Coordinated Effects in the American Airlines-U.S. Airways Merger

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Abstract

I study the potential for collusion before and after the American Airlines-U.S. Airways merger. Results suggest the merger increased legacy airlines' incentives to coordinate their pricing decisions. U.S. Airways was disinclined to collude prior to the merger due to its unique route structure which was highly dependent on connecting products. The merger, by combining the networks of U.S. Airways and American Airlines, homogenized the industry and increased the sustainability of collusion.

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1 Introduction

When American Airlines and US Airways announced plans to merge in February of 2013, the merging airlines faced strong opposition from consumer groups and the US Department of Justice. Among other concerns, the DOJ argued that the merger would result in increased price coordination between remaining airlines (i.e., coordinated effects).[1] Since the merger's approval in November of 2013, empirical studies have documented evidence of large markups and price coordination in the airline industry (Bet, 2021*a*; Kim and Park, 2021; Ciliberto, Watkins and Williams, 2019; Aryal, Ciliberto and Leyden, 2021; Bet, 2021*b*).[2] The purpose of this study is to analyze the extent that the merger may have facilitated increased price coordination and examine why the merger may have enhanced incentives to collude.

The analysis proceeds in four steps. First, I document that US Airways's network was, prior to the merger, highly dependent on connecting products. This was the case because US Airways competed with connecting service against rivals offering direct service in a large proportion of markets. Additionally, markets where US Airways offered direct service were small relative to those of its rivals. Next, I present a theoretical model which illustrates how a merger between a firm with a network highly dependent on connecting products (i.e., US Airways) and a firm less dependent on connecting products (i.e., American Airlines) can facilitate collusion. This model formalizes the arguments of prior literature[3] that US Airways's unique route structure, which emphasized connecting products, limited the firm's incentives to collude prior the merger.

Next, I estimate an index which measures the sustainability of collusion in the airline industry before and after the AA-US merger.[4] I find that, prior to the merger, US Airways was the legacy airline least inclined to collude. Additionally, I find that the AA-US merger increased the sustainability of collusion between legacy airlines. Finally, I conduct a series of counterfactual simulations which illustrate how the observed increase in the sustainability of collusion due to the AA-US merger was caused by US Airways's unique network structure. While both US Airways's relatively large number of connecting service markets and the size of those markets contribute to the observed increase in the sustainability of collusion, the large number of connecting service markets is the strongest explanatory factor. I find that, absent US Airways's dependence on connecting products, the AA-US merger would not have

[1] *U.S. vs. US Airways Group, Inc. and AMR Corporation* (D.D.C. Pa., No. 1:13-cv-01236-CKK 9/5/13) Amended Complaint.

[2] See section 2.1 for descriptive evidence that legacy airline fares have, adjusted for fuel costs, increased since the AA-US merger.

[3] See Porter (2020); Olley and Town (2018) and the DOJ in U.S. vs. US Airways Group, Inc. and AMR Corporation (D.D.C. Pa., No. 1:13-cv-01236-CKK 9/5/13) Amended Complaint.

[4] Brito, Ribeiro and Vasconcelos (2018); Eizenberg, Shilian and Blanga (2020); Igami and Sugaya (2019); Davis and Huse (2010); Ivaldi and Lagos (2017); Eizenberg and Shilian (2019); Duarte and Chaves (2021); Miller, Sheu and Weinberg (2021) follow a similar approach methodologically.

increased the sustainability of collusion (despite a reduction in the number of firms).

Methodologically, this study follows a growing empirical literature which, in contrast to studies estimating firm conduct,[5] examines the sustainability of collusion empirically.[6] This article also combines substantial literatures studying airline mergers[7] and collusion in the airline industry.[8] Notably, Peters (2006); Kim and Singal (1993) study a series of airline mergers in the 1980s and find evidence of post-merger tacit collusion or coordinated effects.

Kim and Park (2021) also examine coordinated effects in the AA-US merger. Their reduced form approach focuses on the prices of connecting products. They conclude that the merger softened price competition between airlines. The current study focuses on studying how the merger affected the sustainability of collusion, not how the merger affected actual prices or conduct. Additionally, the theoretical analysis of Kim and Park (2021) focuses on the merger's impact on non-merging carriers, while I focus on the merger's impact on industry-level incentives to collude. Thus, the analysis of Kim and Park (2021) is complementary to this study.

The analysis proceeds as follows. Section 2 introduces the merger and the Department of Justice's concerns about coordinated effects and presents descriptive evidence. The theoretical model is presented in Section 3. Section 4 presents the data, introduces the demand model and presents demand estimates. In Section 5, I examine how the merger affected the sustainability of collusion between legacy airlines. In Section 6, I conduct a series of counterfactual simulations which suggest that the increase in the sustainability of collusion after the AA-US merger was driven by US Airways's unique route structure prior to the merger. Section 7 concludes. The appendix contains additional details on data restrictions, theoretical foundations, robustness checks and proofs.

2 The AA-US Merger

American Airlines and US Airways announced plans to merge in February of 2013. The merger would create the largest airline in the world.[9] The merger faced strong opposition from both consumer groups and the Department of Justice (DOJ). One of the DOJ's primary concerns was the potential

[5]See, for example, Miller and Weinberg 2017; Michel and Weiergraeber 2018; Ciliberto and Williams 2014; Backus, Conlon and Sinkinson 2021; Brito, Pereira and Ramalho 2013; Khwaja and Shim 2017; Bjornerstedt and Verboven 2016.

