The Effect of Vertical Product Differentiation on Fare and Market Share: Evidence from Delta Air Lines' Middle Seat Policy

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July 2022

Published in *Economics of Transportation*
Volume 31 (September 2022)
Article 100274

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Abstract:

Delta Air Lines engaged in vertical product differentiation during the COVID-19 pandemic. To ensure that passengers did not sit next to a stranger, Delta did not sell the middle seat on its flights that had them. Its principal rivals, American Airlines and United Airlines, sold all seats. Analysis of the non-stop routes on which Delta faced head-to-head competition with American or United reveals that Delta was able to charge a 10% fare premium and increase its relative market share by 4.7 percentage points from its middle seat policy.

Keywords: vertical product differentiation, aviation, pandemic

JEL Codes: L93

Declarations of Interest: None. This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Statement: Both authors shared equally in conceptualization, methodology, formal analysis, and writing.

Highlights:

- Delta Air Lines engaged in vertical product differentiation during the COVID-19 pandemic.
- Delta did not sell the middle seat, unlike American and United Airlines, its principal rivals.
- Delta charged a 10% fare premium on competitive routes.
- Delta also increased its relative market share by 4.7 percentage points on these routes.

1. Introduction

During the initial wave of the COVID-19 pandemic, airlines restricted the number of passengers on their flights and the seats that passengers were able to sit in to ensure that strangers were not sitting next to one another. These policies, commonly but somewhat inaccurately referred to as not selling, blocking, or withholding the middle seat, were implemented in response to the United States (U.S.) Government's recommendation that individuals maintain six feet of distance in public settings to reduce virus transmission.[1] As airlines were not legally required to limit the number of passengers onboard, the policies may have been an attempt to encourage travelers to return to the skies at a time when demand was historically low.

Two of the three large legacy full-service network carriers in the U.S., American Airlines and United Airlines (American and United, respectively), abandoned their in-flight capacity restrictions by the end of June 2020. The other legacy carrier, Delta Air Lines (Delta), continued to block the middle seat until vaccines were widely available in April 2021. Figure 1 shows the monthly load factor (i.e., the percent of seats occupied) for the domestic service of each legacy carrier from January 2019 to December 2021. Demand in spring 2020 was so low that passengers were able to socially distance themselves onboard irrespective of capacity restrictions. By summer 2020, however, American achieved a load factor of 60%, followed by United that fall. When COVID-19 cases surged in winter 2020-21, the load factor for both airlines declined yet again, eventually returning to pre-pandemic levels by spring 2021. Until April 2021, Delta's load factor never rose above 50%, and it did not return to pre-pandemic levels until July 2021.

In an earlier paper on this topic, we calculated that Delta raised its fares by 15% compared to American or United in the period from Quarter 3, 2020 to Quarter 4, 2020 (Hyman and Savage, 2021). The fare premium was equivalent to $23 on an average one-way trip. That paper used data from 1,358 routes. While some of these routes were competitive, most were routes in which one of the three legacy airlines monopolized the route. This paper focuses on the subset of routes in which passengers were always able to choose between a legacy carrier that sold the middle seat and a legacy carrier that did not. Specifically, we analyze vertical product differentiation on 54 non-stop routes where Delta was in head-to-head competition with American or United.

We estimate the magnitude of the fare premium that Delta charged as well as the market share gains Delta may have had from its middle seat policy. We find that Delta was able to charge a fare premium and increase its market share. Because Delta restored its flight schedule sooner than American or United, the market share gains can be attributed to passengers' preferences for higher relative flight frequencies in addition to the extra space onboard. Finally, we investigate if the fare premium and market share gains differ by route. Might regional variation in attitudes towards COVID-19, as measured by vaccination rates, or in relative valuations of air travel, as

[1] Not all aircraft or classes of service have a middle seat, so "middle seat policy" is a shorthand to describe efforts to limit passengers sitting next to someone who was not traveling with them. Delta Air Lines (2020) officially stated "all middle seats will continue to be shown as unavailable or not assignable when selecting seats via the Fly Delta app or online. Additionally, the seat next to you will automatically be blocked upon completion of your reservation, and the block will be visible within the seat map in My Trips. Parties of three or more will also have the ability to book seats together, including middle seats."

measured by the recovery of demand on a route, lend insights into how passengers value space differently during a pandemic?

2. Theoretical Model

Vertical product differentiation exists when one firm produces a higher quality product than another firm. While all consumers agree that higher quality is preferable, they may differ in their willingness to pay for quality. The modern theoretical literature emerged in the late 1970s and early 1980s. Tirole (1988) provides a textbook description (pp. 296-298). Subsequent extensions and generalizations include Champsaur and Rochet (1989) and Wauthy (1996). These models have as many as three stages: (1) entry, (2) quality selection by firms, and (3) price setting and consumer choice. This paper concerns the third stage.

Consider a duopolistic route in which potential travelers, denoted by subscript *i*, make at most one trip per time period. We assume for simplicity that all travelers agree that an empty middle seat reduces the probability of an exposure to COVID-19 by some commonly agreed upon amount.[2] We denote the exposure probability as S. Selling the middle seat results in a "high" exposure, denoted by subscript H, while withholding the middle seat results in "low" exposure, denoted by subscript L, such that $S_H > S_L$. In contrast, travelers may differ in their (negative) valuation of exposure to the virus.[3] We denote the individual absolute value of exposure as $\theta_i \in [\theta^{min}, \theta^{max}]$, in which a higher absolute value of θ indicates a traveler more concerned about an exposure.

Each traveler also has a gross valuation of an airline trip compared to their next best alternative. This is denoted by $v_i \in [v^{min}, v^{max}]$. The next best alternative could be conducting business online, postponing the trip, choosing a different mode of transportation, or using the time for another activity. Finally, the airline that sells the middle seat charges fare F_H, and the airline that does not charges F_L, such that $F_L > F_H$. If this was not the case, then the airline that withholds the middle seat would capture the entire market.

