The Determinants of Pass-Through with Capacity Constraints and Dynamic Demand

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Abstract

Despite its prevalence as a policy tool, little is known about the effects of taxes and subsidies to consumers in industries with capacity constraints and in which consumers can purchase in multiple periods. This project aims at studying the effect of these features on pass through in oligopolistic markets. Using data from the airline industry in Spain I quantify the pass-through of a subsidy increase and how it varies with the intensity of competition, time left to departure and the presence of capacity constraints. I then develop a theoretical model to rationalize the observed effects, and I show that time to departure and capacity constraints are relevant features that affect the usual determinants of pass-through in oligopolistic settings. I also show how the presence of strategic substitutabilities between prices in different periods alter the usual analysis of the effect of competition on pass-through, and how this can explain a negative impact of competition on pass-through rates.

1 Introduction

A classical topic in Public Economics is the effect of public intervention in a market using taxes and subsidies and how it affects the welfare of agents present in that market. One of the most relevant aspects in this topic is how the burden of a tax or the benefits from a subsidy are shared between firms and consumers. When thinking about the case of a subsidy, from the point of view of public policy design, it is of great importance to understand which are the features of a market that determine this split, since large amounts of taxpayer money are used to fund these subsidies. The fact that most of the benefits of a subsidy program designed to favor consumers end up being appropriated by firms is most likely a non-desirable outcome. This paper aims to understand the determinants of the share of the benefits of a subsidy (or burden of a tax) in industries in which firms are subject to capacity constraints and consumers can decide the timing of purchasing the good, using the specific case of the airline industry.

The main tool to measure this split is the pass-through rate, which captures how the price to consumers is affected by the change or the introduction of a tax or a subsidy. Moreover, this measure is also used to study the effect of other changes in firms' environment, such as shocks to marginal costs or changes in market structure. The determinants of pass through have been studied since long time ago in monopoly settings and in perfect competition settings, dating back at least to the work by Cournot (1838) and Jenkin (1871). However, it was not until more recently that pass-through of taxes and subsidies in contexts of imperfect competition has been studied, a question that is comprehensively described in the work by Weyl and Fabinger (2013), giving rise to a new wave of studies about tax incidence in such settings. Nevertheless, there are still several settings in which there is still no work done or no consensus on how pass-through is determined. In particular, this issue is still to be studied in contexts in which demand can be modelled as a dynamic process, i.e. the same good can be sold in different points of time, and consumers can decide to buy the same good in different periods. Last but not least, there is also no consensus on the impact on capacity constraints on the supply side on the pass-through of a tax or a subsidy.

Therefore, the research question analyzed in this paper is then: *What are the determinants of pass-through when (i) there is imperfect competition with differentiated products and capacity constraints and (ii) firms can sell the same product in several periods?*. These two elements are relevant, as I show in my theoretical results, and it is important to understand how they affect the ability of firms to make consumers bear a larger burden of a tax or reap a larger share of a subsidy granted to consumers in these settings. As mentioned above, the specific industry in which I study this issue is the airline industry, which is a perfect example of a market in which the three features listed above are important. Recently, there have been several proposals by policy makers to impose additional taxes on the consumption of air travel services, with an environmental goal in mind. I believe the result of this work can inform these policies since it is important to understand how the burden of such taxes would be distributed between consumers and firms. Understanding the determinants of pass-through in industries with these features can also be useful for designing similar policies in settings where they should be taken into account, such as subsidies to promote the use of electric vehicles or taxation of durable goods in general.

The main results obtained so far are the following ones. First, I define pass-through as the percentage change in effective price (after applying the subsidy) after the increase in the subsidy rate. Since the change in the policy is a subsidy increase, when speaking about a larger pass-through in absolute value I refer to a larger decrease in effective prices. In the empirical analysis, I found that the subsidy increase from 50% to 75% in 2018 caused a decrease in effective prices in all routes, but the effects were heterogeneous depending on the characteristics of the routes. In particular, the price decrease was larger in routes in which the share of subsidized consumers is smaller. Furthermore, the price decrease was larger in the periods farther away from departure. Last but not least, routes with more competitors experienced a smaller pass-through than routes with less firms active. While the first two results are according to expectations and to what is predicted by simple models, the latter result is unexpected, because according to the main literature in this issue markets with a higher degree of competition should experience a larger effective price reduction.

My theoretical results show that pass through depends on three main factors: the degree of competition, the relative elasticity of demand and supply, and the curvature of demand. The last two factors are affected by the share of subsidized consumers, since this group is less price sensitive due to the subsidy. While the relevance of these factors is a standard result in the pass-through literature, I show how the presence of a capacity constraint always makes the pass-through smaller. I also show that the period before departure is relevant to predict pass-through, since pricing decisions in periods before departure are affected by the continuation value of the firm in the following periods, which is in turn affected by the spare capacity determined by the prices chosen in that period. These two factors in the pricing decision are relevant to rationalize the unexpected result of a smaller pass-through in markets with a larger number of competitors.

Last but not least, I show how the interaction between multiple periods of sale and competition modifies the usual effect of competition on pass-through rates found in the static analysis done by the literature so far. The intuition here is that prices in different periods can have strategic substitutability, contrary to the usual strategic complementarities between prices in static Nash-Bertrand competition. As a result of this, a higher intensity of competition can make pass-through rates less complete when prices exhibit strategic substitutability, since a price decrease of a rival firm in a different period of sale generates a response of increasing price. As a result of this, pass-through rates with higher competition can be less complete than with less competition, which is a new outcome compared to the static analysis of pass-through, and which can explain the empirical results of my analysis.

Literature Review

As it was mentioned in the first paragraph, the issue of pass-through has been studied for long, especially in the extreme contexts of perfect competition and monopoly. One of the main results from the initial work is the well known equivalence under perfect competition of ad valorem and unit taxes in terms of economic impacts, which dates at least to Suits and Musgrave (1952). With respect to the magnitude of pass-through, most of the references calculate it in the context of unit subsidies. The main reference I have followed for the determinants of pass-through in these extreme cases is Weyl and Fabinger (2013), which summarize the relevant results reached before them. According to these authors, under perfect competition, pass-through is determined only by the ratio of elasticity of demand and elasticity of supply. The pass-through increases in the ratio of the elasticity of supply relative to that of demand, and with inelastic supply (such as constant marginal cost), pass-through under perfect competition is complete, since the price to consumers adapts fully to keep the price received by the firm constant. In a monopoly situation, the pass-through is also affected by the curvature of demand, i.e. by how the response of demand to prices changes with price itself. A positive curvature (log-concave demand) makes pass-through smaller than 1, that is incomplete pass-through, whereas negative curvature (log-convex demand) allows for pass-through rates above 1, what is known as overshifting. Fabinger and Adachi (2022) have an exhaustive translation of Weyl and Fabinger (2013) results for unit taxes to ad valorem taxes.

This paper, however, aims at developing the strand of the literature that analyzes pass-through in imperfect competition settings, that is, for the intermediate situations between perfect competition and monopoly. Two of the main references are again Weyl and Fabinger (2013) and Fabinger and Adachi (2022). Their main result is to identify a third factor that determines the pass-through rate in settings with imperfect competition, which is a measure of the intensity of competition, which they calculate as the *elasticity-modified Lerner index*. According to their result, pass-through is lower when higher prices lead the industry to be more competitive. Some other important theoretical references are Anderson and de Palma (2001), whose work I follow when deriving the market equilibrium, since they also use a multinomial logit demand and two firms, and recent work by Miravete et al. (2013a, 2023b). The latter authors analyze in more detail two of the determinants mentioned above, the elasticity of demand and the curvature of demand, for discrete choice demand models. Their main result is the importance to allow for more flexibility in the substitution patterns than that given by the basic multinomial logit to be able to predict pass through rates larger than 1.

This paper is also related to the strand of the literature that analyzes pass-through rates empirically, using reduced form analysis relying on observed changes in taxes and subsidies. The main references I have followed here are the papers of Genakos and Pagliero (2019, 2022), in which the authors analyze the effect on gasoline prices in the Greek islands of several tax increases, both in specific taxes (excise duties) and in the VAT, which is an ad valorem tax. Their setting is comparable to mine since they also have several markets, determined by each island, and there is a significant heterogeneity in the number of competitors across markets. Their main result is that pass through of the taxes increases with the number of competitors. Another work that I have followed is that of Cabral et al. (2018), which analyzes the pass-through of a subsidy to premium prices in insurance contexts. Their result, following a similar methodology to that of Genakos and Pagliero (2021) is that pass-through increases with competition. However, since they are analyzing the effects of a subsidy, this implies a larger price reduction, i.e. a larger share of the benefits of the subsidy for the consumers, in markets where there is a higher degree of competition. There are also empirical studies which show that pass-through decreases with competition, such as Miller et al. (2017) and Stolper (2018).

Structure of the paper

The remainder of the paper is structured as follows. In Section 2 I explain in more detail the specific industry in which I am working, explaining how the subsidy works and also presenting the data that I use for the empirical analysis, as well as some descriptive evidence. In Section 3 I conduct a reduced form analysis to measure the pass-through of a subsidy increase that took place in 2018, using a similar empirical strategy to that of Genakos and Pagliero (2021). In Section 4 I set up a theoretical model to explain price decisions by firms in a context with a perishable good, capacity constraints and heterogeneous consumers in terms of entitlement to the subsidy. The goal of this section is to obtain an expression on how does the price equilibrium change when the subsidy rate changes, and how does this variation depend on different features of the model, such as the share of subsidized consumers, the degree of price differentiation or the number of competitors. Finally, in Section 5 I conclude and I outline the next steps to be followed to improve the analysis.