[6]See Brito, Ribeiro and Vasconcelos (2018); Davis and Huse (2010); Ivaldi and Lagos (2017); Kovacic et al. (2007); Eizenberg and Shilian (2019); Eizenberg, Shilian and Blanga (2020); Igami and Sugaya (2019); Bourreau, Sun and Verboven (2021); Starc and Wollmann (2022).

[7]See Li et al. (2018); Porter (2020); Kim and Singal (1993); Benkard, Bodoh-Creed and Lazarev (2010); Das (2019).

[8]See Aryal, Ciliberto and Leyden (2017); Ciliberto and Williams (2014); Ciliberto, Watkins and Williams (2019); Evans and Kessides (1994); Miller (2010); Bet (2021*a*).

[9]After the merger, American Airlines was the largest airline in the world by a number of measures such as passengers carried, fleet size and employees (Source: World Air Transport Statistics. IATA).

for increased price coordination after the merger (i.e., coordinated effects).[10]

In its complaint against the AA-US merger, the DOJ expressed concerns that the proposed merger, essentially the last in a merger wave which commenced eight years prior in 2005, was especially likely to harm consumers for three reasons: 1) the already concentrated nature of the industry, 2) US Airways's unique network structure, and 3) the fact that the airline industry was already highly susceptible to collusion, even prior to the merger.

In the years following September 11th, the airline industry experienced a period of turmoil as many major airlines filed for bankruptcy.[11] This period of turmoil, in addition to the Great Recession, led to a significant merger wave which began when American West Airlines and US Airways merged in 2005.[12] In 2001, the industry consisted of nine major airlines.[13] By 2013, only five airlines remained.[14] Price coordination is easier to sustain when there are fewer competitors and the DOJ contended that the concentrated nature of the industry at the time of the AA-US merger would make coordinated effects more likely to occur. Earlier mergers, such as the Delta-Northwest merger in 2008, faced less opposition because the industry was less concentrated at the time.

Price coordination is also easier to sustain when competitors are relatively symmetric. The AA-US merger increased the degree of similarity between the remaining market participants. As I will show in Section 2.2, US Airways was, prior to the merger, distinct from the other legacy carriers (Delta, United and American Airlines) because of its hub structure. US Airways's hubs were located in cities which face weak demand for nonstop travel. However, these hubs were well positioned geographically for connecting passengers. As a result, US Airways's business model emphasized connecting products to a greater extent than other legacy airlines. Reflecting this, US Airways often set prices on connecting products which were up to 40% lower than the prices of rival's nonstop flights (this pricing policy was known as the "Advantage Fares" program). By merging, the business models and networks of US Airways and American Airlines converged. In other words, the DOJ contended that the merger would increase the degree of similarity between remaining legacy airlines, facilitating collusion.

Even prior to the merger, the airline industry was particularly susceptible to collusive behavior for a number of reasons.[15] Prices can be monitored relatively costlessly and rapidly through online price

[10] *U.S. vs. US Airways Group, Inc. and AMR Corporation* (D.D.C. Pa., No. 1:13-cv-01236-CKK 9/5/13) Amended Complaint.

[11] For instance, US Airways filed for bankruptcy in August of 2002 and again in September of 2004. United Airlines filed for bankruptcy in December of 2002. Northwest Airlines filed for bankruptcy on September 14, 2005. See Doganis (2019) for more details.

[12] Notably, Delta merged with Northwest Airlines in 2008 and United Airlines merged with Continental Airlines in 2010.

[13] American Airlines, Continental Airlines, Delta Airlines, American West, Northwest Airlines, TransWorld Airlines, United Airlines, US Airways and Southwest

[14] American Airlines, Delta Airlines, United Airlines, US Airways and Southwest

[15] See Evans and Kessides (1994); Ciliberto and Williams (2014); Ciliberto, Watkins and Williams (2019); Kim and Singal (1993); Miller (2010).

comparison websites which facilitates the detection of defections from a collusive agreement (either tacit or explicit). Additionally, airlines interact simultaneously in multiple markets. Empirical studies of the airline industry (Evans and Kessides, 1994; Ciliberto and Williams, 2014) have found that multi-market contact, or the repeated interaction of airlines in multiple city-pair markets, facilitates collusion and results in higher prices. When airlines interact in multiple markets, they can punish defections in multiple markets simultaneously. Put differently, airlines can threaten to engage in a network-wide price war in response to a price cut in any particular market. As a result, firms are fearful of undercutting their rivals and instigating a costly, network-wide fare war.

Despite opposition, the DOJ reached a settlement which would allow the merger in November of 2013. The settlement required the merged entity to divest 104 landing slot pairs at Reagan National Airport (DCA) and 34 landing slot pairs at LaGuardia Airport. Additionally, the airlines were required to divest 2 gates at 5 other airports (Olley and Town, 2018).[16] These remedies were intended to encourage and facilitate the entry of low cost carriers into the merged entity's markets to provide additional competition and limit price increases. The merged entity was also required to maintain hubs in Charlotte, New York (JFK), Los Angeles, Miami, Chicago (O'Hare), Philadelphia and Phoenix for a period of 5 years. The merged entity retired the US Airways brand after the merger and flew under the American Airlines brand.

2.1 Descriptive Evidence

The primary objective of this study is the examine how the merger affected incentives to collude rather than whether such collusion actually occurred. However, I first present brief descriptive evidence which suggests that legacy airline fares, adjusted for fuel costs, increased after the AA-US merger relative to non-legacy airlines.

