its own flights following deregulation in 1994. This suggests that the clustering we observe is due to the co-

[32]Note that the passenger variable is less significant in the 1B and 2B models. We use the same passenger variable here as in the aggregated models (1A and 2A). Hence, the lower significance is as expected since the figure for total number of passengers will be less precise as a measure when we only look at the morning and afternoon segments. The DA variable enters as expected with a negative sign in all models and is very stable across models.

[33]These results are available upon request to the authors.

location of the two firms' flights rather than co-location of each firm's own flights. Put differently, a transition to duopoly leads to clustering.

In sum, the explanatory power is high for all models, and all models pass the heteroscedasticity tests.[34] We find no tendency of clustering within incumbent firms, but we find tendency to clustering between firms in duopoly and even more so in the business segment than in general.

6. Some concluding remarks

The purpose of this paper has been to test empirically the time location of flights in the Norwegian airline industry following deregulation. We use a data set which has the nice feature of experimental design in that some routes went from monopoly to duopoly, and some routes continued to be monopoly routes. We find that monopoly leads to less clustering of departures than duopoly, and even more so in the business travellers' segment than in general. Anecdotal evidence and descriptive studies suggest that firms colluded on prices in the business segment, and competed on prices – at least to a certain extent – in the leisure segment. One interpretation of our result is then that collusion on prices in the business segment resulted in intense competition on location in that particular segment.[35]

Our results suggest that public policy in this particular market may have been misguided. In the old regulatory regime, the government imposed regulation on the time location of flights to avoid any clustering. Since we see no significant effect of the time location regulation when a route is served by a monopolist, that particular kind of public measure in the old regulatory regime has been redundant. On the other hand, we find a clustering effect on the duopoly routes following deregulation. This suggests

[34]This is true for all models using the BPG tests, and for 10 out of 24 models using the HARVEY test. The Harvey test suggests heteroscedastisity predominantly in the quadratic models.

[35]In the literature, collusion along one dimension and competition along another dimension is called semicollusion. For surveys of the literature on semicollusion, see Fershtman and Gandal (1994) and Phlips (1995), chpts. 9 and 10.

that there is a larger scope for time location regulation in the new than in the old regulatory regime. Moreover, our results - as well as Borenstein and Netz (1999) - indicate that more price competition would result in less clustering. Hence, any measures which could promote price competition would have two positive effects on welfare: lower prices as well as more freedom of choice concerning departure time.

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Appendix A – The functional form of the clustering index

We are interested in how a marginal change in the location of one flight affects the clustering index. If only one flight is relocated, we know that the effect on total waiting cost is captured if we take into account only three flights; the one in question, the one located earlier and the one located later in time than the one in question. Therefore, let us consider three flights located on a time line; one early, one late and one in the middle. We assume that the early flight is located at 0, the late flight at 1 and the middle flight at a, where $a \in (0,1)$. Given a uniform distribution of travellers and a waiting cost per unit equal to t, the clustering index for the interval [0,1] is the following:

$$CLU = \frac{t\left[\frac{a}{2}\right]^2}{2} + \frac{t\left[a - \frac{a}{2}\right]^2}{2} + \frac{t\left[\frac{a+1}{2} - a\right]^2}{2} + \frac{t\left[1 - \frac{a+1}{2}\right]^2}{2}$$

$$= t\left[\frac{a}{2}\right]^2 + t\left[\frac{1-a}{2}\right]^2 = \frac{t(1+2a^2-a)}{4}$$

(A.1)

Note that departure a's effect on the clustering index is captured by a linear and a quadratic term. The quadratic term has a positive sign while the linear term has a negative sign. It can easily be shown that if we add one (or more) departures, then each departure has still a linear and a quadratic term in the clustering index and the sign of each of them will be as described above.