A traveler has a utility function from flying with an airline that sells the middle seat of

$$U_{iH} = v_i - \theta_i S_H - F_H , \tag{1}$$

and a utility function from flying with the airline that does not sell the middle seat of

$$U_{iL} = v_i - \theta_i S_L - F_L . \tag{2}$$

If a traveler decides not to fly, denoted as subscript 0, the utility gained is normalized to zero

$$U_{i0} = 0 . \tag{3}$$

[2] Modelling by the U.S. Centers for Disease Control and Prevention found that "exposures in scenarios in which the middle seat was vacant were reduced by 23% to 57%, compared with full aircraft occupancy" (Dietrich et al., 2021).
[3] Passengers have always preferred more space aboard an aircraft, and even prior to the pandemic a subset of passengers was willing to pay more for this space in the forms of wider seats and seats with more legroom (Kuo and Jou, 2017; Lee and Luengo-Prado, 2004; Mumbower et al., 2015).

Equating Eq (1) and Eq (3) gives the boundary condition, denoted by $v_{H0}(\theta)$, where travelers are indifferent between flying with the airline that sells the middle seat and not flying

$$v_{H0}(\theta) = F_H + \theta S_H \,. \tag{4}$$

Similarly, equating Eq (2) and Eq (3) gives the boundary condition, denoted by $v_{L0}(\theta)$, where travelers are indifferent between flying with the airline that does not sell the middle seat and not flying

$$v_{L0}(\theta) = F_L + \theta S_L \,. \tag{5}$$

Finally, for travelers who do fly, equating Eq (1) and Eq (2) gives the boundary condition, denoted by θ_{HL}, where travelers are indifferent between flying with the airline that sells the middle seat and the airline that does not

$$\theta_{HL} = \frac{F_L - F_H}{S_H - S_L} \,. \tag{6}$$

Figure 2 plots these boundary conditions in a rectangular space with θ on the horizontal axis and v on the vertical axis. For purposes of illustration, the boundary conditions are plotted assuming that the market is covered. This assumption means that for each value of θ, there is at least one potential traveler who is willing to fly. The boundary conditions define six regions. Individuals in regions V and VI do not fly.[4] Those in regions I and II fly with the airline that sells the middle seat, and those in regions III and IV fly with the airline that does not. The absolute number of travelers in each region depends on the distribution of potential travelers across θ and v.

Therefore, by maintaining its capacity restrictions unlike American and United, Delta was preferred by two types of passengers: (1) travelers in region III who were willing to pay the higher Delta fare due to their high value of θ, and (2) travelers in region IV who otherwise would not have flown if they had to sit next to a stranger. Delta, however, lost the opportunity to serve travelers in regions I and II.[5]

3. Empirical Technique

A difference-in-differences technique is used to analyze data in 13 quarters for nonstop routes in which Delta is in head-to-head competition with American or United. There is a pre-pandemic period from Quarter 1, 2018 to Quarter 1, 2020, and a pandemic period from Quarter 2, 2020 to Quarter 1, 2021. Delta's capacity policies differ from those of American and United from Quarter 3, 2020 to Quarter 1, 2021.

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[4] These regions represent most potential travelers. Daily counts of people passing through security checkpoints from the Transportation Security Administration (2021) showed a 95% decline in April 2020 compared to April 2019. By the end of March 2021, when our analysis ends, checkpoint pass-throughs were still 40% down compared to March 2019.

[5] For clarity, the foregoing discussion presumes that P_H remains unchanged had Delta emulated American and United.

We compare Delta to its principal rivals, American and United, because these three airlines offer comparable services and networks. Middle-market low-cost carriers such as Alaska Airlines, JetBlue Airways, and Southwest Airlines (Alaska, JetBlue, and Southwest, respectively) and ultra-low-cost carriers such as Frontier Airlines, Spirit Airlines, and Sun Country Airlines (Frontier, Spirit, and Sun Country, respectively) are also present on some routes, but their product attributes and networks are less comparable.

The regression specification, with airline denoted by subscript *j*, route by subscript *k*, and quarter by subscript *t* is

$$Y_{jkt} = \alpha + \beta_1 Delta_j + \sum_{t=10}^{13} \gamma_t Pandemic_t + \beta_2 \left(Delta_j * Middle_t\right)$$
$$+ \beta_3 \left(Delta_j * Middle_t * (X_k - \bar{X})\right) + \sum_{k=1}^{54} \lambda_k Route_k + \varepsilon_{jkt} .$$

Y_{jkt} is the outcome of interest (fare or market share). $Delta_j$ is a dummy variable equal to “1” when the airline is Delta and “0” for American or United. $Middle_t$ is the treatment dummy variable equal to “1” during the period of vertical product differentiation from Quarter 3, 2020 onwards and “0” otherwise. We include route-level proxies for θ or v in three separate regressions to analyze differences in attitudes and valuations across routes. The data for each proxy, denoted by X_k, are normalized by subtracting their mean value. Every regression includes time fixed effects for the four quarters of the pandemic period, route fixed effects, and an error term clustered at the route-level.

4. Data

4.1 Number of Observations

The analysis concerns competitive, domestic, and non-stop bidirectional routes in the lower 48 states. A route has to have Delta and either American or United present in all thirteen quarters to be included,[6] so on each there is a minimum of 26 observations and a maximum of 39. Surprisingly, there are only 54 non-stop routes which met these criteria. This number is small because the three legacy carriers do not often co-locate their hub airports.[7] We also treat airports in a metropolitan area, such as the three major airports in the New York City region, as separate places. If airports in the same metropolitan area are treated as the same place, then the number of competitive routes would be larger. Of the 54 eligible routes, most are duopolies among the large network carriers as the average number of observations per route is 29.6. Consequently, the analysis is conducted on 1,597 observations.

[6] Presence in a quarter was determined by an airline issuing non-stop (one coupon) tickets between the end points of the route as recorded in the U.S. Department of Transportation’s 10% ticket sample database.
[7] The major exception is Chicago O’Hare at which competition is between American and United.

4.2 Fare

Fare data is from the 10% sample of airline tickets in the U.S. Department of Transportation's quarterly Origin and Destination Survey, commonly known as DB1B. The mean and deciles of one-way fares are calculated from one-way and round trip single-coupon domestic tickets with dollar values that the Department of Transportation flags as credible. By using one-way and round trip single-coupon tickets, we focus on those travelers who flew non-stop between the end points of a route and did not connect onto other destinations. These travelers faced the clearest choice between Delta and its principal rivals.