Figure 1 plots quarterly average fares[17] and jet fuel spot prices[18] by carrier from 2011 to 2016.[19] Prior to the approval of the merger by the DOJ in November of 2013, airline prices were relatively constant and closely tracked movements in jet fuel prices, the primary source of temporal variation in air fares. After the merger, prices gradually rose for all legacy carriers with the highest prices occurring in mid-2014. Note that this increase occurred despite declining fuel prices throughout 2014. The price increase of American Airlines (the merged entity) was more modest relative to Delta and United which

[16] These airports were Boston Logan International Airport, Chicago's O'Hare International Airport, Dallas's Love Field, Los Angeles International Airport and Miami International Airport.

[17] Figure 1 depicts one-way fares. Round trip fares are divided by 2 for comparability.

[18] Jet fuel spot prices are from the US Gulf Coast Kerosene-Type Jet Fuel Spot price, as reported by the US Energy Information Association.

[19] The other group includes ultra low cost carriers (e.g., Spirit Airlines, JetBlue Airlines and Frontier Airlines) as well as Alaska Airlines. WN denotes Southwest Airlines.

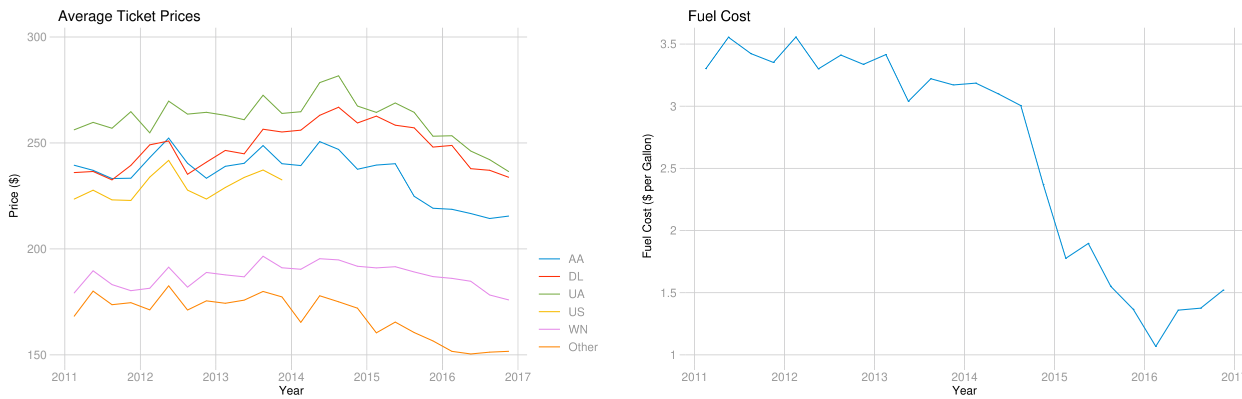

Figure 1: Average Fares by Carrier (left) and Jet Fuel Spot Price (right)

Notes: This figure presents average ticket prices by carrier from 2011-2016 (left) and fuel costs from 2011-2016 (right). Average ticket prices are one-way fares. Round trip fares are divided by 2 for comparability. The other group includes ultra low cost carriers (e.g., Spirit Airlines, JetBlue Airlines and Frontier Airlines) as well as Alaska Airlines. WN denotes Southwest Airlines. Fuel costs are the US Gulf Coast Kerosene-Type Jet Fuel Spot price, as reported by the US Energy Information Association.

may represent the opposing effect of merger synergies on the airline's fares. In 2015 and 2016, airline fares declined modestly while jet fuel costs remained low. Across airlines, Figure 1 also shows that legacy airlines typically charged higher prices than other airlines. However, among legacy airlines, US Airways charged the lowest prices. This may reflect US Airways's status as a maverick firm or, more specifically, its Advantage Fares program.

Next, I supplement Figure 1 with a regression analysis. I consider the following Diff-N-Diff specification:

$$log(p_{jct}) = \beta_0 + \beta_1 post_t * legacy_c + \beta_2 w_{ct} + \gamma_t + \alpha_{jc} + \epsilon_{jtc}$$

where p_{jct} denotes carrier c's average fare in period t for air travel product j.[20] $post_t$ is a dummy variable that takes on the value of 1 in the post merger period (2014-2016) and $legacy_c$ is a dummy variable which is 1 if the carrier is American Airlines, Delta Airlines or United Airlines. γ_t are year-quarter fixed effects, α_{jc} are product fixed effects and ϵ_{jtc} is an error term. w_{ct} is an airline's unit cost of fuel. The primary coefficient of interest is β_1, the coefficient on $post_t * legacy_c$. This coefficient, if positive, suggests that the difference between legacy and non-legacy fares was greater in the post-merger period than in the pre-merger period.

Results from ordinary least squares estimation are presented in Table 1. In all specifications, the coefficient on $post_t * legacy_c$ is positive and statistically significant at a high level. In the first

[20] A product is defined by three characteristics: the directional airport pair, the carrier offering the product and the service type (connecting vs. nonstop). For example, an American Airlines connecting flight from LGA to SFO constitutes a single product. See Section 4 for additional details.