Then we have the following first and second order effects of a change in departure time:

$$\frac{\partial CLU}{\partial a} = \left[a - \frac{1}{2}\right]t \text{ and } \frac{\partial^2 CLU}{\partial^2 a} = t$$

If $a > ½$, we see that an increase in a increases the clustering index, while the opposite is true for $a < ½$. This implies that the clustering index is at a minimum when $a = 1/2$, where the mid flight is located with an identical distance to the two neighbouring flights. This is the maximum differentiation situation. We see that a relocation, either to the left or to the right, result in a higher clustering index. In particular, we see that a marginal relocation's effect on the clustering index depends on a, the initial location. The further away from maximum differentiation, the larger effect on the clustering index by a further shift away from maximal differentiation. Let us consider the case of an endpoint to the left. Then it is sufficient to consider two flights: the one nearest to the end point, and the one closest to this flight (to the right of it). Let zero be the endpoint, and flights located in a and 1, respectively, where $a < 1$. Then the clustering index would be the following:

$$CLU = \frac{t[a]^2}{2} + \frac{t\left[\frac{a+1}{2} - a\right]^2}{2} + \frac{t\left[1 - \frac{a+1}{2}\right]^2}{2} = \frac{t(1 + 3a^2 - 2a)}{4}$$

It can easily be checked that the CLU index has the same characteristics as described above.

Finally, let us check how an increase in the number of departures will affect our clustering index. Let us now extend the number of departures to four. We assume that the early flight is still located at 0, and the latest flight at 1. The two intermediate flights are located at a_1 and a_2, respectively, where $a_i \in (0,1)$ for i=1,2 and $a_1 < a_2$. Then we have the following expression:

$$CLU = t\left[\frac{a_1}{2}\right]^2 + t\left[\frac{a_2 - a_1}{2}\right]^2 + t\left[\frac{1 - a_2}{2}\right]^2 = \frac{t(1 + 2a_2^2 + 2a_1^2 - 2a_1a_2 - 2a_2)}{4} \qquad \text{(A.2)}$$

We can easily check that if $a_1 = a_2$, co-location of the two intermediate flights, the CLU index formula for three flights (see A.1) is identical to the CLU index formula for four flights (A.2). Then we can easily check the effect of an extra flight that is not co-located, *i.e.*, $a_1 < a_2$. If we interpret a_1 as the additional flight, we see that a_1 enters as both a linear and a quadratic term. Put differently, new departures will enter the CLU index with both a linear and a quadratic term.

Appendix B - Data definitions and data sources

Table B1 Routes, number of departures , and number of firms

Number	**Codes**	**City-pair**	**Non-stop Depart. 1996**	**Number of Firms**	**Market Share Dom. Firm**
1	FBU-TRD	Oslo - Trondheim	27	2	59%
2	FBU-BOO	Oslo - Bodø	7	2	71%
3	FBU-TOS	Oslo - Tromsø	9	2	67%
4	FBU-BGO	Oslo - Bergen	24	2	71%
5	FBU-STV	Oslo - Stavanger	24	2	63%
6	BGO-STV	Bergen - Stavanger	20	2	75%
7	TRD-AES	Trondheim - Ålesund	4	1	
8	FBU-KRS	Oslo - Kristiansand	7	1	
9	FBU-AES	Oslo -Ålesund	6	1	
10	FBU-HAU	Oslo - Haugesund	8	1	
11	FBU-MOL	Oslo - Molde	5	1	
12	FBU-KSU	Oslo – Kristiansund	3	1	

Departures, flight schedules and information on air carriers are found in the «*Books of Norwegian flight schedules - Winter-routes*», 1991, 1992, 1993, 1995, 1996 and 1997. The Passenger variable is defined as the total number of passengers that travelled the route in these years. Passenger figures on route-level are provided by the Norwegian Civil Aviation Authority.

Tables

Table 1 *The empirical results from the WLS estimation when the flights for both carriers are included ((Data for 12 routes, for the period 1991-97, n=72)*

Model/			FIXED EFFECT				FIXED EFFECT	
Parameter	1A (quadratic)	1A (linear)	1A (quadratic)	1A (linear)	2A (quadratic)	2A (linear)	2A (quadratic)	2A (linear)
b_{DEP}	-0.911*	-0.800*	-0.612**	-0.805*	-0.871*	-0.809*	-0.475**	-0.774*
	(0.172)	(0.054)	(0.310)	(0.118)	(0.177)	(0.055)	(0.361)	(0.115)
b_{DEP2}	0.025		-0.060		0.015		-0.096	
	(0.037)		(0.089)		(0.039)		(0.110)	
b_{PASS}	-0.191*	-0.199*	-0.218**	-0.223*	-0.194*	-0.198*	-0.210**	-0.213*
	(0.044)	(0.042)	(0.099)	(0.099)	(0.044)	(0.042)	(0.099)	(0.099)
b_{MON}	-0.115*	-0.117*			-0.123*	-0.124*		
	(0.044)	(0.044)			(0.043)	(0.043)		
b_{REG94}	0.093**	0.099**	0.142***	0.107				
	(0.048)	(0.047)	(0.086)	(0.068)				
b_{DEP94}					0.034***	0.036**	0.056	0.031
					(0.019)	(0.018)	(0.038)	(0.025)
$\bar{R}^2$	0.965	0.965	0.965	0.966	0.965	0.965	0.965	0.965
BPG-test $c^2_{(4,5,14,15)}$	6.200*	5.715*	15.040*	13.637*	6.453*	6.168*	14.828*	13.943*
Harvey's test $c^2_{(4,5,14,15)}$	11.778*	15.624	28.744	29.308	15.173	10.238*	32.521	32.107
Wald-test Fixed effect $c^2_{(11)}$			17.21	17.65***			18.65***	18.19***