2 Setting and Motivating Evidence

To answer my research question, I analyze the Spanish airline industry, an applied setting that reunites the two relevant features I want to study: (i) oligopoly markets with differentiated products and capacity constraints and (ii) perishable good with several purchasing periods. This industry is a textbook example of these two features. Furthermore, the presence of a subsidy to consumers in the Spanish airline industry makes it a suitable setting to answer this research question. A third relevant fact for the empirical study is that there is heterogeneity among consumers with respect to entitlement to the subsidy. In particular, the group of entitled consumers are those whose residence is set in the so-called remote Spanish territories[1], are entitled to an ad-valorem price discount on the posted price by airlines, for any trip with beginning and endpoint in the national territory of Spain. The remainder of the price is paid by the government to the airlines. The rest of consumers pay the full price charged by the airline. This subsidy program has been in place since the 1960s, and as I explain below the discount rate has been changing along its existence.

[1] Canary Islands, Balearic Islands, Ceuta and Melilla

I have access to two sources of data from this industry. First, I have a dataset which contains the universe of purchases done under the subsidy program between July 2015 and July 2019. That is, all purchases by the group of subsidized consumers during that time span. For each observation, I know the origin and destination of the flight, its time and date, the airline, the posted price and the discount the consumer enjoyed. Moreover, I also observe the date of purchase of the ticket, which allows me to know how long in advance before departure such ticket was bought. I also observe a consumer identifier number for each purchase, which allows me to observe repeated purchases for some consumers and a discrete variable informing of whether a ticket was purchased as part of a multi-flight trip, and which leg of the trip that specific flight represents. Apart from this, I have a second dataset, from the management company of Spanish airports, AENA, which contains information on all the flights on Spanish territory during the same time span, including capacity (seats) of the aircraft and final occupancy (number of passengers). Using information about the time and date, the route and the airline, I can merge the two datasets to add the information about capacity and occupancy provided by the second dataset.

The subsidy change

Crucially for the research question in this paper, the subsidy rate, which was initially set at 50 % of the price at the beginning of the time span of my data, in 2015, was increased to 75 % in July 2018[2]. This allows me to observe how prices reacted to a change in the subsidy rate. In this industry markets are normally defined as a combination of route and month (or period of the year). Therefore, this setting also provides rich heterogeneity between markets in terms of competition, as well as in terms of presence of subsidized consumers. I can observe how differently prices reacted in the different markets according to these characteristics. Importantly, this change was a quite unexpected policy decision in the middle of the national government budget in Spain, which needed the vote of a congress member from a Canarian regional party to be approved. Therefore, the subsidy change can be considered as an unexpected measure and unanticipated, since it was announced shortly before it was implemented. Nevertheless, I add a robustness test of my results replicating the analysis removing the period between the announcement and the entry into force of the subsidy increase[3]

Descriptive Evidence

First, let's look at average prices per day in the year window around the subsidy change, which was implemented for purchases made from July 16th, 2018 on. The initial effect is not so obvious, although the months after the subsidy increase prices are higher than in the previous year. However, in the summer one year after the subsidy increase, the prices have dramatically increased, with a spike in the month of July of 2019.

This changes are more clearly seen if we look at the yearly evolution of prices in the year immediately below the subsidy increase (July 2017 to July 2018), and after (July 2018 to July 2019). In this graph it can be seen how prices after the subsidy change are for every day above the equivalent day on the year before. It can also be noticed how the pass through to prices is also different depending on the time of the year, with some clear increase on prices during the fall months, almost no price increase around New Year, and then an increase on the pass through to prices that grows larger during winter and spring, and becomes quite large in June and July. Looking at the graph of effective prices, there seems to be a quite constant decrease along the year, except for the summer, in which the pass through to effective prices is 0, i.e. consumers are paying the same prices as before.

Looking to find some first evidence related to my research question, i.e. how is the pass through affected by (i) competition, (ii) time to departure and (iii) presence of subsidized consumers, I analyze how have prices changed

[2]For tickets in routes between the remote territories and Mainland Spain. The subsidy had increased to 75% already in 2017 for flights between two remote territories.

[3]Between the announcement on May 27th, 2018 and entry into force on July 16th, 2018.

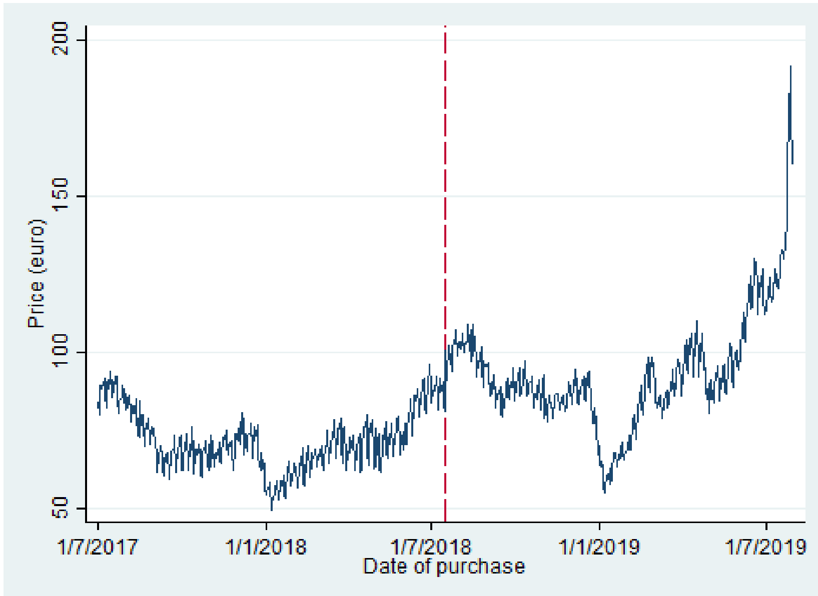
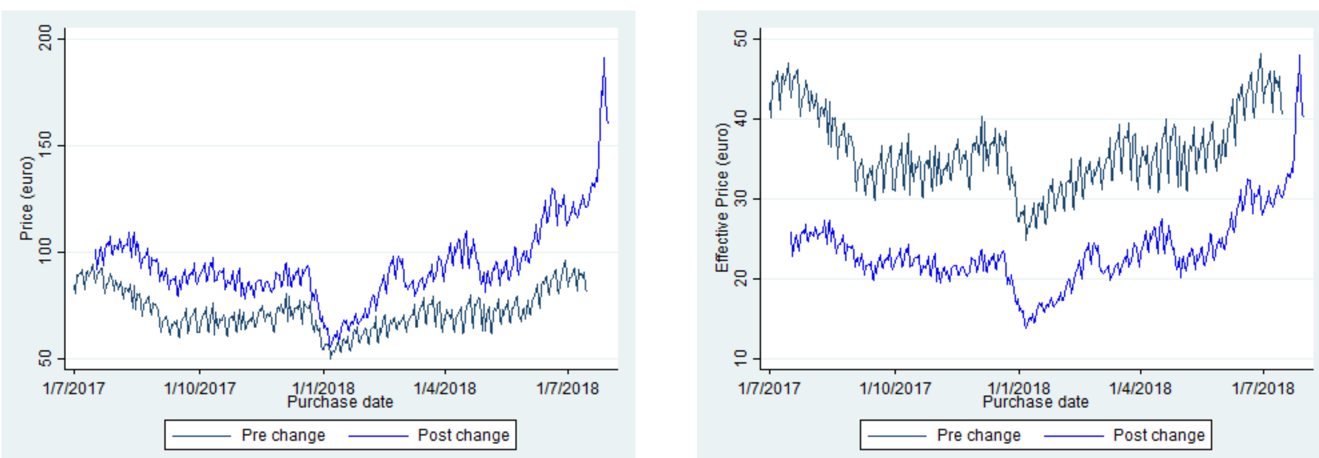


Figure 1: Evolution of prices per purchase date, around subsidy change



(a) Prices

(b) Effective Prices

Figure 2: Evolution of prices per purchase date, year before and after subsidy change

depending on those aspects. First of all, I will establish my definition of observed pass-through in my data. I calculate pass-through for every day before departure, t, as follows:

$$PT_t = \frac{\bar{P}_t^1 - \bar{P}_t^0}{\bar{P}_t^0}$$

$\bar{P}_t$ is the average price t days away from departure, for a selected set of markets (which, as a reminder, is defined as a pair route - period of the year). The result of this formula are interpreted as percentage change, for the 50 % observed change in the subsidy, prices have increased (or decreased. if result is negative) by x %. The first graph depicts the average pass-through for each day prior to departure, computed using the above formula. In it we can see how pass through is incomplete, always between -36 % and - 42 %. The other important aspect of this graph is that pass-through increases in absolute value in the final days before departure. Indeed there is a slight increase until the final week of sale, and then a sharp growth of the pass-through in the final week before departure (since I am analyzing a subsidy increase, then a more negative pass-through means a larger reduction in the effective price, i.e. a larger pass-through).