Table 1: Reduced Form Results

Model	(1)	(2)	(3)	(4)	(5)
Post Legacy	0.0497***	0.0543***	0.0566***		
	(0.00180)	(0.00183)	(0.00182)		
Post AA				0.0226***	
				(0.00223)	
Post DL				0.0799***	
				(0.00232)	
Post UA				0.0549***	
				(0.00262)	
Post Legacy 14					0.0280***
					(0.00184)
Post Legacy 15					0.0376***
					(0.00226)
Post Legacy 16					0.0907***
					(0.00275)
Fuel Cost	0.0536***		0.188***	0.0364***	0.0655***
	(0.00210)		(0.00993)	(0.00198)	(0.00220)
Fuel Cost Sq.			-0.0290***		
			(0.00202)		
Fuel Cost*Itin. Dist.		0.0273***			
		(0.000570)			
Constant	5.240***	5.269***	5.092***	5.290***	5.208***
	(0.00608)	(0.00327)	(0.0129)	(0.00583)	(0.00639)
N	583,227	583,227	583,227	583,227	583,227
Product FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES

Notes: This table presents reduced form estimates of the merger's impact on prices. Standard errors are in parentheses and are heteroskedasticity robust. *** p<.01, ** p<.05, *p<.1. The dependent variable in all regressions is $log(p_{jct})$.

specification, column (1), the estimate of β_1 is .0497 which implies that legacy airline prices increased by approximately 5% relative to other airlines after the merger. I also include two other specifications (Columns (2) and (3)) which account for fuel cost in different ways. In column (2), I control for fuel costs using an interaction between per gallon fuel costs and itinerary distance. This specification allows fuel costs to vary by the distance flown. In column (3), I include the square of fuel (per gallon) costs. Results are similar under all three specifications.

In the fourth column, I estimate a specification which decomposes legacy airline post-merger price increases by carrier. American Airline's price increase after the merger relative to non-legacy airlines is approximately 2% while Delta's price increase is 8% and United's price increase is 5.5%. The smaller price increase of American Airlines could reflect non-fuel cost related merger synergies.[21] In the fifth column, I estimate a specification which decomposes legacy airline post-merger price increases by year. Results suggest that prices steadily increase after the merger.

Even after adjusting for changes in fuel cost, increased prices do not imply coordinated effects. Increased prices could be the result of increased market power (i.e., unilateral effects), demand shocks, cost shocks unrelated to fuel cost, entry/exit[22] or increases in price coordination not caused by the merger.

2.2 Networks

Firms offering only connecting service in a market are at a competitive disadvantage when competing against rival airlines offering direct service. This is case for two reasons. First, the marginal cost of connecting products typically exceeds the marginal cost of direct products. This is due to the increased fuel requirements (due to longer flight times and additional take-offs), airplane maintenance costs and labor costs involved in transferring passengers between planes. Second, firms offering only connecting service are also at a competitive disadvantage due to weaker demand. Consumers prefer direct flights because they involve less travel time.[23] In summary, firms offering connecting service when a rival offers direct service face both a demand and cost disadvantage.

In this section, I provide evidence supporting the assertion that US Airways's network was, prior to the merger, highly dependent on connecting products. US Airways's network was dependent on

[21] For example, if post-merger price coordination resulted in a 6% increase in fares and American Airlines experienced merger synergies equivalent to a 4% price decrease, then the net increase in AA fares after the merger would be approximately 2% (as estimated).

[22] For instance, if the merging airline exits markets where it faces competition and enters markets without competition, the average price, across markets, may increase.

[23] When estimating demand in Section 7 (See Table 7), I find that the coefficient estimate on the nonstop dummy variable is positive and statistically significant which indicates that consumers prefer direct service (i.e., direct service is a superior product).

Table 2: Competitive Disadvantage Ratio for US Airways

Entry Condition	US-AA	US-DL	US-UA
>= 50 Passengers	1.4	1.38	3.28
>= 100 Passengers	2.13	1.54	5.08
>= 150 Passengers	2.85	1.61	6.91
>= 200 Passengers	3.42	1.65	8.44

Notes: This table presents the competitive disadvantage ratio between US and other legacy airlines. The table uses 2011-2013 data.

connecting products for two reasons: differences in the proportion of markets where US Airways faced a competitive disadvantage (i.e., competed with connecting service against a rival's direct service) and differences in the size of US Airways's nonstop markets relative to rivals.

2.2.1 Number of Connecting Service Markets

In this subsection, I consider the ratio (hereafter, the competitive disadvantage ratio) of the number of markets, in the three years prior to the merger, where US Airways faced a competitive disadvantage to the number of markets where US Airways faced a competitive advantage. A market is defined as a directional metropolitan statistical area (MSA) pair (e.g., the New York MSA to the Atlanta MSA).

US Airways faced a competitive disadvantage when it offered only connecting service and a rival legacy airline offered direct service. US Airways faced a competitive advantage when it offered direct service and a rival legacy airline offered only connecting service.[24] If this ratio exceeds 1, then US Airways competes against a rival airline's direct product with only connecting service in more markets than it competes against the rival airline's connecting service with direct service (i.e., a competitive advantage). Table 2 presents results.[25] I define an airline to have entered a market with direct (connecting) service if it transports at least 50 passengers, in a quarter, via direct (connecting) service.[26] I also consider alternative, more strict, entry conditions in Table 2. US Airways's competitive disadvantage ratio with all other legacy airlines exceeds 1 for each entry condition. Thus, US Airways typically competes with other legacy airlines primarily in markets where it faces a competitive disadvantage.

[24] In the model of Section 3, this ratio is $\frac{N+x}{N-x} > 1$.

[25] See Appendix E for additional details related to the competitive disadvantage ratio.

[26] Data on passenger numbers and product offerings is from the DB1B Database. See Section 4 for details.