$^{*/}$significance level 2,5%, $^{**/}$significance level 5%, $^{***/}$significance level 10%
(Constant term and fixed effects dummies are not reported)

Table 2 *The empirical results for the business segment, WLS estimation when the flights for both carriers are included on the four largest routes (The period from 1991-97, n=48))*

Model/			FIXED EFFECT				FIXED EFFECT	
Parameter	1B (quadratic)	1B (linear)	1B (quadratic)	1B (linear)	2B (quadratic)	2B (linear)	2B (quadratic)	2B (linear)
b_{DEP}	-1.192*	-0.856*	-1.173**	-0.868*	-1.069*	-0.867*	-1.099**	-0.880*
	(0.358)	(0.085)	(0.369)	(0.092)	(0.382)	(0.089)	(0.414)	(0.094)
b_{DEP2}	0.123		0.114		0.076		0.083	
	(0.128)		(0.134)		(0.139)		(0.153)	
b_{PASS}	-0.092	-0.095***	-0.174	-0.180	-0.097***	-0.099***	0.054	-0.009
	(0.056)	(0.056)	(0.416)	(0.414)	(0.057)	(0.042)	(0.422)	(0.402)
b_{DA}	-0.186*	-0.193*	-0.189*	-0.194*	-0.188*	-0.191*	-0.190*	-0.193*
	(0.034)	(0.034)	(0.035)	(0.034)	(0.035)	(0.025)	(0.035)	(0.035)
b_{REG94}	0.180*	0.202*	0.208***	0.231***				
	(0.049)	(0.043)	(0.120)	(0.117)				
b_{DEP94}					0.102*	0.111*	0.080	0.100
					(0.030)	(0.025)	(0.073)	(0.063)
$\bar{R}^2$	0.870	0.871	0.867	0.868	0.865	0.867	0.861	0.863
BPG-test $c^2_{(4,5,7,8)}$	8.878*	10.440*	12.417*	12.602*	9.316*	9.980*	11.884*	12.089*
Harvey's test $c^2_{(4,5,7,8)}$	14.030	5.239*	8.273*	5.348*	13.901	9.804*	18.668	15.167*
Wald-test Fixed effect $c^2_{(3)}$			1.94	2.14			1.84	1.87

*/significance level 2,5%, **/significance level 5%, ***/significance level 10%
(Constant term and fixed effects dummies are not reported)

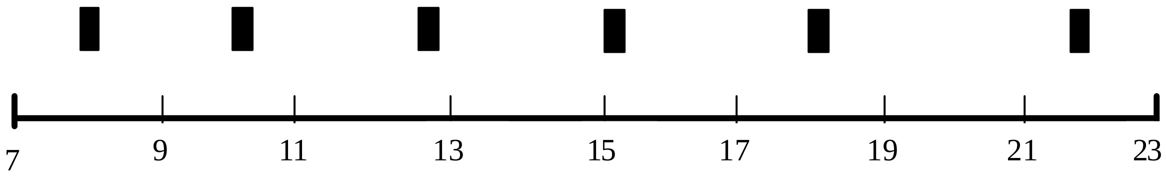
Table 3 *The empirical results from the WLS estimation we only include the dominant firm, (Data for 12 routes, for the period 1991-97, n=72)*