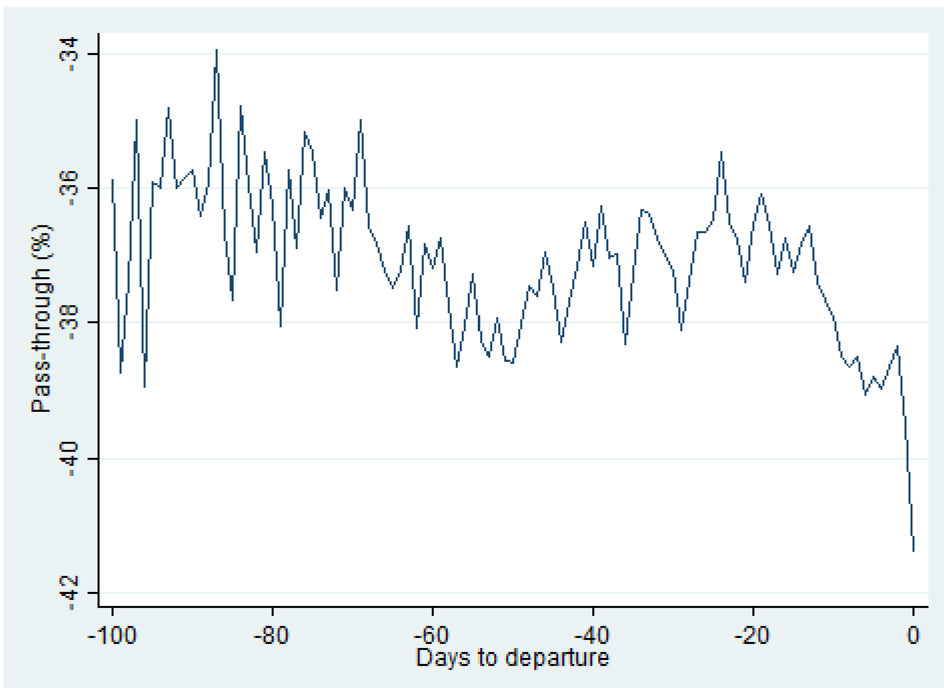
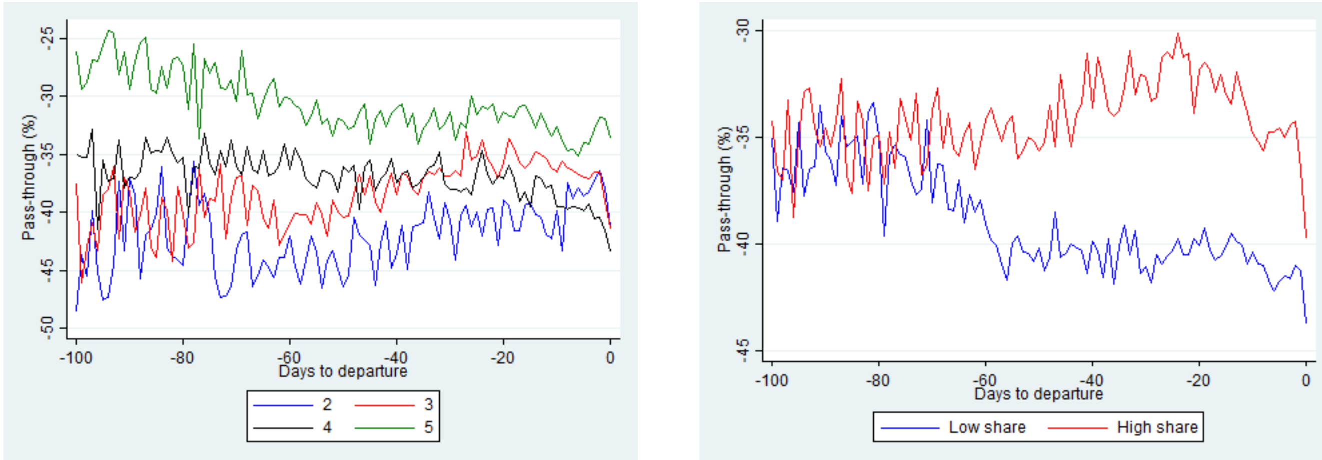


Figure 3: Pass through along time to departure

If one analyzes this more in detail, separating routes by number of competitors, the result is as follows. Firstly, by number of competitors, pass through was smaller in markets with a higher number of competitors. This may seem unexpected, since the higher the level of competition, the lower the price reduction, and therefore the higher the share of the subsidy increase that firms have been able to appropriate. Apart from this, pass through is more or less constant along time to departure for routes with lower number of competitors (2 or 3), and the increasing trend towards the final periods of sale is caused by the routes with a larger number of competitors (4 or 5).

Looking at how the pass-through varies depending on the presence of subsidized consumers in the market, depicted in panel b, the pass through seems more or less equal in the initial periods of sale, but as it could be expected, 2



(a) By Number of Competitors

(b) By Share of Subsidized

Figure 4: Pass through along time to departure, by competition and share of subsidized consumers intensity

months before departure there is a divergence, with the pass through in routes with a lower share of residents getting larger. The gap widens until getting stable at around 5 percentage points. The pass-through in both types of routes also gets larger towards the final days before departure, especially in the final week. The differences in the pass through could be indicative of firms pricing differently depending on the intensity of subsidized consumers in each route. The higher pass through in routes with a low share of resident consumers can be explained with the fact that increasing prices much in those routes may not be profitable since some the many consumers who are not entitled to the price discount would stop buying. This smaller increase of posted price generates a larger decrease of the effective price, and therefore a larger pass-through.

3 Econometric Measurement of Pass-Through

In this section, I dig deeper on the descriptive evidence presented in the previous one. To do so, I run a regression analysis to measure how the change in prices after the subsidy increase correlates with different characteristics of each route. The regression analysis relies on the observed change in the policy in July 2018, the increase of the price discount from 50% to 75%. For the estimates to be consistent, the following two conditions are required: (i) unanticipation of subsidy change, (ii) independence between evolution of prices and characteristics of interest. With respect to the first point, it can be argued that the policy change was unexpected and did not create large anticipation effects, because it was implemented one month and a half after its announcement. The main reason to believe it can be considered as an unexpected policy change is that the policy change was approved as a measure to win a single favorable vote of a Canarian regional party, which were needed to approve the Spanish national budget in 2018. The negotiations to approve such budget were long and tough, and to secure those final, necessary votes, the national government implemented this increase in the subsidy. Had this vote not been necessary, this policy change would not have been implemented (or it would have been implemented at a different time). Due to this, this policy change can be considered as exogenous to the market and unexpected.

With respect to the second point, since I am interested in understanding the difference in pass-through across markets depending on the level of competition and on the intensity of the capacity constraint, it is required that the change in the unobserved factors explaining prices before and after the subsidy change are uncorrelated with such market characteristics. To illustrate this, for instance considering the effect of competition on pass-through, the requirement is that all unobservable factors that influence prices evolve equally between routes with different number of competitors around the subsidy change.

3.1 Base Specification and Average Pass-Through

For measuring the pass-through in a more systematic way, I first select a certain set of routes. I select the bigger routes in terms of passengers that join the Balearic Islands and the Canary Islands with Mainland Spain, dropping all routes with less than 1,000 observations per month. In addition to this, I also merged the dataset on purchases with that of occupancy and capacity of the aircraft. Despite some discrepancies between the time of departure between the two datasets, the percentage of successfully merged observations is quite high. Those observations which could not be merged are dropped[4]. After this subsampling, the dataset contains almost 11.2 million of observations. Table 1 contains some summary statistics.

Competitors	**Observations**	**Markets**	**Share of residents**	**Price before**	**Price after**
2	689, 177	345	0.266	40.82€	24.44€
3	2, 657, 415	812	0.256	34.52€	21.76€
4	3, 444, 981	445	0.251	32.26€	20.26€
5	4, 301, 980	220	0.230	36.91€	25.14€

Table 1

As it can be seen in the leftmost column of the table, there is a large number of observations for all number of competitors, although there are less observations (purchases) and markets[5] with 2 competitors than with 3, 4 and 5 active airlines. With respect to the share of subsidized consumers, i.e. the share of resident consumers, it is always close to 25 % on average, although it is strictly decreasing on the number of competitors. This is calculated as the total number of subsidized purchases in a month and route, divided by the total number of passengers obtained from the AENA database. Last but not least, the table also reports the average effective prices (i.e. after applying the discount) in these routes, before and after the subsidy. Effective prices fell significantly in all four groups, but in none of them full pass-through is reached, since no price reached a decrease of 50%.

The used specification used to measure pass-through in the literature, for instance as in Genakos and Pagliero (2021) and Cabral et al. (2018), uses the natural logarithm of consumer prices as a dependent variable. Pass-through is measured using the coefficient multiplying the tax (or subsidy) rate. However, in my setting I do not observe a local change, but a rather large change, since the subsidy rate increases by 50%. Therefore the logarithm is no longer a good approximation to the percent change in prices after such a large increase in the discount rate. Therefore, the strategy I follow is to estimate a specification in which the dependent variable is the level of subsidized prices, and the relevant explanatory variable is an indicator of whether the purchase happened after the increase in the subsidy rate, either on its own or interacted with other characteristics of interest, such as the level of competition or the presence of subsidized consumers in a market. After estimating the coefficients, I calculate the elasticity of subsidized price with respect to the post change indicator. This gives me the percent change in the subsidized price after the increase in the subsidy rate, which is the measure used in Fabinger and Adachi (2022) and in Genakos and

[4]The most likely possibility for unsuccessful merge is a very large delay in the flight, since the purchases database contains the scheduled time of departure and the AENA database contains the actual time registered by the airport authorities. Therefore the very large discrepancies come from large delays.

[5]A market is defined as a combination of unidirectional route (origin-destination) pair and month.

Pagliero (2021) to define the pass-through of an ad-valorem tax. The specification is as follows, with $\mathbf{X}$ refering to the characteristics of interest which may be interacted with the post subsidy change indicator[6]:

$$p_{t,armd} = \alpha_0 + \alpha_1 Post_t + \mathbf{X}'_{\mathbf{rm}}\boldsymbol{\beta} + \left(Post_t \times \mathbf{X}'_{\mathbf{rm}}\right)\boldsymbol{\gamma} + \mathbf{W}'_{\mathbf{rm}}\boldsymbol{\omega} + \epsilon_{t,armd}$$

The unit of observation is per purchase. An effective price can have a value $t \in \{0, 1\}$ depending on whether it was bought before or after the day of the implementation of the subsidy change, July 15th, 2018. Furthermore, each ticket has a selling airline a, for a route r, during month m and is bought d days prior to departure. The regressors of interest in this initial specification are the following ones. First of all, the dummy variable $Post_t$ is an indicator of whether the ticket was bought before or after the subsidy change. Its coefficient α_1 measures the average change in effective price for a ticket with the baseline values of the other variables. Secondly, there are the interactions between such post-implementation binary variable, and certain characteristics of interest defined at market (route-month) level, contained in the vector $\mathbf{X_{rm}}$. These characteristics are the level of competition $Comp_{rm}$ and the intensity of the capacity constraint, measured by the average level of aircraft occupancy in a route in a certain month, $Occupancy_{rm}$. The coefficients γ measure the differential change in effective price after the subsidy increase depending on the intensity of competition and on the share of subsidized consumers in a market. Last but not least, the specification includes a series of controls, among them the level of competition and the occupancy level. I also include as a control the proportion of subsidized consumers in the market, measured as the average share of entitled consumers in the flights of a certain route r on month m, as well as a series of fixed effects (FEs), namely airline, route and month FEs.