Table 3: Legacy Airline Hubs and Populations

Airline	AA	DL	UA	US
Largest Hub	DFW	ATL	EWR	PHL
Largest Hub MSA Population	6.8 million	5.5 million	19.9 million	6.0 million
2nd Largest Hub	ORD	MSP	IAH	CLT
2nd Largest Hub MSA Population	9.5 million	3.4 million	6.3 million	2.3 million
3rd Largest Hub	LAX	DTW	ORD	PHX
3rd Largest Hub MSA Population	13.1 million	4.3 million	9.5 million	4.4 million
4th Largest Hub	MIA	LGA	SFO	DCA
4th Largest Hub MSA Population	5.8 million	19.9 million	4.5 million	5.9 million
Average Population	8.8 million	8.2 million	10.1 million	4.6 million

Notes: Number of passenger enplanements at legacy airlines' 4 largest hubs. Using 2013 Quarter 3 data.

2.2.2 Differences in Market Size

Next, I provide evidence suggesting that the markets where US Airways faced a competitive advantage were typically small. Legacy carriers such as US Airways operate a hub and spoke network. A hub and spoke network involves operating direct flights to and from major hubs. Passengers connect, through the airline's hub, to their final destination. Thus, the majority of an airline's direct flights are either to or from a hub. However, US Airways's hubs were typically positioned in smaller markets.

Table 3 presents the top four[27] hubs, in terms of passenger enplanements, of the four main legacy airlines in 2013 Quarter 3 (just prior to the merger's approval). Additionally, Table 3 includes the population size of the metropolitan statistical area in which the hub is located.[28] Table 3 also presents the average population, across the top 4 hubs, for each airline. US Airways's hubs were typically located in substantially smaller markets. Notably, US Airways did not have a hub in any of the top 5 Metropolitan statistic areas by population (New York, Los Angeles, Chicago, Dallas and Houston).[29]

Next, I examine the average market size in markets where US Airways faced a competitive disadvantage relative to markets where US Airways faced a competitive advantage. Following prior literature (Ciliberto and Williams, 2014), the size of a market is defined as the geometric mean of the population

[27] US Airways had only 4 hubs at the time of the merger.

[28] For example, LGA (La Guardia Airport) resides in the New York Metropolitan Area.

[29] US Airways operated hubs in Charlotte, Philadelphia, Phoenix and Washington D.C. In the past US Airways operated additional hubs in Las Vegas and Pittsburgh.

Table 4: Market Sizes and Competitive Advantage for US Airways

Entry Condition		AA	DL	UA
>= 50 Passengers	US Comp. Adv.	3.6	3.28	2.79
	US Comp. Disadv.	4.48	3.3	3.98
>= 100 Passengers	US Comp. Adv.	3.71	3.18	2.91
	US Comp. Disadv.	4.69	3.5	4.21
>= 150 Passengers	US Comp. Adv.	3.84	3.08	3.15
	US Comp. Disadv.	4.79	3.66	4.35
>= 200 Passengers	US Comp. Adv.	3.95	2.98	3.27
	US Comp. Disadv.	4.91	3.82	4.5

Notes: This table presents markets sizes in US comp. adv. and disadv. markets by rival airline. Using 2011-2013 data. Market sizes in millions of people.

of the origin and destination metropolitan statistical area. Table 4 presents results for a variety of entry conditions. For each entry condition and rival airline, the average size of markets where US Airways faced a competitive advantage are smaller than the average size of markets where US Airways faced a competitive disadvantage.

While US Airways's hubs did not receive the same level of direct traffic as other legacy airline hubs, they were well positioned geographically for transporting connecting passengers. For example, Charlotte airport is well positioned to connect passengers from New York to Florida (a large vacation travel market). Additionally, US Airways's Phoenix hub is well positioned for connecting passengers to California from Texas (or vice versa).

2.2.3 Historical Differences

US Airways's heavy dependence on connecting products relative to other legacy airlines may have arisen due to historical differences between US Airways and other legacy carriers. American, Delta and United were all original trunk carriers. Trunk carriers were airlines permitted, by the Civil Aeronautics Act of 1938, to provide interstate service prior to de-regulation. US Airways (then known as Allegheny Airlines) was, at the time of de-regulation, a regional airline. While trunk carriers operated major intercontinental routes prior to deregulation and, as a result, had a wide national network of routes in place at the time of deregulation, Allegheny Airlines/US Airways's flights pre-deregulation were more regional and concentrated around Pennsylvania. Post de-regulation, US Airways grew through a series of mergers and acquisitions (e.g., the acquisition of Pacific Southwest Airlines in 1988, the acquisition

Table 5: Summary of Market Conditions: Pre-Merger

	Product			Number of Markets
	Firm 1	Firm 2	Firm 3	(or Market Size)
Market Type A	I	II	Absent	N
Market Type B	II	I	Absent	N
Market Type C	Absent	I	II	$N+x$
Market Type D	Absent	II	I	$N-x$
Market Type E	I	Absent	II	$N+x$
Market Type F	II	Absent	I	$N-x$

of Piedmont Airlines in 1989 and a merger with American West in 2005) which expanded its network, especially to the west. These historical differences may have contributed to US Airways's unique hub structure and, as a result, its dependence on connecting products.

3 Theoretical Model

In this section, I present a theoretical model which illustrates how a merger between a firm dependent on connecting products (US Airways) and a firm less depdendent on connecting products (American Airlines) can increase the sustainability of collusion. I analyze an infinitely repeated game involving 3 firms (denoted firm 1, 2 and 3) with common discount factor $\delta \in (0,1)$. There are two types of products. The first product (product I) represents a product that is either cheaper to produce, preferred by consumers or both cheaper to produce and preferred by consumers. Product I is intended to represent nonstop products. The second product (product II) represents a product that is more expensive to produce than Product I, of a lower quality than Product I or both more expensive and of a lower quality. Product II is intended to represent connecting products.