The data includes coach (economy), business class, and first-class tickets. A ticket is associated with an airline based on the ticketing airline. DB1B also lists the operating carrier of each ticket. We did not use this narrower classification because flights on some routes were operated by a combination of the legacy carrier and its subcontracted regional carriers (companies operating as American Eagle, Delta Connection, or United Express). The middle seat policy applied to both Delta and Delta Connection branded services.

4.3 Market Share

Ticket data in DB1B is used to calculate market share. Market share is calculated as the proportion of one-way and round trip single-coupon tickets issued on a route in each quarter by an airline compared to all such tickets in the 10% sample. The denominator of market share is not limited to tickets sold by American, Delta, and United; it includes passengers on flights ticketed and operated by middle-market and ultra-low-cost carriers.

4.4 Flight Frequency and Aircraft Capacity

Quarterly data on the number of non-stop flights performed (i.e., departures performed) on each route is obtained from the U.S. Department of Transportation's T-100 Monthly U.S. Air Carrier Capacity and Traffic Data Report. Data in this report are listed by operating carrier, but on some routes, the legacy carriers partly, or entirely, subcontract service to affiliated regional carriers, such as SkyWest Airlines and Republic Airways. We are able to identify the regional carrier(s) which operated on behalf of a legacy carrier on a route in each quarter using data in DB1B because DB1B lists the ticketing and operating carrier of each ticket.

Data on the number of flights performed is transformed into a variable called schedule delay. This variable represents the difference between a passenger's preferred time for taking a flight and the scheduled departure time. For example, a passenger who wishes to take a 1:00pm flight when the nearest scheduled flight is at 1:35pm suffers a schedule delay of 35 minutes.

Following Panzar (1979), we assume that passengers take the flight closest to their preferred time, and they are indifferent between taking an earlier or later flight. If departure time preferences and flight schedules are uniformly distributed across the day, then the average schedule delay is a quarter of the time between flights. For example, if flights depart every two hours, the average passenger suffers a schedule delay of 30 minutes. To calculate average schedule delay for each airline on a route in a quarter, we assume flights depart in a 15-hour period each day, essentially from 6:00am to 9:00pm. The average time between flights is 15 hours divided by the number of departures performed in each direction per day, which is then divided by four to estimate schedule delay.

Finally, the T-100 database also reports the number of seats flown. We calculate the average size of aircraft flown by dividing total seats flown by the number of departures performed on a route. This aircraft capacity variable allows us to determine if Delta may have flown larger planes to accommodate its middle seat policy.

4.5 Proxies for θ and v

As a proxy for θ, we use state-level data from the Centers for Disease Control and Prevention on the percentage of people 18 years or older who were fully vaccinated as of June 30, 2021 (CDC, 2021). Vaccination rate may be indicative of the degree of concern about an exposure to COVID-19 early on in the pandemic. Since most routes cross state lines, we generated a weighted average of the vaccination rates at the end points of a route.[8] There was considerable variation in this variable as low vaccination rates were observed on routes across Southern states or in Utah (Delta has a hub in Salt Lake City), and high vaccination rates were observed on routes across the Northeast.

As an additional proxy for θ, we consider the effect of the length of a flight. Travelers may be more fearful of a COVID-19 exposure on a longer flight rather than a shorter flight. Flight length is measured as the great circle length of the route in statute miles. Routes vary in distance from 200 miles to more than 2,500 miles.

As a proxy for v, we use the ratio of tickets recorded on a route in DB1B in Quarter 1, 2021 compared to Quarter 1, 2019. We include tickets on any airline on that route. The intuition is that the routes with the highest recovery ratio are those in which potential travelers place the highest value on an airline trip. Routes with the highest recovery ratio are typically those serving destinations in states that offer outdoor recreation, such as Arizona, Florida, or Colorado. In contrast, routes serving business cities, such as Boston, New York, Washington, D.C., or San Francisco, saw weaker recovery. While we may think of business trips as high value and leisure trips as low value, these values may have been reversed during the pandemic. Value in this context is defined as the valuation of an airline trip compared to the next best alternative, and video conferencing easily replaced business travel whereas the benefits of a beach or a mountain vacation could not be obtained online.

To visualize the ranges of these variables, Figure 3 plots the 54 routes with vaccination rate on the horizontal axis and recovery rate on the vertical axis. The data points are labeled with the three-letter airport codes of the end points. The figure illustrates the considerable variation in θ and v across routes. Also notable is the group of routes with a low recovery rate and high vaccination rates at the end points. These routes are predominantly within the Northeast or on

[8] We weight the vaccination rate at each end of a route by the proportion of passengers who started their trip at either end of that route. The proportion is obtained by analyzing one-way and round-trip tickets in the DB1B database on the route irrespective of carrier in Quarter 3, 2020, Quarter 4, 2020, and Quarter 1, 2021.

transcontinental routes to California, and while residents in these states may have shown greater reluctance to return to the skies, the end points on these routes are major business destinations.

4.6 Descriptive Statistics

Table 1 reports descriptive statistics for fare, market share, vaccination rate, route distance, recovery rate, and schedule delay variables. The vaccine, distance, and recovery variables were subsequently normalized around their mean values prior to inclusion in regressions.

5. Analysis of Fare Premium

5.1 Comparison with Hyman and Savage (2021)

The 54 highly competitive routes analyzed in this paper are a subset of the 1,358 nonstop routes analyzed in our earlier paper (Hyman and Savage, 2021). The routes in the earlier paper had to have at least one of the three legacy carriers present in each quarter, but they did not require Delta to be present or in head-to-head competition with American or United. So that the current results can be placed in a wider context, we re-estimate the main regression from Hyman and Savage (2021). The re-estimation has two modifications that make the results more comparable with the current analysis: (1) data for Quarter 1, 2021 is included, and (2) only routes in the lower 48 states are included.[9] This reduces the number of routes to 1,005.

Column (1) of Table 2 shows that the average one-way fare was $215 prior to the pandemic. Delta's fares were on average $4.40 higher than American's or United's, but the result is barely statistically significant at the 10% level. The pandemic reduced average fares by $40 in Quarter 2, 2020, and by about $65 in subsequent quarters for all airlines. Delta was able to charge a fare premium of $25, or about 17%, from its middle seat policy, yet its fares remained well below pre-pandemic levels.