The main objective of this measurement exercise is to obtain a reliable estimate of the coefficients in $\boldsymbol{\gamma}$, that is, how does the pass-through of the subsidy to effective prices depend on competition and the share of subsidized consumers. The average level of pass-through, measured by α_1 is also of interest, but the main objective of this project is to document and explain how the ability of firms to appropriate the subsidy (or to pass-through a tax) varies with competition and with the stringency of the capacity constraint, which I measure using the level of average occupancy in the route. Therefore, to obtain a reliable measure we need to make sure there are no endogeneity issues between the effective price and the interactions between the post-change dummy and the intensity of competition or the level of occupancy. There are potential problems of endogeneity in this analysis, mostly in the analysis of how does pass-through change with the level of competition, caused by the fact that it is likely that some elements in the error, which are relevant to determine variation in prices around the subsidy change, are also relevant to determine the level of competition. Genakos and Pagliero (2021) acknowledge this threat to identification of the effect of competition on pass-through, and deal with it using population of each island, which is interpreted as a measure of market size, as instrument for competition. I have done a similar analysis as robustness check of my results, and the direction of the effects is unchanged. However, a nice step ahead would be to find a more credible instrument in terms of exclusion, since it is debatable that market size only affects prices through competition.

For interpreting the results, I will use the concept of *more complete / less complete* pass-through, which is usual in the literature. More complete pass-through means that a larger percentage of the subsidy increase was passed through to prices, which is the case when the coefficient is negative and larger in absolute value.

The results of these initial specification are as follows. Column 1 is just an average pass-through regression with controls, but no differential effects depending on the intensity of competition or on the share of subsidized consumers. As depicted in the table, the average pass-through after the subsidy change was -38.09%. This means

[6] X is a vector that may contain up to 2 variables: {Number of competitors, Occupancy}. If some of this variables are not included in a certain specification, the entry corresponding to such variables has a value of 0.

that on average, effective price to subsidized consumers decreased by 38.09%. Since the subsidy increased by 50%, the percentage of the subsidy increased passed-through to consumer prices was on average 76.18%[7], which is an incomplete pass-through (below 100%). In Row 2 I analyze the pass-through of the subsidy change depending on the average level of occupancy of aircrafts in the market. To do so, I report the semi-elasticity of the effective price with respect to the post change indicator for percentiles 25, 50 and 75 of the occupancy levels. The larger the occupancy level is, the less complete pass-through is. As I will show in Section 4, this is consistent with the theoretical results are that the higher is the occupancy level, the smaller the price reduction after the subsidy increase. In Row 3 and 4 I look at the effect of competition on pass-through, measured by the number of firms active in a market. At larger levels of competition (more firms present in the market), pass-through is less complete. As robustness check, I also introduce some of this features simultaneously. Letting the level of occupancy and number of competitiors act at the same time does not seem to have any qualitative impact in the effects described above.

Variable	Mean	P25	P50	P75
No Interaction	-0.3809^{***}			
	(0.000)			
Occupancy	-0.3923^{***}	-0.4027^{***}	-0.3846^{***}	-0.3764^{***}
	(0.003)	(0.004)	(0.003)	(0.004)
	2	3	4	5
Ncomps	-0.4761^{***}	-0.4099^{***}	-0.3738^{***}	-0.3604^{***}
	(0.002)	(0.001)	(0.001)	(0.001)

Table 2: Static Pass-Through, by level of competition and share of subsidized consumers

3.2 Pass-Through and Time to Departure

In addition to this, and since one of the research questions of this project is the effect of the time left until the deadline to sell the perishable good (i.e. departure time) on the pass-through of the subsidy increase, I now develop a reduced form analysis to measure the different pass-through depending on how much time there is left to sell the good. First of all, and in order to smooth prices and obtain more reasonable estimates, I aggregate time to departure into four bins, according to the quartiles of the distribution of purchases along time to departure:

- **Bin 1:** Last 7 days before departure.
- **Bin 2:** Weeks 2 and 3 before departure.
- **Bin 3:** Week 4 to 1.5 months (45 days) before departure.
- **Bin 4:** More than 1.5 months (45 days) before departure.

The specification used to measure the effect of time left to departure on pass-through is as follows:

$$\ln p_{t,armd} = \alpha_0 + \alpha_1 Post_t + \mathbf{X}'_{\mathbf{rm}}\boldsymbol{\beta} + \sum_{d=1}^{D} \delta_d TimetoDep_d + \left(Post_t \times \mathbf{X}'_{\mathbf{rm}}\right)\boldsymbol{\gamma} + \\ + \sum_{d=1}^{D} \left(Post_t \times TimetoDep_d \times \mathbf{X}'_{\mathbf{rm}}\right)\mathbf{\Pi}_d + \mathbf{W}'_{\mathbf{rm}}\boldsymbol{\omega} + \epsilon_{t,armd}$$

[7] $\frac{0.3809}{0.5} = 0.7618$

Compared to the original specification above, notice that there is a set of dummy variables for each of the 4 bins before departure, a set of interactions between these dummies and the post subsidy change indicator variable $Post_t$. Each of these interactions measures the differential pass-through in the respective time to departure bin, compared to the baseline period. I begin showing the results for the effect of time to departure on pass-through, without interacting it with the other factors of interest (competition and stringency of the capacity constraint). This is depicted in Figure 5. Pass-through is more complete for tickets bought in the time bin furthest away from departure. In the remaining three bins, pass-through becomes slightly more complete as departure approaches, but the change is very small.

The set of interactions multiplied by the level of competition or by the level of occupancy provide differential effects of these features on pass-through depending on the time to departure. As it can be seen in Figure 6, the level of competition is only relevant in the initial periods of sale. The pass-through of the subsidy increase was larger in more concentrated routes in the initial periods of sale, but this difference disappears as departure approaches. With respect to the effect of the level of occupancy, as expected, routes with a lower occupancy experienced a larger pass-through. However, this difference also reduces as departure time approaches.

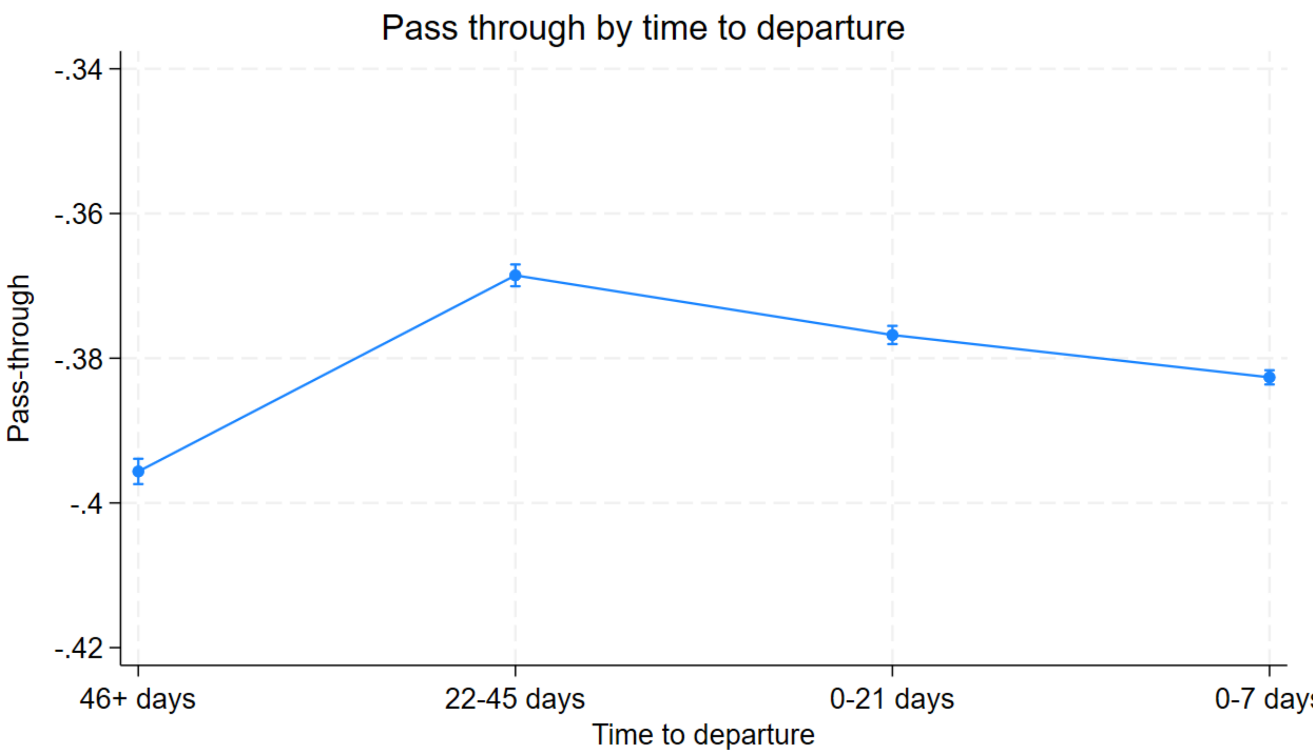
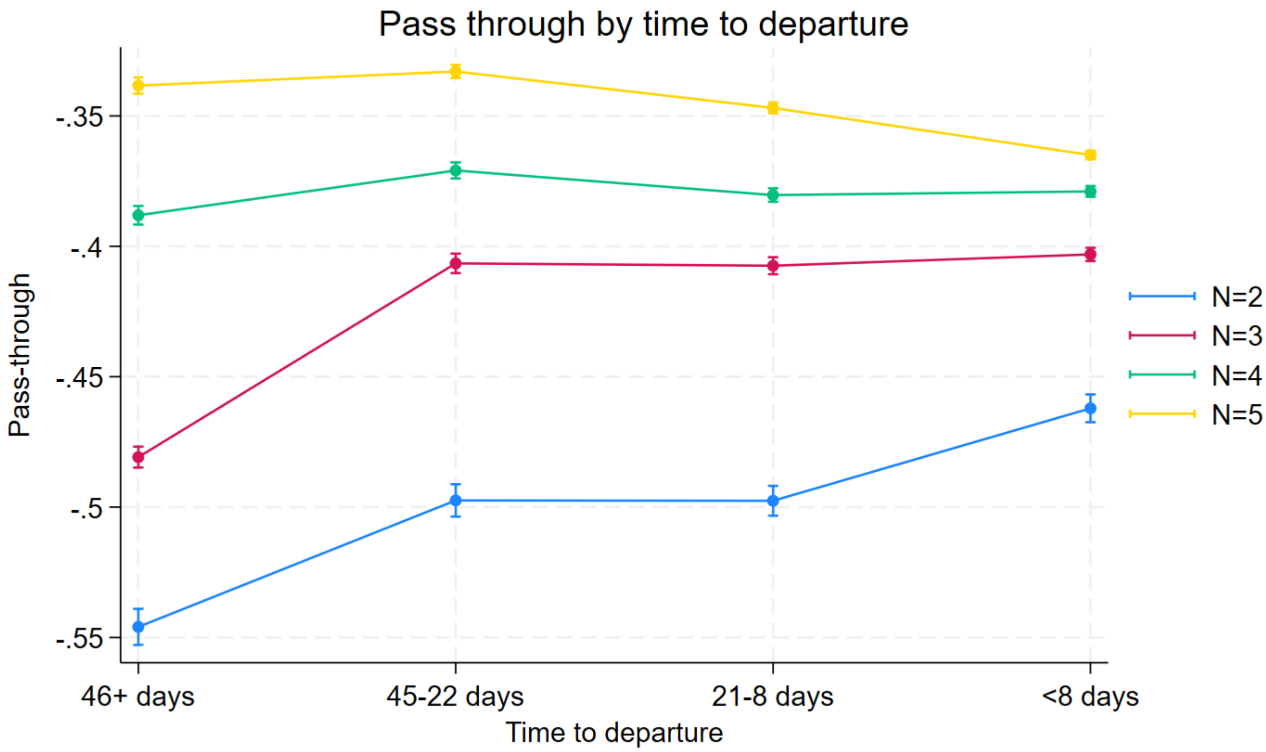