There are six types of markets (denoted market type A, B, C, D, E and F), each of which is a duopoly. Firm 1 and firm 2 compete in all markets of type A and type B. In type A markets, firm 1 produces product I while firm 2 produces product II. Thus, firm 1 has a competitive advantage in market type A. This advantage is either a result of a demand advantage (if product I is of a higher quality), a marginal cost advantage (if product I is cheaper to produce) or both a demand and marginal cost advantage. In type B markets, products are reversed and firm 2 produces product I while firm 1 produces product II.

Firm 2 and firm 3 compete in all markets of type C and type D. In type C markets, firm 2 produces product I while firm 3 produces product II. Production is reversed in markets of type D and firm 3 produces product I while firm 2 produces product II. Firm 1 and firm 3 compete in all markets of type E and type F. In type E markets, firm 1 produces product I and firm 3 produces product II. Production is reversed in market type F and firm 3 produces product I while firm 1 produces product II.

There are N markets of type A and B. Also, there are $N + x$ markets of type C and E and $N - x$ markets of type D and F where $x \in \{0, 1, 2 \dots N - 1\}$. Therefore, when $x > 0$, firm 3 competes in a larger number of markets with a competitive disadvantage, and a smaller number of markets with a competitive advantage than its rivals.

The model can be reinterpreted in terms of market size differences instead of differences in the number of markets of each type. I define a market's size as a multiplicative factor which increases the level of demand and, as a result, profit.[30] To illustrate, suppose a firm earns profit Π_k in a market of type $k \in \{A, B, C, D, E, F\}$. If the firm competes in N markets of type k, then it earns a total profit $N\Pi_k$ from these markets. Alternatively, if there is one market of type k but that market has size N, then the firm earns a total profit $N\Pi_k$ from this market. Either interpretation yields identical results and, thus, the effects of this section could be driven by differences in the number of markets where Firm 3 faces a competitive disadvantage or the size of those markets. For concreteness, I interpret results in terms of differences in the number of markets, instead of differences in market size, for the remainder of this section.

Table 5 summarizes market conditions. To facilitate comparison with the airline industry, I refer to the set of markets served by each firm as a firm's network (e.g., firm 1's network prior to the merger is $\{A, B, E, F\}$). Let Π_j^C denote market-specific collusive profits for a firm producing product $j \in \{I, II\}$. Let Π_j^N denote market-specific Nash equilibrium profits for a firm producing product $j \in \{I, II\}$. Let Π_j^D denote market-specific defection profits for a firm producing product $j \in \{I, II\}$.

I consider a merger between firm 1 and firm 3.[31] After the merger, I denote the merged firm as firm 1. In markets where both firm 1 and firm 3 participated prior the merger, firm 1 chooses to produce product I (the superior product) after the merger.[32] In all other markets, production is unchanged. Table 6 summarizes market conditions after the merger. Firm 1 (the merged entity) competes in all markets and is a monopolist in markets of type E and F.

[30] For example, if demand in a market of size 1 is $D(p)$ when the market price is p, then demand in a market of size N is $ND(p)$.

[31] A merger between firm 2 and firm 3 yields equivalent results.

[32] Results are not dependent on this assumption, the merged airline could choose to offer product II (perhaps due to high fixed costs associated with product I) or exit the market entirely.

Table 6: SUMMARY OF MARKET CONDITIONS: POST-MERGER

	Product		Number of Markets
	Firm 1 (merged with Firm 3)	Firm 2	(or Market Size)
Market Type A	I	II	N
Market Type B	II	I	N
Market Type C	II	I	$N+x$
Market Type D	I	II	$N-x$
Market Type E	I	Absent	$N+x$
Market Type F	I	Absent	$N-x$

Firms collude by means of grim trigger strategies (Friedman, 1971). Each firm sets the collusive price in each market unless any firm has deviated in any prior period. If any firm has deviated in any prior period, all firms engage in Nash competition in all markets in perpetuity. Collusion is sustainable if

$$\frac{\pi_i^C}{1-\delta} \geq \pi_i^D + \delta \frac{\pi_i^N}{1-\delta} \tag{1}$$

for all $i \in \{1,2,3\}$ where π_i^C denotes the collusive profit of firm i across all markets,[33] π_i^D denotes the defection profit of firm i across all markets and π_i^N denotes the Nash equilibrium profit of firm i across all markets. The critical discount factor for firm i is the smallest discount factor δ such that firm i does not wish to deviate from the collusive agreement (i.e., inequality 1 holds). The industry critical discount factor is the smallest discount factor for which each firm finds it most profitable to abide by the terms of the collusive agreement.

Condition 1. $\frac{\Pi_{II}^D-\Pi_{II}^C}{\Pi_{II}^D-\Pi_{II}^N} > \frac{\Pi_I^D-\Pi_I^C}{\Pi_I^D-\Pi_I^N}$

Condition 1 states that, if collusion were to occur only in a single market (consisting of one firm offering product I and the other firm offering product II), collusion is harder to sustain for the firm offering product II. Note that Condition 1 does not state that the critical discount factor is higher for the firm offering product II than the firm offering product I. This is the case because firms interact in multiple markets and the critical discount factor is determined by the sustainability of collusion across all markets jointly, not one particular market. I will show this condition is satisfied in multiple common models of multi-market collusion.