Hyman and Savage (2021) also analyzed the fare premium on three subsets of routes defined by Delta's market share (routes with a market share greater than zero but less than 33%, between 33% and 67%, and greater than 67%).[10] Column (2) of Table 2 again investigates how the fare premium varies with Delta's market share. This regression is estimated on the full sample of 1,005 routes and includes Delta's market share as an explanatory variable interacted with the middle seat policy variable. The regression predicts greater market power has a significant and positive effect on the fare premium.

Most of the 1,005 routes which include Delta were a Delta monopoly or near-monopoly. They are mainly spoke routes which originate at a Delta hub (e.g., Atlanta to Roanoke, Virginia).[11] Delta's average market share on routes in which it was present was 75%, and the median was

[9] Hyman and Savage (2021) analyzed domestic routes that included lengthy routes with Alaska, Hawaii, Guam, Puerto Rico, and the U.S. Virgin Islands as end points.

[10] By definition, it was not possible to calculate a fare premium on a fourth subset of routes on which Delta was not present.

[11] There is indirect competition on this route as passengers may book connecting service to Roanoke on American through Charlotte or United through Washington Dulles.

95%. At the lower quartile of Delta's market share (which is a 50% market share), the regression predicts that Delta charged a fare premium of 14.4%, and at the upper quartile (which is a 100% market share), the predicted premium is 19.1%.

5.2 Analysis of Average Fare

In contrast to the analysis in the previous section where Delta, when it was present, typically held a large market share, the remainder of the paper deals with 54 competitive routes. Delta's median market share on these routes is 40%, and the interquartile range is from 28% to 56%. Passengers on these routes had a choice between airlines that did and did not sell the middle seat.

Table 3 reports regressions on average market fare for the 54 competitive routes. The pre-pandemic one-way fare on the average route was $190. Fares were substantially lower during the pandemic, by $30 in Quarter 2, 2020 and $65 thereafter. Delta's fares did not differ significantly from those of American or United prior to the pandemic. In the previous section, we found that Delta had slightly higher pre-pandemic fares compared to American or United. Hyman and Savage (2021) speculated that this was due to the types of routes that Delta operated rather than a pure price premium. That supposition is supported by Table 3 as the fares of the three legacy carriers were comparable on competitive routes prior to the pandemic.

Columns (1) through (3) analyze how the fare premium developed over time by looking at data from Quarter 1, 2018 to each of Quarter 3, 2020, Quarter 4, 2020 and Quarter 1, 2021. We find that Delta charged a $10 premium in Quarter 3, 2020, a $13.50 premium in Quarter 4, and a $12.50 premium in Quarter 1, 2021. Delta's price in Quarter 1, 2021 is equivalent to a 10% premium over the predicted $125 fare which American or United charged in that quarter. Even with the fare premium, however, Delta's fare was still well below its pre-pandemic fare of $190.

Columns (4) through (6) report the regressions that include the proxies for θ and v. Data on the proxies are normalized around their mean. The *Delta*Middle* variable represents the fare premium for the average route, and the *Delta*Middle*X* variables measure the effect of deviating from the mean value of the variable. For all three variables, we cannot reject a null hypothesis that there is no variation across routes.

This finding is consistent with the theoretical literature. The Nash-equilibrium prices when the market is covered depend on θ^{min} and θ^{max}, not on the distribution of θ between these bounds (Tirole, 1988). It is likely that in every market there are at least some individuals who care little about the possibility of contracting the virus and some individuals who are highly sensitive to the possibility.

5.3 Analysis of Fare Deciles

Airline tickets are not sold at a uniform price. Pricing is based on yield management in which the seat inventory is divided into different fare buckets. As the lowest-priced seats sell out, the next passengers who book tickets pay a higher fare. McGill and van Ryzin (1999) provide a survey of the yield management literature. Empirical papers investigating fare dispersion and product quality in competitive airline markets include Gerardi and Shapiro (2009), Netessine and

Shumsky (2005), Prince and Simon (2015), Puller et al. (2009), and Sengupta and Wiggins (2014). Therefore, to gain further insight into the middle seat policy and the uniformity of the premium across fare buckets, we re-estimate the regression in column (3) of Table 3 for each fare decile from the 10th percentile to the 90th percentile.

The results are shown in Table 4. Delta was not able to extract a statistically-significant premium for the very lowest bucket of fares (i.e., the 10th percentile). These fares may be promotional, contract, or government rate fares that do not vary across airlines. The very highest bucket of fares (i.e., the 90th percentile) also does not vary significantly across airlines. For all intermediate deciles, though, Delta was able to charge a price premium. Remarkably, the premium is quite uniform in the \$12 to \$17 range, which means the lower fare deciles then have a greater percentage fare premium compared to the higher fare deciles. The premium at the 20th to 40th percentiles of fares is about 20%, and the premium at the 70th and 80th percentiles of fares is about 7%.

5.4 Robustness Checks

Our principal result, the equation in column (3) of Table 3, is robust to the introduction of additional time fixed effects and variables representing the presence of low-cost competitors. The first robustness check interacted the *Delta*Middle* variable with dummy variables indicating the presence of either low-cost (Alaska, JetBlue, Southwest) or ultra-low-cost (Frontier, Spirit, Sun Country) carriers on a route in each quarter. The second checks introduced time period dummy variables for every time period in the pre-pandemic period (with Quarter 1, 2018 as the excluded variable) or quarter dummy variables (with quarter 1 as the excluded variable). In both checks, the additional variables were statistically insignificant and the point estimate of the fare premium did not change.

6. Analysis of Market Share

It is theoretically indeterminate whether Delta's middle seat policy would change its market share and what direction the change would be. With reference to Figure 2, Delta had forgone attracting a portion of the travelers in regions I and II, but now exclusively served travelers in region III and attracted travelers in region IV who otherwise would not have flown.[12] Changes to market share then depend on the relative number of travelers in each region. Moreover, any change is inversely related to the fare premium. If Delta was aggressive in seeking a fare premium, then it would do so at the expense of market share as θ_{HL} would shift to the right.

6.1 Initial Regressions

Table 5 reports the regressions on market share. Before the pandemic, Delta's average market share on the 54 routes was 38.4%. The share for American or United averaged 29.1%. While American, Delta and United are similar sized airlines, the larger Delta share on these routes is not surprising. The selection criteria require Delta to be present in every quarter, thereby favoring the routes which form Delta's core network.