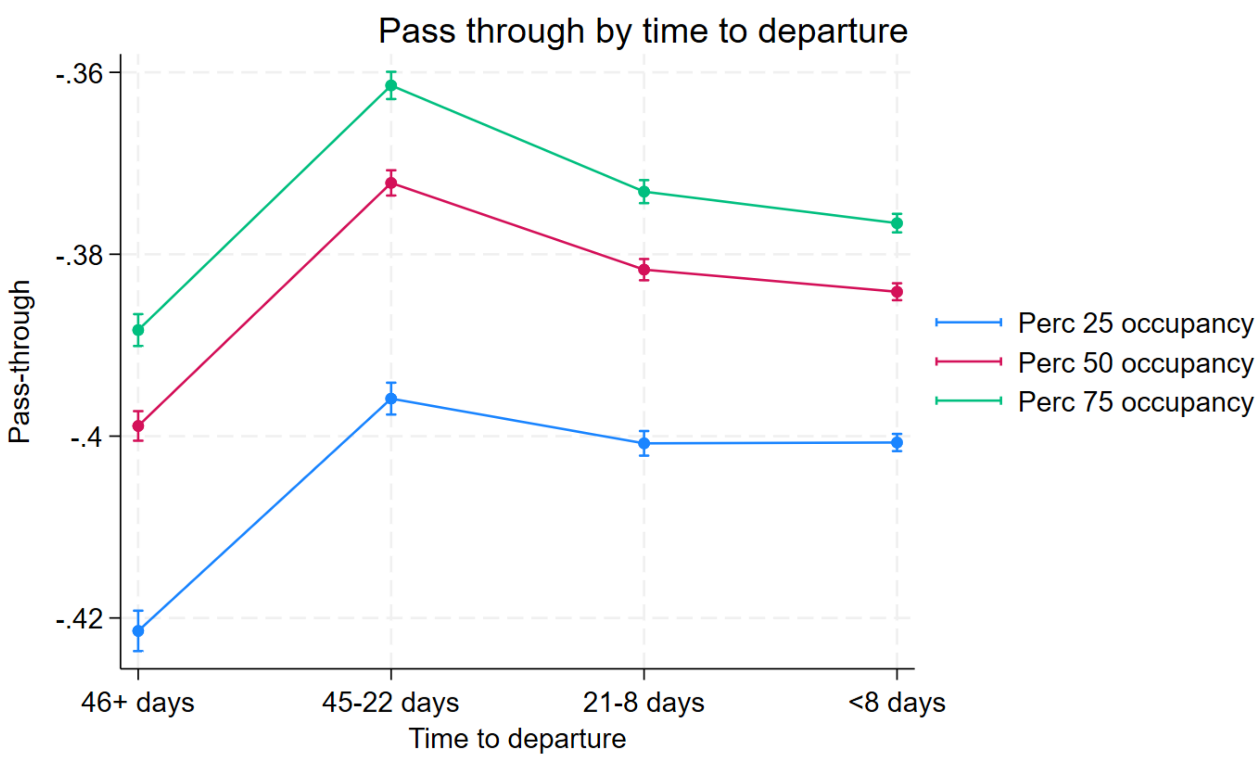
Figure 5: Pass-through by time to departure

4 Model and Interpretation of Effects

To understand the above results and interpret them, I develop a theoretical model of pricing decision by airlines with 2 periods to sell the good and the presence of a capacity constraint. I allow the intensity of competition to vary in



(a) By Concentration (HHI)



(b) By Level of Occupancy

Figure 6: Pass through along time to departure, by competition and intensity of capacity constraint

order to understand how it affects the pass-through of the subsidy increase to consumer prices. I start with a simple version of the model with only one period and no capacity constraint, and add these features sequentially to show how they impact the benchmark pass-through case with a static model and no capacity constraints.

4.1 Primitives of the Model

The current version of the model contains N firms selling one good (N airlines selling seats in a plane) during 2 periods. The good is identical irrespective of the period it is purchased on, but some consumers arrive in the early period and some consumers arrive in the late to the market, as I explain in the following paragraph. Firms choose prices in both periods with no commitment. The components of the model are the following ones:

1. **Consumers:** In period 1, consumers have the following utility from purchasing a ticket for flight j at consumer price p_{j1}: $u_{ij1} = \delta v_j - \alpha p_{j1} + \epsilon_{ij1}$. In period 2, $\delta \leq 1$, which is a discount factor, disappears, so period 2 consumers have a larger willingness to pay ($u_{ij2} = v_j - \alpha p_{j2} + \epsilon_{ij2}$). The idiosyncratic terms specific to each consumer ϵ_{ijt} is iid across flights j, periods t and consumers i, and distributed according to a Extreme Value Type I distribution, with scale parameter σ. Notice that in this simple version of the model with no difference in the mean utility across different products, σ fully governs the degree of price differentiation, with a high σ corresponding to higher product differentiation. This is because a higher scale parameter implies a higher volatility of the idiosyncratic shock to preferences, and therefore more dispersed utility levels across products and consumers. In addition to this, a fraction ψ of consumers are entitled to an *ad-valorem* subsidy r every time they purchase a ticket. I will refer to each of these two groups as two types of consumers, subsidized (s) and non-subsidized (ns). The former group of consumers pay a consumer price $p_j^s = (1-\tau)p_j^{ns}$. In the model, price p refers to the price paid by subsidized consumers, i.e. p^s. Non-subsidized consumers thus pay $\frac{p}{1-\tau}$. Both types of consumers must make a one-off purchase decision after arriving to the market, either they buy the ticket or leave the market for ever. In the current version, the mass of consumers is equal in size across the two periods, although this is something to be changed in future versions.

2. **Per-period demand:** Since consumers either buy or leave, the mass of consumers present in the market in each period, M_t, is independent of how many tickets were sold in the previous period. Therefore, and given the distribution of the unobserved, idiosyncratic term in the utility function, the per-period demand for each product is given by the mass of consumers of each type present times the probability of purchase of the corresponding consumer type. Since I use p_{jt} to refer to the subsidized consumer price (i.e. after applying the discount), per-period demand is thus given by the following formula ($T = \frac{1}{1-\tau}$ represents the increase in price for ns consumers):

$$D_{jt} = M_t \left[\psi \underbrace{\frac{\exp\left\{\frac{\delta^{2-t} v_j - \alpha p_{jt}}{\sigma}\right\}}{1 + \sum_k \exp\left\{\frac{\delta^{2-t} v_k - \alpha p_{kt}}{\sigma}\right\}}}_{s_{jt}^s} + (1-\psi) \underbrace{\frac{\exp\left\{\frac{\delta^{2-t} v_j - \alpha T p_{jt}}{\sigma}\right\}}{1 + \sum_k \exp\left\{\frac{\delta^{T-t} v_k - \alpha T p_{kt}}{\sigma}\right\}}}_{s_{jt}^{ns}} \right]$$

3. **Firm side:** There are N firms competing in this market, and each of them sells one product j, which also indices the firm. Each of them has a constant marginal cost per unit sold c_j. Additionally, each firm faces a capacity constraint given by the maximum capacity of the aircraft K_j, which is the maximum units of the product which can be sold. Firms choose subsidized prices p_{jt} in both periods, and their objective is to maximize total profits from the product, i.e. the sum of profits made in each period of sale, subject to the sum of units sold across periods being smaller or equal than their capacity K. Firms have no ability to commit, and

therefore maximize in each of the two periods. In $t = 1$ firms take into account the effects of their choices on their future self in $t = 2$, and internalize its future self choice given the spare capacity that will be inherited. To simplify the maximization and the comparative statics to compute the pass-through rates (i.e. how does optimal choice of price change with the subsidy rate), I multiply the profit by $\frac{1-\tau}{1-\tau}$, which does not affect the solution of the problem. Thanks to this, the subsidy enters the objective function multiplying marginal cost, instead of dividing subsidized price. This simplifies significantly the analysis of changes in the pass-thorugh rate that I will do later in this section. Let me call $\tilde{c} = c(1-\tau)$ *effective marginal cost*. Therefore, at $t = 1$ firm j solves:

$$\max_{p_{j1}} \Pi_j = \frac{1}{(1-\tau)} \left(p_{j1} - c(1-\tau)\right) D_{j1}(p_{j1}, p_{-j1}, \tau) + \frac{1}{(1-\tau)} \left(p_{j2}(K - D_{j1}) - c(1-\tau)\right) D_{j2}(p_{j2}, p_{-j2}, \tau)$$

$$\text{subject to } \sum_{t}^{2} D_{jt} \leq K$$

However, firms have no ability to commit, and therefore re-optimize the price in every period. At period 1, firms know that all they can do is predict how their future self will choose given the inherited spare capacity and internalize that reaction in their own decision process. Therefore, we can rewrite the period problem for the firm using dynamic programming as follows (I drop the subscript j for convenience):

$$V_1\ (K) = \max_{p_1} \left(p_1 - c(1-\tau)\right) D_t + V_2(k_2) \quad \text{subject to } D_t \leq k_t \text{ and } k_2 = k_1 - D_1$$

In period 2, the value function is:

$$V_2\ (k_2) = \left(p_2 - c(1-\tau)\right) D_2 \quad \text{subject to } D_2 \leq k_2$$

.