US Airways's Advantage Fares program, which involved undercutting rival direct products in mar-

[33] For example, $\pi_1^C = (2N+x)\,\Pi_I^C + (2N-x)\,\Pi_{II}^C$ prior to the merger.

kets where it offered connecting service, indicates an unwillingness to collude in markets where US Airways faced a competitive disadvantage prior to the merger. This suggests collusion was difficult to sustain, in these markets, for the carrier offering connecting service, which is consistent with Condition 1. Condition 1 is also consistent with the industry practice of an airline offering connecting service "respecting" the pricing of the non-stop carrier in a market. As the DOJ Complaint states, "the legacy airlines 'generally respect the pricing of the non-stop carrier [on a given route],' even though it means offering connecting service at the same price as nonstop service." This suggests collusion involves airlines allocating large collusive profits to the firm offering direct service (Product I) and relatively small profits to the firm offering connecting service (Product II) which implies the firm offering product II will have weak incentives to collude in that particular market, as Condition 1 states.

Let $\delta^*_{pre,i}$ denote firm i's critical discount factor before the merger and let $\delta^*_{pre} = \max_i \left\{\delta^*_{pre,i}\right\}$ denote the industry critical discount factor before the merger. Let $\delta^*_{i,post}$ denote firm i's critical discount factor after the merger and let $\delta^*_{post} = \max_i \left\{\delta^*_{post,i}\right\}$ denote the industry critical discount factor after the merger.

Theorem 1. *Suppose Condition 1 holds. If $x = 0$, then $\delta^*_{post} = \delta^*_{pre}$. If $x \in \{1, 2 \ldots N-1\}$, then*

(i) $\delta^*_{post} < \delta^*_{pre}$,

(ii) $\delta^*_{1,pre} < \delta^*_{1,post}$, *and*

(iii) $\delta^*_{2,pre} = \delta^*_{2,post}$.

Proof. See Appendix G. □

Theorem 1 part (i) reports that, when $x > 0$, the merger reduces the industry critical discount factor (i.e., the merger increases the sustainability of collusion). Theorem 1 part (ii) reports that while the merger reduces the industry critical discount factor, it increases the critical discount factor of firm 1. Theorem 1 part (iii) reports that the critical discount factor of the non-merging firm (firm 2) is unchanged. Theorem 1 also states that the merger does not affect the sustainability of collusion when $x = 0$.

Intuitively, firm 3 is disinclined to collude when $x > 0$ due to its network structure. Firm 3 faces a competitive disadvantage in a large number of markets relative to other airlines (market types C and E of which there are $N+x$) and competitive advantage in a small number of markets (markets of type D and F of which there are $N-x$). Note that the firm offering product II (i.e., a competitive disadvantage) has weak incentives collude, in that particular market, because of its high cost and/or lower quality product (See Condition 1). This is the case because a firm offering a lower quality and higher cost product gains less from collusion while potentially earning large profits from defection. Because Firm

3 competes in a disproportionately large number of markets with product II, it is disinclined to collude and has a high critical discount factor.

In summary, firm 3 is disinclined to collude because its network relatively dependent on markets in which it faces a competitive disadvantage (market types C and E). As the industry critical discount factor is determined by the firm least inclined to collude, the industry critical discount factor is firm 3's critical discount factor. The merger combines the networks of firm 1 and firm 3 which combines the incentives of firm 1 (a firm more inclined to collude) and firm 3 (a firm less inclined to collude). The merged entity, compared to firm 3 prior to the merger, is less dependent on markets where it suffers a competitive disadvantage. As a result, the merger reduces the industry critical discount factor and facilitates collusion as stated in Theorem 1 part (i). As reported in Theorem 1 part (ii), the merger increases firm 1's critical discount factor. Firm 1 inherits the network of firm 3 in the merger and, as a result, is more dependent on markets in which it faces a competitive disadvantage after the merger. Therefore, its incentives to defect are enhanced and the sustainability of collusion for firm 1 is reduced.

Next, I introduce a number of settings where Condition 1 holds and, as a result, Theorem 1 is applicable.

Example 1 (**Bernheim and Whinston (1990)**)**.** This model is an extension of Bernheim and Whinston's model of multi-market collusion under symmetric advantage (See Section 5 of Bernheim and Whinston (1990)). Product I is produced with marginal cost 0. Consumers derive utility r from consumption of product I. Product II is produced with marginal cost $c \geq 0$. Consumers derive utility $r - \Delta$ from consumption of product II where $\Delta \geq 0$. Δ represents the difference in product quality between product II and product I. If $\Delta = 0$, products are homogenous. I assume $0 < c + \Delta$ which implies that product I is either cheaper to produce (if $c > 0$), preferred by consumers (if $\Delta > 0$) or both cheaper to produce and preferred by consumers (if $c\Delta > 0$).[34] Consumers have perfectly inelastic unit demand. Thus, a unit mass of consumers purchase product I (product II) if $r - p_I > r - \Delta - p_{II}$ ($r - p_I < r - \Delta - p_{II}$) where p_I denotes the price of product I and p_{II} denotes the price of product II.

Following Bernheim and Whinston (1990), firms collude by setting prices that maximize joint industry profit. Thus, production within a market is allocated entirely to the firm with a marginal cost and/or demand advantage (i.e., production is allocated entirely to the producer of product I). For example, in market A, firm 1 sets price r for product I and serves all demand while firm 2 sets a price exceeding $r - \Delta$ for product II and serves zero demand.[35] In the Nash equilibrium of the stage

[34] I also assume $c + \Delta < r$. If $r < c + \Delta$, then production of product II is never profitable.