Model/ Parameter			FIXED	EFFECT			FIXED	EFFECT
	1D (quadratic)	1D (linear)	1D (quadratic)	1D (linear)	2D (quadratic)	2D (linear)	2D (quadratic)	2D (linear)
b_{DEP}	-1.077* (0.222)	-0.788* (0.055)	-0.853*** (0.445)	-0.833* (0.117)	-1.114* (0.228)	-0.783* (0.056)	-0.909*** (0.464)	-0.829* (0.117)
b_{DEP2}	0.073 (0.055)		0.006 (0.129)		0.085 (0.057)		0.024 (0.136)	
b_{PASS}	-0.178* (0.041)	-0.195* (0.040)	-0.226* (0.095)	-0.225* (0.094)	-0.194* (0.044)	-0.197* (0.040)	-0.223* (0.094)	-0.222* (0.093)
b_{MON}	-0.110* (0.043)	-0.115* (0.043)			-0.102* (0.042)	-0.111* (0.042)		
b_{REG94}	-0.052 (0.044)	-0.041 (0.043)	-0.028 (0.055)	-0.027 (0.052)				
b_{DEP94}					-0.025 (0.020)	-0.015 (0.019)	-0.016 (0.025)	-0.014 (0.022)
$\bar{R}^2$	0.958	0.958	0.959	0.960	0.959	0.957	0.959	0.960
BPG-test $c^2_{(4,5,14,15)}$	6.806*	5.846*	18.916*	16.290*	6.546*	5.539*	18.582*	15.842*
Harvey's test $c^2_{(4,5,14,15)}$	8.932*	14.513	32.435	27.024*	8.691*	15.557	39.630	30.807
Wald-test Fixed effect $c^2_{(11)}$			17.15	20.66**			17.01	20.83**

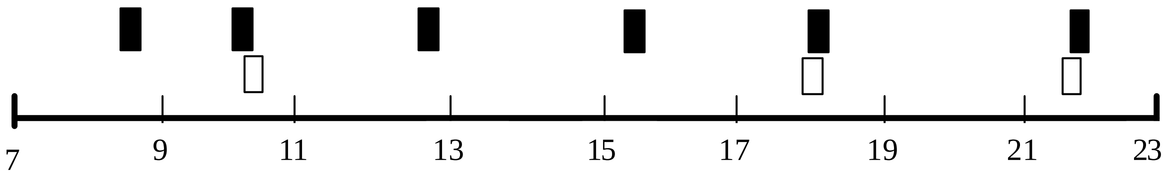
*/significance level 2,5%, **/significance level 5%, ***/significance level 10%
(Constant term and fixed effects dummies are not reported)

Figure 1. *Flight departures Oslo-Bodø before and after deregulation*

Before deregulation (winter 93):



After deregulation (winter 96):



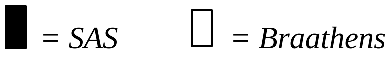
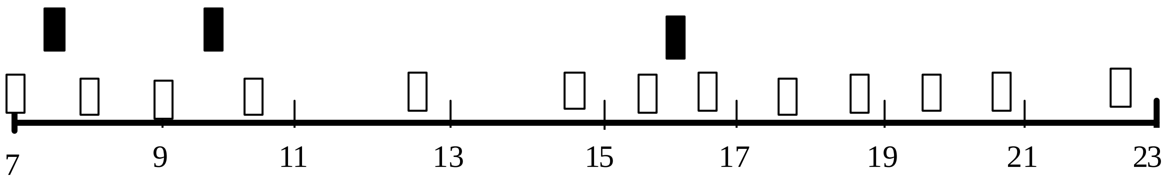
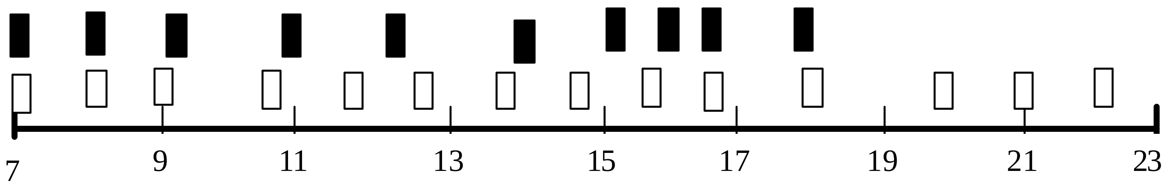


Figure 2. *Flight departures Oslo-Stavanger before and after deregulation*

Before deregulation (winter 93):



After deregulation (winter 96):



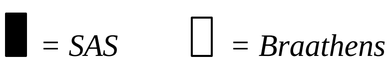


Figure 3. *Market structure in 1995 on the 12 domestic routes*