[12] For simplicity, this statement assumes that P_H remains unchanged had Delta emulated American and United.

We find two conflicting effects on Delta's market share. First, the middle seat policy improved Delta's market position compared to American or United. Columns (1) through (3) analyze the trajectory of market share during the middle seat policy period and suggest that Delta's market share gains increased over time. Delta did not gain any market share in Quarter 3, 2020, but its advantage over American or United grew to 2.2 percentage points by the end of Quarter 4, 2020, and to a statistically significant 4.7 percentage points by the end of Quarter 1, 2021. Those passengers who travelled early in the pandemic may have been the least concerned about the virus, and as demand recovered, more reticent travelers decided to fly and were attracted to Delta's offer of more space. Second, the pandemic reduced the market share for all three legacy carriers by 2.5 percentage points. Business travel declined more during the pandemic than leisure travel, and business travelers traditionally prefer the legacy carriers over the lower-cost carriers which also provided service on some routes.

The final two rows of Table 5 summarize these conflicting effects and estimate the market shares of Delta and of American or United. By the end of Quarter 1, 2021, Delta had a net market share improvement of 2.2 percentage points, from 38.4% to 40.6%. In contrast, American or United saw their market shares decline by 2.5 percentage points, from 29.1% to 26.6%. Delta was able to expand its relative market share despite charging a fare premium.

Columns (4) through (6) analyze the effect of the proxies for θ and v. One might theorize that Delta would have gained the most market share in the regions of the country where the population was the most eager to get the vaccine. The same might be true on longer flights in which the duration of proximity to fellow passengers is greater.[13] However, we find no evidence of variation in market share by route with respect to vaccination rate or flight length.

There is a suggestion at the 5% significance level that Delta gained less market share on routes with a higher rate of demand recovery. The magnitude of the effect is quite large. Using the estimates from column (6), Delta's predicted market share in Quarter 1, 2021 on the 25th percentile route in terms of demand recovery (measured from lowest to highest) is 43.3% while its predicted market share at the 75th percentile is 37.9%. The routes with the highest demand recovery are to leisure destinations, and low-cost carriers primarily serve these passengers while the legacy carriers disproportionately serve passengers traveling for business purposes. As leisure travel rebounded and business travel did not, the recovery favored the low-cost airlines.

6.2 Accounting for Flight Frequency

Delta's improved market share may not be solely attributable to the additional space onboard its aircraft. Delta was far more aggressive in restoring its pre-pandemic flight schedule compared to its competitors. An analysis of the number of flight departures on the 54 routes, shown in the second through fourth columns of Table 6, indicates that by Quarter 1, 2021 Delta was operating 70% of the number it had in Quarter 4, 2019. In contrast, American and United offered slightly

[13] The effect of flight duration is muted because security checks mean that passengers arrive at the airport up to several hours before their flight regardless of flight duration. Passengers are also exposed to potential virus transmission at the airport, and poorer air circulation in airports compared to onboard aircraft heightens the potential risk at airports.

less than 50%. Some of the market share gain may be due to Delta's relatively more convenient flight schedule.

To investigate, we introduce a schedule delay variable to the regression. This variable is added as a standalone term because passengers value more convenient flight schedules irrespective of airline or whether there is a pandemic. The regression with schedule delay is reported in column (7) of Table 5 and should be compared to column (3). The point estimate on schedule delay is highly statistically significant and, as expected, is negative. The magnitude of the *Delta*Middle* variable is reduced from 4.7 percentage points in column (3) to 3.6 percentage points in column (7). The difference of 1.1 percentage points is explained by the passengers who were attracted to Delta because of its faster restoration of flights compared to American or United.

6.3 Robust Check

Our principal result, the equation in column (3) of Table 5 is robust to the introduction of additional time fixed effects. Robustness checks introduced dummy variables for every time period in the pre-pandemic period (with Quarter 1, 2018 as the excluded variable) or quarter dummy variables (with Quarter 1 as the excluded variable). With the exception of the Quarter 1, 2019 variable, the additional time-period variables were statistically insignificant, and the point estimate of the *Delta*Middle* variable did not change.

7. Discussion and Conclusions

7.1 Fare Premium

By vertically differentiating its product during the COVID-19 pandemic, we find that Delta was able to charge a fare premium of 10%, or about $13 on an average one-way flight, on competitive routes compared to its principal rivals, American and United. The premium was similar in dollar values for most deciles of fares (in the range of $12 to $17), which means that those passengers paying the lowest fares paid the highest markup. Specifically, fares in the 20th to 40th percentiles rose by about 20%, and fares in the 70th and 80th percentiles rose by about 7%. Even with the premium, however, Delta's fares were considerably below pre-pandemic levels.

One explanation is that most passengers shared a similar dollar value they were willing to pay to avoid sitting next to a stranger. An alternative explanation is Delta may have had a smaller inventory of seats to sell and therefore did not sell its lowest-priced bucket of seats. As a result, average fares would increase. The higher percentage premium for lower fare deciles would support this rationing theory.

In actuality, the seat inventory offered by Delta did not differ markedly from that offered by American and United. Table 6 shows the number of flights, the average aircraft size, and the effective seat inventory for each legacy carrier in each quarter from Quarter 4, 2019 to Quarter 1, 2021 on the 54 routes. As we have already observed, Delta was far more aggressive in restoring its flight schedule than its competitors. In terms of the aircraft size, American and Delta operated aircraft of similar capacity in all time periods.[14] United slightly reduced its average aircraft size by subcontracting a higher proportion of their flights to regional partners which operate smaller regional jets.

If we assume that withholding the middle seat reduces the effective seat inventory for all three legacy airlines by one-third in Quarter 2, 2020 and only for Delta in subsequent quarters, then we can calculate an index of effective seat inventory. These indices are shown in the final three columns of Table 6. By Quarter 1, 2021 Delta had an effective seat inventory which was equivalent to 46% of its inventory in Quarter 4, 2019. American's and United's inventory were 50% and 41% of pre-pandemic levels, respectively. United had reached 50% of pre-pandemic levels in Quarter 4, 2020, but scaled back its number of flights and average aircraft size in Quarter 1, 2021. Delta's middle seat policy relied on an increase in flight frequency, yet its effective number of seats for sale did not differ much from American or United. The hypothesis that Delta's fare premium was from rationing is less persuasive because of these results.