4.2 Solving for the equilibrium

Following Dana and Williams (2020), I assume capacity is small enough to rule out mixed strategies equilibria. Therefore I focus on characterizing pure strategies equilibria and analyzing comparative statics around those equilibrium prices. This way, I can analyze how changes in the subsidy affect equilibrium prices, and also analyze how this effect of the subsidy varies depending on the degree of competition and the percentage of subsidized consumers, restricting to pure strategy equilibria (PSE).

Focusing on PSE, depending on the parameters, there can be three types, depending on which firms exhaust capacity. I assume parameters and initial capacity are such that firms never choose prices to exhaust capacity in the initial period, since selling at least some units in the second period generates a large increase in profits. The three cases are (i) **all firms exhaust**, (ii) **no firm exhausts** and (iii) **some firms exhaust while others do not**. I will derive the equilibrium case by case and focus mostly on the first two cases, which are the ones arising in the model when parameters and initial capacity are homogeneous across firms.

1. **No firm exhausts**
   When no firm exhausts in equilibrium, all of them choose the unconstrained Bertrand Nash equilibrium, given by the prices that solve the system of equations provided by the FOC of the second period:

$$p_{j2}\ : D_2(p) + \frac{\partial D_2}{\partial p_{j2}}(p_{j2} - c(1-\tau)) = 0\ \forall j$$

In the first period, anticipating the equilibrium in the second period will be the Nash-Bertrand unconstrained price, with associated value V_2^*, firms choose prices to solve the unconstrained FOCs of the first period:

$$p_{j1} \ : D_1(p) + \frac{\partial D_1}{\partial p_{j1}}(p_{j1} - c(1-\tau)) - \frac{\partial V_2^*}{\partial K_2}\frac{\partial D_1}{\partial p_{j1}} = 0$$

Since in this model, the Bertrand Nash price in $t = 2$ is independent of spare capacity, V_2^* is also not affected by K_2, and hence the last term disappears from the FOCs, yielding two identical sets of equilibrium conditions across periods. The equilibrium price $\mathbf{p}^*$ is identical across periods, and it is determined as the unique solution to the system of equations of the FOCs in both periods.

2. **All firms exhaust**
This case arises when initial capacity is small enough. In particular, when the sum of demand at the unconstrained equilibrium price over the two periods is strictly larger than initial capacity. Since I am focusing on ex-ante identical firms and symmetric equilibria, if firms cannot serve the sum of demand over the two periods at the symmetric, unconstrained equilibrium price, then the equilibrium will be such that capacity is exhausted in $t = 2$. This sufficient condition is as follows:

Exhaust if $K < \bar{K}$, where:

$$\bar{K} = D_{j1}(\mathbf{p}^*) + D_{j2}(\mathbf{p}^*)$$

$\mathbf{p}^*$ refers to the unconstrained equilibrium defined in the previous subcase.

Using backwards induction, beginning from the last period, when firms exhaust in the second period, they set the price p_{j2} that exactly sells all their spare capacity, given the price set by their rivals. This is because any price lower or higher than that would decrease their second period profits (lowering price would not increase units sold due to the capacity constraint). This happens when spare capacity is smaller than the quantity sold under the unconstrained Bertrand-Nash equilibrium of the second period subgame, so that firms also do not want to increase prices, since this is profit-decreasing. Therefore, the optimality condition for firm j in period 2 is:

$$p_{j2} \ : D(p_{j2}, p_{-j2}, \tau) = K_2$$

This yields an optimal price rule $\bar{p}_2(K_2)$ defined implicitly by the above condition, which satisfies that $\bar{p}_2(K_2)$ is decreasing in K_2. The value function associated to spare capacity K_2 is as follows: $V_2(K_2) = K_2[\bar{p}_2(K_2) - c(1-\tau)]$. Given this value function, the first period problem becomes:

$$V_1(K) = \max_{p_j 1} D(p_{j1}, p_{-j1}, \tau)(p_{j1} - c(1-\tau)) + V_2(K_2) \text{ subject to } K_2 = K - D_1$$

This problem yields the following optimal choice of period 1 price:

$$p_{j1} \ : D_1(p) + \frac{\partial D_1}{\partial p_{j1}}(p_{j1} - c(1-\tau)) - \frac{\partial V_2}{\partial K_2}\frac{\partial D_1}{\partial p_{j1}} = 0$$

3. **Some firms exhaust**
The equilibrium conditions in this case are a combination of the first case for those firms which exhaust capacity in period 2, and of the second case for those firms which do not exhaust. Unconstrained prices change compared to case 2 as a reaction to the higher price set by firms which exhaust capacity. However, with enough differentiation across firms and homogeneous firms this equilibrium does not occur.

4.3 Deriving the pass-through rate

I define the pass-through rate as the semi-elasticity of consumer (subsidized) price with respect to the subsidy rate, as it is done by Fabinger and Adachi (2022). Therefore, the expression to derive the pass-through rate is the following one:

$$\rho \equiv \frac{dp}{d\tau}\frac{1}{p}$$

The differential $dp/d\tau$ is obtained from the equilibrium conditions using the Implicit Function Theorem. In this subsection, I will derive the pass-through rate corresponding to each of the three equilibria characterized above and explain the intuition behind its components, as well as provide some bounds for the values pass-through rates can take in each case. I first derive the pass-through rate assuming all consumers are entitled to the price discount as a benchmark, and then I discuss how the introduction of non-subsidized consumers would alter the pass-through rate. For each equilibrium, I will first characterize the final period pass-through rate and then the initial period one. I assume equilibria are symmetric in the following way: equilibrium prices in both periods are equal across firms for firms that exhaust (although firms can have different prices in $t = 1$ and $t = 2$). Likewise, equilibrium prices in both periods are equal across firms for firms that do not exhaust. Thus, after a change in the subsidy rate, prices move simultaneously for all firms. Therefore, when I refer to change in prices in the equilibrium conditions, I refer to changes in the prices of all firms, since all firms react simultaneously to changes in the subsidy rate. The derivatives with respect to p_t refer to derivatives with respect to changes in all prices at period t, whereas the derivatives with respect to p_{jt} refer to changes only in the price of firm j.

1. **Unconstrained equilibrium**
   Since the FOC has the same structure in the two periods, the pass-through rate also has the same structure in the two periods:

$$\rho = \frac{dp}{d\tau}\frac{1}{p} = -\frac{c\frac{\partial D_{jt}}{\partial p_{jt}}}{\frac{\partial D_{jt}}{\partial p_t} + \frac{\partial^2 D_{jt}}{\partial p_{jt}\partial p_t}(p_{jt} - c(1-\tau)) + \frac{\partial D_{jt}}{\partial p_{jt}}}$$

   Let me explain the components in a bit more detail. In the numerator we have the effect of a change in the subsidy rate on the equilibrium conditions. Recall that in this benchmark I assume all consumers are entitled to the subsidy, and hence demand is not affected directly by changes in the subsidy rate, since the price included in the demand function is the subsidized price. The only direct effect of the subsidy rate is through the effective marginal cost $c(1-\tau)$, which decreases as the subsidy rate increases. This decrease in marginal cost is mediated by the effect of price on demand $\partial D_{jt}/\partial p_{jt}$. The intuition here is that an increase in the subsidy rate increases the per-unit markup.

   With respect to the components in the denominator, the first component $\partial D_{jt}/\partial p_t$ captures how demand for firm j is affected by an increase in *all prices* at time t. This is different than the own-price derivative $\partial D_{jt}/\partial p_{jt}$, and in particular the latter one is larger in absolute value, since in the former the drop in demand caused by an increase in own-price is moderated by the price increase in competitors' products. I assume that demand is such that cross-price derivatives are small enough not to fully compensate the own-price effect, i.e. $\partial D_{jt}/\partial p_t \leq 0$. With respect to the second component, it captures the effect of *all prices* on the own-price derivative, multiplied by the per-unit markup. As with the first component, I assume that the second own-price derivative determines the sign of this object, i.e. if demand is concave this object is negative. I assume demand is small enough so that demand is convex for all products (logit demand is convex when market shares are below 1/2). Finally, the third element is the own-price derivative.

This pass-through rate is negative due to the SOC being satisfied (which makes the numerator negative). Pass-through is also smaller than -1 in absolute value, which means that pass-through is not fully complete, as long as demand is not too convex. With equal demand parameters across the two periods, pass-through is also constant across the two periods since equilibrium prices are also equal across periods. In this case, the dynamic component does not change anything with respect to the static analysis, and therefore I focus my analysis on the second case, with firms exhausting capacity, in which the time component does have an impact on prices and pass-through rates.