7.2 Market Share

By not selling the middle seat, Delta increased its market share by 4.7 percentage points compared to its rivals. This is remarkable given that Delta was charging a fare premium. The net effect ended up being smaller as Delta, American and United were all estimated to lose 2.5 percentage points of market share due to changes in the types of passengers who flew during the pandemic. Business travel did not recover as quickly as personal and leisure travel, and unlike leisure passengers who also patronize low-cost airlines, business travelers favor the legacy carriers. Further analysis finds that Delta's 4.7 percentage point gain can be attributed to 3.6 percentage points from passengers who value not having to sit next to a stranger, and 1.1 percentage points from passengers who value Delta's more convenient flight schedule.

7.3 Longer Term Implications

The analysis does not consider potential long-run payoffs from Delta's middle seat policy. On the demand side, there may be reputational benefits. Delta's behavior during the pandemic may be favorably viewed as altruistic. In addition, market share gains may persist if former American or United passengers who sampled Delta's service liked what they experienced and shift their allegiances. On the supply-side, more flight crews maintained operational experience each month and fewer aircraft were placed into long-term storage to accommodate the middle seat policy, so Delta may have been more prepared for the recovery in passenger demand as the pandemic waned.

7.4 Implications for Profitability

It is also an open question as to whether the middle seat policy was profit-enhancing given the costs of operating additional flights. Delta abandoned its policy soon after vaccines became widely available. Delta would seem to have reached the same conclusion that American did in 2004 when American abandoned its four-year-old "More Room Throughout Coach" experiment

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[14] It would appear that Delta did not maintain its effective seat inventory by redeploying its large jets (displaced from severely curtailed international services) to domestic service.

in which rows of seats had been removed to give passengers 3 to 5 more inches of legroom. In normal times, passengers are not willing to pay enough to make it worthwhile to reduce density throughout the entire economy cabin.

A financial evaluation of the middle seat policy is further clouded by the extraordinary levels of support provided by the federal government to the airlines during the COVID-19 pandemic. Delta alone was allocated more than $11.9 billion in total anticipated payroll support from the Coronavirus Aid, Relief, and Economic Security (CARES) Act of 2020, the Consolidated Appropriations Act of 2021, and the American Rescue Plan Act of 2021 (U.S. Department of the Treasury, 2021). This is equivalent to 30% of annual pre-pandemic operating expenses. Did the payroll support from these Acts reduce the effective marginal cost to Delta of flying more flights to such an extent that not selling the middle seat became a temporarily attractive business strategy? Or did the protracted length of the pandemic mean that capacity restrictions that were essentially costless early in the pandemic when demand was very low ultimately became a financial liability as demand recovered?

Acknowledgement

We would like to thank the Co-Editor, Philippe Gagnepain, and two anonymous referees for helpful comments that made this a better paper.

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Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Range
Average Fare ($)	173.4	58.2	43.3 – 678.7
Market Share	0.330	0.182	0.001 – 0.931
Vaccination Rate	0.580	0.047	0.490 – 0.689
Route Distance (miles)	891	594	184 – 2611
Recovery Rate	0.443	0.216	0.039 – 1.006
Schedule delay (hours)	2.265	12.490	0.244 – 225.000

Table 2: Regressions on Mean Quarterly One-Way Fares with Route Fixed Effects for Larger Set of Routes

	(1)	(2)
Constant	213.96 (262.03)	213.71 (258.48)
Delta	4.41 (1.64)	5.23 (1.91)
Pandemic 2020Q2	-39.77 (35.30)	-39.76 (35.32)
Pandemic 2020Q3	-67.22 (57.70)	-67.14 (57.81)
Pandemic 2020Q4	-66.14 (55.57)	-66.15 (55.56)
Pandemic 2021Q1	-60.79 (47.24)	-60.86 (47.17)
Delta * Middle	25.45 (16.08)	14.79 (3.83)
Delta * Middle * Share		14.27 (3.21)
Observations	15,879	15,879
Groups (routes)	1,005	1,005
R^2		
Within Groups	0.5181	0.5189
Between Groups	0.0077	0.0042
Overall	0.2012	0.2028
Predicted Delta Fare in 2021Q1		
Selling Middle Seat	$151.15	
Blocking Middle Seat	$176.60	
Fare Premium	16.8%	
Predicted Delta Fare in 2021Q1 at Lower Quartile Share		
Selling Middle Seat		$151.80
Blocking Middle Seat		$173.70
Fare Premium		14.4%
Predicted Delta Fare in 2021Q1 at Upper Quartile Share		
Selling Middle Seat		$151.80
Blocking Middle Seat		$180.86
Fare Premium		19.1%

Notes: Standard errors are clustered by route and t-statistics are reported in parenthesis.

Table 3: Regressions on Mean Quarterly One-Way Fares with Route Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)
Data from 2018Q1 to:	2020Q3	2020Q4	2021Q1	2021Q1	2021Q1	2021Q1
Constant	187.47 (118.86)	187.42 (109.81)	187.48 (97.49)	187.48 (97.95)	187.48 (99.41)	187.47 (98.19)
Delta	3.55 (1.10)	3.70 (1.15)	3.98 (1.25)	3.99 (1.26)	3.98 (1.25)	4.01 (1.26)
Pandemic 2020Q2	-30.21 (6.88)	-30.12 (6.86)	-30.05 (6.86)	-30.05 (6.86)	-30.04 (6.86)	-30.04 (6.86)
Pandemic 2020Q3	-62.89 (14.59)	-64.36 (15.50)	-63.92 (15.04)	-63.92 (15.04)	-63.92 (15.03)	-63.92 (15.04)
Pandemic 2020Q4		-64.13 (16.21)	-63.69 (15.41)	-63.69 (15.41)	-63.70 (15.38)	-63.68 (15.41)
Pandemic 2021Q1			-67.79 (11.53)	-67.79 (11.52)	-67.82 (11.46)	-67.79 (11.52)
Delta * Middle	10.16 (3.18)	13.49 (4.76)	12.53 (4.10)	12.48 (4.00)	12.72 (3.42)	12.61 (4.00)
Delta * Middle * Vaccine				-43.34 (0.68)		
Delta * Middle * Distance					-0.01 (1.18)	
Delta * Middle * Recovery						11.29 (0.90)
Observations	1,352	1,474	1,597	1,597	1,597	1,597
Groups (routes)	54	54	54	54	54	54
R^2						
Within Groups	0.3375	0.4420	0.4798	0.4981	0.5003	0.4982
Between Groups	0.0024	0.0055	0.0259	0.0314	0.2180	0.0380
Overall	0.0996	0.1499	0.1868	0.1864	0.1763	0.1860
Predicted Delta Fare in Final Quarter of Analysis						
Selling Middle Seat	$128.13	$126.76	$127.54			
Blocking Middle Seat	$138.29	$140.25	$140.07			
Fare Premium	7.9%	10.6%	9.8%			

Notes: Standard errors are clustered by route and t-statistics are reported in parenthesis.

Table 4: Regressions on Decile Quarterly One-Way Fares with Route Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Percentile	10	20	30	40	Median	60	70	80	90
Constant	68.10	107.86	128.00	146.07	164.36	185.75	213.10	256.13	336.36
	(33.58)	(107.88)	(115.28)	(123.88)	(127.63)	(127.29)	(119.41)	(72.25)	(47.42)
Delta	-3.27	-0.98	1.69	4.90	8.40	10.94	13.69	11.44	3.64
	(0.78)	(0.54)	(0.75)	(1.89)	(2.88)	(3.27)	(3.61)	(1.86)	(0.33)
Pandemic 2020Q2	-24.40	-29.99	-24.36	-19.71	-20.89	-22.12	-21.28	-32.24	-58.01
	(8.69)	(9.59)	(7.14)	(5.07)	(4.75)	(4.39)	(3.64)	(4.61)	(5.13)
Pandemic 2020Q3	-28.43	-46.09	-54.69	-60.12	-62.40	-64.55	-70.45	-84.14	-100.69
	(7.41)	(13.90)	(15.24)	(15.61)	(15.59)	(15.01)	(14.12)	(12.32)	(8.99)
Pandemic 2020Q4	-24.90	-43.08	-50.33	-55.25	-58.72	-62.82	-69.90	-85.46	-108.33
	(7.79)	(14.57)	(16.17)	(17.03)	(16.64)	(17.04)	(16.20)	(12.48)	(9.64)
Pandemic 2021Q1	-23.78	-49.62	-58.40	-63.22	-64.73	-67.42	-74.49	-89.50	-107.22
	(7.31)	(15.99)	(16.13)	(14.70)	(14.23)	(14.06)	(12.86)	(9.99)	(7.23)
Delta * Middle	2.90	12.46	14.51	17.01	15.94	13.59	11.80	12.08	7.07
	(1.00)	(5.92)	(6.40)	(6.61)	(5.21)	(4.28)	(3.25)	(2.01)	(0.86)
Observations	1,597	1,597	1,597	1,597	1,597	1,597	1,597	1,597	1,597
Groups (routes)	54	54	54	54	54	54	54	54	54
R^2									
Within Groups	0.1427	0.4491	0.4565	0.4465	0.4430	0.4285	0.4433	0.4177	0.3237
Between Groups	0.0093	0.0217	0.0116	0.0004	0.0021	0.0079	0.0133	0.0008	0.0788
Overall	0.1090	0.2456	0.2442	0.2377	0.2283	0.2164	0.2177	0.1907	0.1082
Predicted Delta Fare in 2021Q1									
Blocking Middle Seat	$39.30	$73.25	$89.51	$107.87	$126.30	$145.73	$168.13	$195.51	$246.38
Selling Middle Seat	$36.41	$60.79	$75.00	$90.86	$110.35	$132.13	$156.33	$183.43	$239.31
Price Premium	8.0%	20.5%	19.3%	18.7%	14.4%	10.3%	7.6%	6.6%	3.0%

Notes: Standard errors are clustered by route and t-statistics are reported in parenthesis.

Table 5: Regressions on Quarterly Market Share with Route Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Data from 2018Q1 to:	2020 Q3	2020 Q4	2021 Q1	2021 Q1	2021 Q1	2021 Q1	2021 Q1
Constant	0.2910 (25.21)	0.2911 (25.24)	0.2911 (25.26)	0.2911 (25.23)	0.2911 (25.28)	0.2913 (25.42)	0.2937 (25.44)
Delta	0.0929 (3.54)	0.0930 (3.55)	0.0933 (3.56)	0.0932 (3.56)	0.0933 (3.56)	0.0928 (3.55)	0.0918 (3.53)
Pandemic 2020Q2	-0.0089 (0.97)	-0.0089 (0.96)	-0.0088 (0.95)	-0.0088 (0.96)	-0.0088 (0.95)	-0.0089 (0.96)	0.0047 (0.48)
Pandemic 2020Q3	-0.0065 (0.65)	-0.0198 (2.31)	-0.0312 (3.59)	-0.0312 (3.59)	-0.0312 (3.59)	-0.0312 (3.59)	-0.0241 (2.79)
Pandemic 2020Q4		-0.0140 (1.56)	-0.0252 (2.84)	-0.0252 (2.85)	-0.0252 (2.84)	-0.0253 (2.85)	-0.0119 (1.67)
Pandemic 2021Q1			-0.0254 (3.22)	-0.0254 (3.22)	-0.0254 (3.23)	-0.0255 (3.22)	-0.0091 (1.06)
Delta * Middle	-0.0084 (0.47)	0.0215 (1.48)	0.0470 (3.35)	0.0475 (3.44)	0.0472 (3.33)	0.0456 (3.39)	0.0357 (2.62)
Delta * Middle * Vaccine				0.3914 (1.13)			
Delta * Middle * Distance					-0.0000 (0.36)		
Delta * Middle * Recovery						-0.1828 (1.98)	
Schedule Delay							-0.0019 (9.12)
Observations	1,352	1,474	1,597	1,597	1,597	1,597	1,595
Groups (routes)	54	54	54	54	54	54	54
R^2							
Within Groups	0.1247	0.1341	0.1515	0.1533	0.1517	0.1598	0.1791
Between Groups	0.3592	0.3546	0.3598	0.2853	0.3760	0.3179	0.2976
Overall	0.1006	0.1067	0.1184	0.1151	0.1194	0.1194	0.1390
Predicted Market Share in Final Quarter of Analysis (%)							
Delta	36.9	38.6	40.6				
America / United	28.5	27.1	26.6				