2. **Capacity-exhausting equilibrum**
   Recall the last period optimality condition, $\{p_{j2} \ : D(p_{j2}, p_{-j2}, \tau) = K_2\}$. From here, it is easy to see that pass-through rate is 0, since the optimality condition is not affected by the subsidy rate. This is because subsidized consumers demand as a function of the subsidized price is not affected by the subsidy rate. The price charged by the firm does change, since it increases to absorb all the increase in the subsidy rate, and therefore the subsidized price stays unchanged. The firm is already choosing the maximum subsidized price to sell out all spare capacity and therefore it does not need to change it. Therefore, when all firms exhaust capacity, in the second period there is **full appropriation of the subsidy increase by firms**, i.e. zero pass-through. Adding a positive share of non-subsidized consumers makes pass-through more complete, i.e. pushes it below 0, as firms need to decrease consumer price in order to keep demand at spare capacity due to the presence of non-subsidized consumers, which pay the firm price.

   In the first period, the pass-through rate looks as follows:

$$\rho = \frac{dp}{d\tau}\frac{1}{\tau} = \rho = \frac{dp}{d\tau}\frac{1}{p} = -\frac{\frac{\partial D_{j1}}{\partial p_{j1}}(c-c)}{\frac{\partial D_{j1}}{\partial p_1} + \frac{\partial^2 D_{j1}}{\partial p_{j1}\partial p_1}(p_{j1} - c(1-\tau) - \frac{\partial V_{j2}}{\partial K_{j2}}) + \frac{\partial D_{j1}}{\partial p_{j1}}\left(1 + \frac{d(\partial V_{j2}/\partial K_{j2})}{dK_2}\frac{\partial D_1}{\partial p_1}\right)}$$

   As one can see, the pass-through rate when there are only subsidized consumers would be equal to 0, since the direct effects of the subsidy rate on the equilibrium conditions cancel out. This is because the decrease in effective marginal cost due to the subsidy increase happens in both periods, and therefore the effects cancel due to the presence of the opportunity cost of marginal profits in $t = 2$ present in the optimality conditions of $t = 1$. Thus, I allow for a strictly positive share of non-subsidized consumers in the rest of the analysis ($\psi > 0$). I use D_{jt} to refer to total demand for firm j at time t, and (D^s_{jt}, D^{ns}_{jt}) to demand of each group of consumers. I use the same notation for derivatives. Therefore, the optimality conditions become:

$$D^s_{j1} + D^{ns}_{j1} + \left(\frac{\partial D^s_{j1}}{\partial p_{j1}} + \frac{\partial D^{ns}_{j1}}{\partial p_{j1}}\right)\left(p_{j1} - c(1-\tau) - \frac{\partial V_{j2}}{\partial K_{j2}}\right) = 0$$

   The variation of this condition with respect to the subsidy rate is a different than in the benchmark with no non-subsidized consumers, due to the fact that the subsidy rate affects non-subsidized demand, because for a same subsidized price p, those consumers pay a higher price $\frac{p}{1-\tau}$ if the subsidy rate is larger[8]

$$d\tau = \frac{\partial D^{ns}_{j1}}{\partial \tau} + \frac{\partial(\partial D^{ns}_{j1}/\partial p_{j1})}{\partial \tau}\left(p_{j1} - c(1-\tau) - \frac{\partial V_{j2}}{\partial K_{j2}}\right) - \left(\frac{\partial D^s_{j1}}{\partial p_{j1}} + \frac{\partial D^{ns}_{j1}}{\partial p_{j1}}\right)\left(\frac{\partial K_{j2}}{\partial \tau}\frac{\partial^2 V_{j2}}{\partial K^2_{j2}}\right)$$

[8] The variation with respect to prices written in the denominator above can be decomposed as follows:

$$dp_1 = \left(\frac{\partial D^s_{j1}}{\partial p_1} + \frac{\partial D^{ns}_{j1}}{\partial p_1}\right) + \left(\frac{\partial(\partial D^s_{j1}/\partial p_{j1})}{\partial p_1} + \frac{\partial(\partial D^{ns}_{j1}/\partial p_{j1})}{\partial p_1}\right)\left(p_{j1} - c(1-\tau) - \frac{\partial V_{j2}}{\partial K_{j2}}\right) - \left(\frac{\partial D^s_{j1}}{\partial p_{j1}} + \frac{\partial D^{ns}_{j1}}{\partial p_{j1}}\right)\left(1 + \frac{\partial^2 V_{j2}}{\partial K_{j2}\partial K_2}\right)$$

.

I assume that this term, which is the numerator of the pass-through rate, is negative, which is needed for the pass-through rate to be negative, since the SOC guarantees that the denominator is negative. The first term is negative since at a higher subsidy rate, non-subsidized demand is lower since their price $p/(1-\tau)$ is larger. Because of assuming convex demand, the second term is positive. The third term is negative due to the assumption of second period profits being concave on spare capacity $\frac{\partial^2 V_{j2}}{\partial K_{j2}^2} \leq 0$. Therefore the pass-through rate in the capacity constrained equilibrium in period 1, with presence of non-subsidized consumers, looks as follows:

$$\rho = \frac{dp}{d\tau}\frac{1}{\tau} = \rho = \frac{dp}{d\tau}\frac{1}{p} = -\frac{\frac{\partial D_{j1}^{ns}}{\partial \tau} + \frac{\partial(\partial D_{j1}^{ns}/\partial p_{j1})}{\partial \tau}\left(p_{j1} - c(1-\tau) - \frac{\partial V_{j2}}{\partial K_{j2}}\right) - \left(\frac{\partial D_{j1}^{s}}{\partial p_{j1}} + \frac{\partial D_{j1}^{ns}}{\partial p_{j1}}\right)\left(\frac{\partial K_{j2}}{\partial \tau}\frac{\partial^2 V_{j2}}{\partial K_{j2}^2}\right)}{\frac{\partial D_{j1}}{\partial p_1} + \frac{\partial^2 D_{j1}}{\partial p_{j1}\partial p_1}(p_{j1} - c(1-\tau) - \frac{\partial V_{j2}}{\partial K_{j2}}) + \frac{\partial D_{j1}}{\partial p_{j1}}\left(1 + \frac{d(\partial V_{j2}/\partial K_{j2})}{dK_2}\frac{\partial D_1}{\partial p_1}\right)}$$

Focusing on the denominator, I analyze the new elements with respect to the unconstrained pass-through rate. The markup in this case has a new element, $\frac{\partial V_{j2}}{\partial K_{j2}}$, which is the option value lost when selling an extra unit in the first period, i.e. the opportunity cost of selling one unit today, which is having one unit less to sell in $t = 2$. This extra term in the markup modifies the impact on price on the optimality conditions in two ways: first, the markup multiplying the second derivative of demand includes this extra term, which reduces the markup. Taking advantage of the assumption of demand being convex, and since this extra term is negative, we can state that this extra term makes the second component of the denominator smaller. Since this second term is positive and the denominator is negative (for the SOC to be satisfied), then the denominator gets more negative, i.e. larger in absolute value. This generates a reduction in the absolute value of the pass-through rate, i.e. a less complete pass-through compared to the unconstrained case.

Secondly, changing price in the first period changes spare capacity in period 2 (a price increase makes K_2 larger). As a result, the derivative of period 2 profits with respect to spare capacity varies, and the sign depends on whether V_2 is concave or convex with respect to spare capacity K_2. The derivative $\partial D_1/\partial p_1$ is negative[9], and therefore the sign of this extra term will be the opposite to the sign of the second derivative $\frac{\partial(\partial V_{j2}/\partial K_{j2})}{\partial K_2}$. I assume that the effect of own spare capacity dominates over the cross-spare capacity effects. Unless demand is very convex in period 2, we can assume that the second derivative is negative, i.e. that second period profit is concave in spare capacity. Therefore, the extra term is positive. Since it is multiplying a negative term $(\partial D_{j1}/\partial p_{j1})$, it makes the denominator more negative, i.e. larger in absolute value, and this in turn makes the ratio, i.e. the pass-through rate, smaller in absolute value. Therefore, the two extra terms push in the same direction of making the pass-through in period 1 less complete (i.e. smaller in absolute value) when firms exhaust in period 2, compared to the unconstrained case. This is consistent with the results of the empirical analysis, which showed that routes with higher occupancy experienced less complete pass-through.

We can also affirm pass-through is not complete, i.e. larger than -1. This is because of the following. Firstly, the first and second derivatives of demand with respect to the subsidy rate are the derivatives of demand of only one group of consumers, the non-subsidized ones. Secondly, the denominator contains the derivatives of demand with respect to subsidized price, which consists of the sum of the derivatives of the two groups of consumers. Hence, the denominator is always larger in absolute value than the numerator. The larger the

[9]This is a vector containing the total derivatives (i.e. wrt all prices) of $t = 1$ demand. This vector multiplies in an inner product way the vector of derivatives $\partial V_{j2}/\partial K_2$, i.e. the derivatives of $t = 2$ profits for firm j with respect to spare capacity of all firms. The sign of both entries of this vector is negative, since a raise in all prices decreases demand of all products. Therefore, the sign of this extra term in the denominator will be determined by the curvature of V_2.

share of non-subsidized consumers, the closer in absolute value the numerator and the denominator are, and therefore the closer to complete pass-through the value will be. With only non-subsidized consumers there is complete pass-through when the equilibrium is capacity constrained.

3. **Combined case**
   In the case in which the equilibrium is such that some firms exhaust capacity and some others do not, the pass-through rates are a combination of the two cases above, with firms that do not exhaust capacity having the pass-through rate expression of case 1, while those firms that exhaust capacity have the pass-through rate of case 2.

4.4 Comparative statics: Pass-Through and Competition

One of the main aims of this paper is to characterize how the intensity of competition affects pass-through, in an environment in which a good is sold over multiple periods and with capacity constraints. Therefore, in this subsection I try to characterize the effect of competition on pass-through, in each of the two periods, and for the different situations characterized above with respect to firms exhausting capacity or not. The way in which I introduce changes in competition is by modifying the number of firms in the market, although this could also be done using the differentiation parameter σ. By making it smaller goods become better substitutes between them, which also increases the intensity of competition.