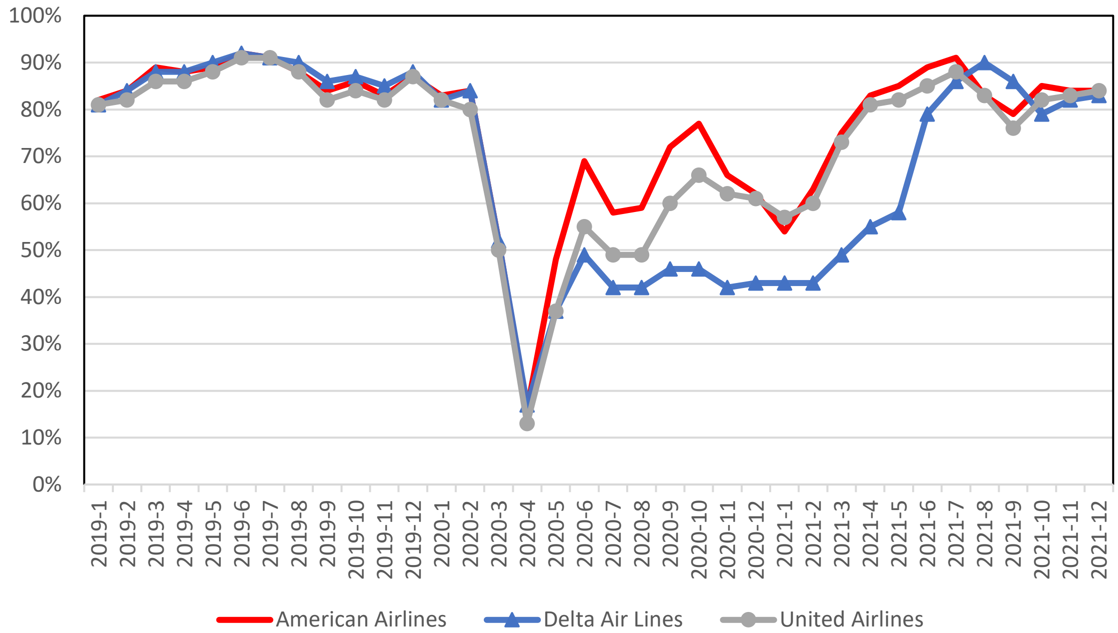
Notes: Standard errors are clustered by route and t-statistics are reported in parenthesis.

Table 6: Analysis of Seat Inventory on the 54 Routes

	Index of Departures (2019Q4 = 100)			Average Aircraft Size (seats)			Index of Effective Seat Inventory (2019Q4 = 100)		
	American	Delta	United	American	Delta	United	American	Delta	United
2019Q4	100	100	100	138	136	115	100	100	100
2020Q1	92	91	90	132	135	113	88	91	88
2020Q2	26	29	19	134	121	95	18	17	12
2020Q3	50	62	46	135	127	111	52	38	46
2020Q4	47	69	52	134	130	114	48	44	50
2021Q1	48	71	47	136	132	104	50	46	41

Notes: Average aircraft size is calculated as seats divided by departures. Effective seat inventory is calculated by assuming that only two-thirds of seats are available for sale by all three airlines in 2020Q2, and for Delta in 2020Q3, 2020Q4 and 2021Q1.
Source: U.S. Department of Transportation, Monthly U.S. Air Carrier Capacity and Traffic Data (Database T-100).

Figure 1: Monthly Load Factor for Domestic Service on Aircraft Operated Directly by a Legacy Carrier, 2019-2021



Source: U.S. Department of Transportation, U.S. Air Carrier Traffic and Capacity Summary by Service Class (Database T1) for flights operated directly by the airline.

Figure 2. Consumer Choice Between Not Traveling by Air and Traveling with an Airline that Does (High Transmission) or Does Not (Low Transmission) Sell the Middle Seat

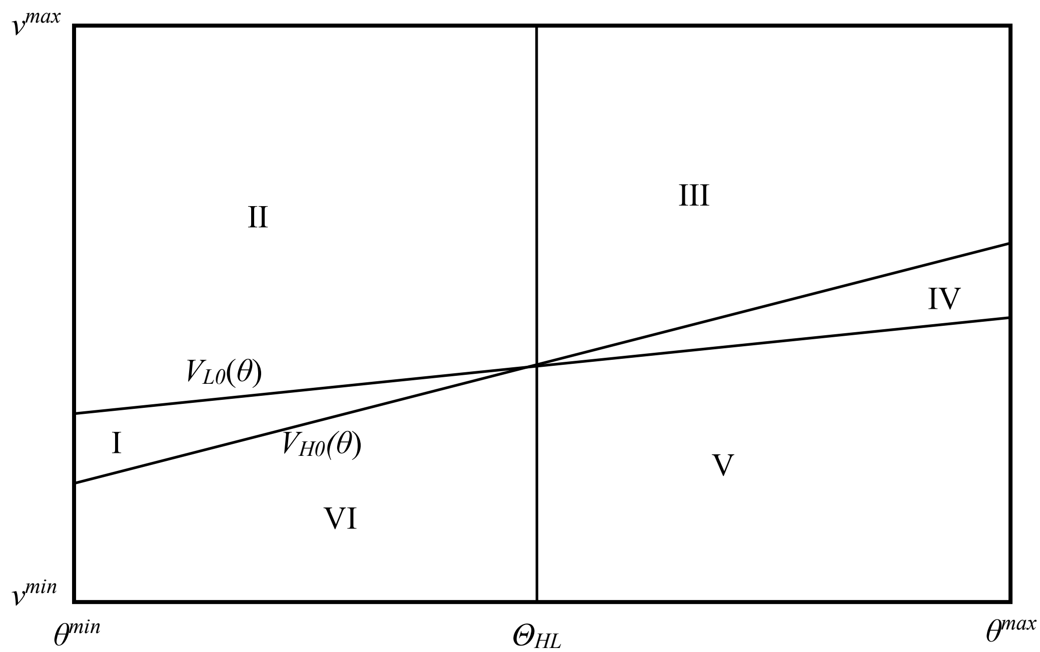


Figure 3. Distribution of Routes by Vaccination Rate (*θ*) and Recovery Rate (*ν*)