To understand the effects of competition, let's first analyze how the impact the components of the pass-through rates derived above, in particular the first and second derivatives, with respect to own price and with respect to all prices. For any level of prices, an extra firm decreases demand, since there's an extra competitor that steals market share from the other firms. Also, with an extra competitor equilibrium prices decrease, both in the unconstrained and in the constrained equilibria. This is how the components of the pass-through rate are affected by the entry of an additional firm. In this derivations I use the chosen functional form of logit demand, as well as the assumptions of demand being convex due to market shares being below 1/2 for all products[10]:

- **Own-price derivative:**
  $$\frac{\partial D_{j1}}{\partial p_{j1}} = -\alpha D_{j1}(1 - D_{j1}) \leq 0$$
  An additional competitor generates a decrease in D_{j1}. I assumed demand is convex, this means that the first derivative is increasing in D_{j1}. Since this derivative is negative, this means it gets smaller in absolute value with an additional competitor.

- **Total price derivative:**
  $$\frac{\partial D_{j1}}{\partial p_1} = \frac{\partial D_{j1}}{\partial p_{j1}} + \sum_{k \neq j} \frac{\partial D_{j1}}{\partial p_{k1}} = -\alpha D_{j1}(1 - D_{j1}) + \sum_{k \neq j} \alpha D_{j1} D_{k1} = -\alpha D_{j1} \overbrace{(1 - D_{j1} - \sum_{k \neq j} D_{k1})}^{D_{01}} \leq 0$$
  An additional competitor generates a decrease both on D_{j1} and on the share of the outside option D_{01}. Therefore, the total derivative gets smaller in absolute value when an additional competitor is present.

[10]This is consistent with defining market share as total units sold divided by population of the cities in the beginning and end of the routes, which is the usual market share definition in the empirical airline industry literature.

- **Demand second derivative:**

$$\frac{\partial\left(\partial D_{j1}/\partial p_{j1}\right)}{\partial p_1}=\frac{\partial^2 D_{j1}}{\partial p_{j1}^2}+\sum_{k\neq j}\frac{\partial^2 D_{j1}}{\partial p_{j1}\partial p_{k1}}=\alpha^2 D_{j1}(1-2D_{j1})D_{01}\geq 0 \iff D_{j1}\leq\frac{1}{2}$$

As above, D_{j1} and D_{01} decrease if an additional competitor is present, whereas $(1-2D_{j1})$ increases. This decrease in D_{j1} translates into a decrease in the full derivative if $D_{j1}\leq 1/4$. For the sake of simplicity, since the change of this object would be given by the product of four terms smaller than 1, I will assume such change is negligible and can be assumed to be equal to 0.

- **Period 2 profits derivative:**

$$\frac{\partial V_{j2}}{\partial K_{j2}}=(\bar{p}_2(K_2)-c(1-\tau))+K_{j2}\frac{\partial \bar{p}_2}{\partial K_{j2}}=(\bar{p}_2(K_2)-c(1-\tau))+K_{j2}\frac{1}{\partial D_{j2}/\partial p_{j2}}$$

An additional firm has two effects on this derivative. First of all, the sellout price $\bar{p}_2$ is smaller for any given K_{j2}, since the entry of an additional firm requires a lower price to keep demand constant. Secondly, the derivative of such sellout price with respect to own spare capacity is affected in the following manner. Such derivative is the inverse of own-price derivative, which gets smaller in absolute value with an additional firm. Thus, its inverse gets larger in absolute value (and of course remains negative). Therefore, the first term, which is positive, gets smaller, and the second term, which is negative, gets larger, leading to decrease in this term. An additional competitor decreases the marginal profit in period 2 from having an extra unit of spare capacity.

- **Period 2 profits second derivative:**

$$\frac{\partial\left(\partial V_{j2}/\partial K_{j2}\right)}{\partial K_2}=\frac{\partial^2 V_{j2}}{\partial K_{j2}^2}+\sum_{k\neq j}\frac{\partial^2 V_{j2}}{\partial K_{k2}^2}$$

I assume the own-spare capacity second derivative dominates, and this element is smaller than 0, i.e. second period profits are concave on all firms spare capacity.

- **First derivative of demand with respect to the subsidy rate:**

$$\frac{\partial D_{j1}}{\partial \tau}=-\alpha\frac{p_{j1}}{(1-\tau)^2}D_{j1}^{ns}D_{01}^{ns}\leq 0$$

When the subsidy rate changes, all prices change simultaneously for non-subsidized consumers. Therefore, the derivative is very similar to the total price derivative, but mediated by $1/(1-\tau^2)$. As in the analysis above, an additional competitor generates a decrease in D_{j1}^{ns}. I assume that each subgroup of consumers also has convex demand, which means that the first derivative is increasing in D_{j1}. Since this derivative is negative, this means it gets smaller in absolute value with an additional competitor.

- **Derivative of the derivative of demand with respect to price, with respect to the subsidy rate:**

$$\frac{\partial\left(\partial D_{j1}/\partial p_{j1}\right)}{\partial \tau}=\alpha^2\frac{p_{j1}}{(1-\tau)^2}D_{j1}D_{01}(1-2D_{j1})\geq 0 \iff D_{j1}\leq\frac{1}{2}$$

As with the derivative of the derivative with respect to price, I will assume the change of this object when a new competitor is introduced is negligible and can be assumed to be equal to 0.

Pass-through and competition

I will focus on analyzing the effect of competition on pass-through in the capacity constrained case, since the unconstrained case has a pass-through rate equal to the static case one, and this analysis has already been done by the literature. I will analyze the case in which non-subsidized consumers are present in the market, since when there are only subsidized consumers pass-through is equal to 0 in both periods, irrespective of the level of competition.

I measure the intensity of competition using the number of firms present in the market. To analyze the effect of competition in the pass-through rate, I will study how this rate changes when a new firm enters the market. Building on the work done to analyze how all components change, after the introduction of a new competitor, both the numerator and the denominator get smaller in absolute value. Therefore the effect of competition on the pass-through rate will be determined by whether the direct impact of the change in the subsidy change on the optimality conditions is larger or smaller than the effect on the optimality conditions of changing all prices. If the change in the numerator is larger, then the pass-through rate would get smaller in absolute value with an additional firm in the market, since the additional firm makes both the numerator and the denominator decrease in absolute value.

However, one also needs to take into account the effects of changing prices on prices on the other period, i.e. the effects of p_1 on p_2, and vice versa. With a positive share of subsidized consumers, pass-through in the second period when capacity is exhausted looks as follows:

$$\rho_2 = -\frac{\partial D_2^{ns}/\partial \tau}{\partial D_2/\partial p_2} \leq 0$$

An increase in the subsidy rate will generate initially a (i) decrease in all firm prices in period 1, and (ii) a decrease in all firm prices in period 2, due to pass-through rates being negative. However, this decrease in all prices in period 1 will increase demand for all firms in that period. As a result, spare capacity K_2 will be lower for all firms. Since we are in the capacity constrained equilibrium, lower spare capacity generates an increase in period 2 prices, since firms need to sell a lower amount. Therefore, in this situation we have strategic substitutability between period 2 prices p_2 and period 1 prices p_1. The higher the number of competitors, the larger the effects of strategic substitutability between prices in both periods in the capacity constrained equilibrium. This increase in period 2 prices has a feedback effect in period 1 prices. If such feedback effect on period 1 prices pushes period 1 prices further down, then the upward pressure on second period prices would increase even further. This would generate a large pass-through in absolute value in period 1 and a smaller pass-through in period 2. It remains work in progress to characterize the intertemporal feedback effects between prices and what determines its sign, but for certain values of the parameters this can explain how a higher intensity of competition can generate less complete pass-through in the initial periods of sale, which are the results of the empirical section.

5 Conclusion

In this paper, I analyze how the pass-through of a subsidy is determined in industries with perishable goods that can be sold along several periods, with capacity constraints and different groups of consumers in terms of entitlement to the subsidy. I also analyze how the pass-through rate varies depending on the level of competition and on the presence of subsidized consumers. For that, I first conduct a regression analysis on the evolution of prices in the airline industry in Spain, in which some consumers are entitled to an ad valorem price discount, while some others are not, relying on an observed change in the subsidy rate during the summer of 2018. The results of these analysis are that (i) pass through was larger in the initial periods of sale, farther away from departure, (ii) pass through is larger in markets where the share of subsidized consumers is smaller and (iii) pass through is smaller in markets with more competitors. Whereas the first two results can be explained with the existing results in the literature, the third one is more difficult to reconcile.

In order to interpret the empirical results and to understand how the presence of a capacity constraint and several periods of sale affect the pass-through rate and its usual determinants, I develop a theoretical model containing these features. The goal is to understand how such features affect pass-through, both directly and through the usual determinants identifed by the literature, particularly through the intensity of competition. In this section, I have already been able to show how the novel features of my model, namely the presence of a capacity constraint and the possibility of selling the good in multiple periods change pass-through rates compared to the static, unconstrained analysis, when the equilibrium is such that capacity is exhausted. In addition to this, I explain how the presence of strategic substitutabilities between prices in different periods can explain a less complete pass-through in markets with a higher intensity of competition.

In addition to this, there are some aspects of the project that can be improved and some findings that can be made more robust. Firstly, in the empirical part, the main robustness check to be done is to eliminate the presence of possible confounders on the results of the correlation between number of competitors and pass-through. A possible alternative is to use as an instrument for the number of competitors the population of the origin and destination cities of each route, which can be considered a measure of market size. My first attempt using this technique shows results are robust to it. However, one could still argue that this is not enough to solve the possible bias generated by the fact that the markets with higher number of competitors are also the markets in which demand is more inelastic.

Furthermore, in the theoretical section, I plan to add results from simulations using a wide range of values of parameters. These results would be useful to understand how components of pass-through change with the different values of the parameters, and across the different equilibria characterized in the theoretical section. Moreover, this would allow me to make claims about the sign of different effects identified analytically that are ambiguous depending on parameter values.

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