[35] This reflects the industry practice, as stated by an American Airlines executive and mentioned by the DOJ in its complaint against the merger, of airlines offering connecting service "respecting" the pricing of the non-stop carrier in a market. As the DOJ Complaint states, "the legacy airlines 'generally respect the pricing of the non-stop carrier [on a

game, the price of product I is $c + \Delta - \epsilon$ and the price of product II is c in all markets. All consumers purchase product I in the Nash equilibrium. In Appendix A, I show that condition 1 is satisfied in this setting.

Example 2 (Singh and Vives (1984) Demand). Product $i \in \{I, II\}$ is produced with marginal cost c_i where $c_I \leq c_{II}$. Following Singh and Vives (1984), I assume the demands for the firms' products result from the utility-maximizing choice of a representative consumer. The representative consumer's utility when she consumes q_i units of good $i \in \{I, II\}$ is

$$U(q_I, q_{II}) = (1 + \Delta)\, q_I + q_{II} - \frac{1}{2}\left(q_I^2 + q_{II}^2 + 2bq_Iq_{II}\right) + m \tag{2}$$

where m denotes the numeraire good. The parameter $b \in (0, 1)$ measures the degree of horizontal differentiation. $b = 0$ represents the case of completely independent goods and $b = 1$ represents the case of perfect substitutes. Δ denotes the quality or demand advantage of product I. When $\Delta = 0$, the two products have the same quality. When prices are such that there is positive demand for both products, this utility function results in the following demand functions:[36]

$$D_I(p_I, p_{II}) = \frac{1}{1 - b^2}\left[1 - b + \Delta - p_I + bp_{II}\right] \tag{3}$$

and

$$D_{II}(p_I, p_{II}) = \frac{1}{1 - b^2}\left[1 - b - b\Delta - p_{II} + bp_I\right]. \tag{4}$$

If the difference in prices is sufficiently large, the higher priced product receives 0 demand. Specifically, $D_I(p_I, p_{II}) = 1 - p_I$ and $D_{II}(p_I, p_{II}) = 0$ if $1 - b - b\Delta + bp_I < p_{II}$, and $D_I(p_I, p_{II}) = 0$ and $D_{II}(p_I, p_{II}) = 1 + \Delta - p_{II}$ if $1 - b + \Delta + bp_{II} < p_I$. In Appendix A, I show that if firms collude by choosing prices to maximize their joint profit in each market (i.e., $\max_{p_I, p_{II}} \Pi_I(p_I, p_{II}) + \Pi_{II}(p_I, p_{II})$ where $\Pi_i(p_I, p_{II}) = D_i(p_I, p_{II})\,(p_i - c_i)$), then Condition 1 holds.

Example 3 (Hotelling (1929) Linear City Model). Next, I consider a Hotelling (1929) model of product differentiation.[37] I assume each market is a linear city of length 1. Consumers are uniformly distributed over the line. Consumers purchase either one or zero units of the good and have a reservation price of r. Transportation costs are linear and the unit transportation cost is $t > 0$. Firm I

given route],' even though it means offering connecting service at the same price as nonstop service." Note that, as the DOJ argues, US Airways notably did not conform to this pricing practice. *U.S. vs. US Airways Group, Inc. and AMR Corporation* (D.D.C. Pa., No. 1:13-cv-01236-CKK 9/5/13) Amended Complaint.

[36] If the model is interpreted in terms of market size differences instead of differences in the number of markets, the demand functions are $M_iD_I(p_I, p_{II})$ and $M_iD_{II}(p_I, p_{II})$ where M_i is the market size of market $i \in \{A, B, C, D, E, F\}$ (e.g., N,$N - x$ or $N + x$).

[37] The model in this example closely follows Colombo (2011).

(intended to represent the firm offering product I) is located at point $x_I \in [0,1)$ while firm II (intended to represent the firm offering product II) is located at point $x_{II} \in (x_I, 0]$. Firm 1 is located more centrally in the Hotelling line than Firm II. Specifically, $x_I = m - \frac{d}{2}$ and $x_{II} = m + \frac{d}{2}$ where $m > \frac{1}{2}$ is the midpoint between the two firms and d is the distance between the two firms. Firm I (which offers product I) is placed in a more central location on the Hotelling line than Firm 2 (which offers product II) to reflect the superior quality of product I. This results in a greater number of consumers purchasing product I at equal prices. Put differently, the majority of consumers prefer product I (i.e., are located closer to product I on the Hotelling line).[38] Firms collude, in each market, by charging the uniform price which maximizes joint profit.[39] Colombo (2011)'s Proposition 3 shows that condition 1 is satisfied in this setting.

Example 4 (**Quantity Competition**)**.** As in Example 2, I assume the demands for the firms' products result from the utility-maximizing choice of a representative consumer (Singh and Vives, 1984) with a utility function given in Equation 2. However, I assume firms set quantities instead of prices.[40] Utility maximization results in the inverse demand functions

$$P_I(q_I, q_{II}) = 1 - q_I - bq_{II}$$

and

$$P_{II}(q_I, q_{II}) = 1 + \Delta - q_{II} - bq_I.$$

Δ denotes the quality or demand advantage of product I. Product $i \in \{I, II\}$ is produced with marginal cost c_i where $c_{II} \geq c_I$. First, consider the case of no horizontal differentiation ($b = 1$). In this case, the output strategy during collusion which maximizes total profit involves the low cost/high quality firm, in a particular market, producing the monopoly level of output and the high cost/low quality firm producing 0 output. Condition 1 holds trivially in this case as the firm offering product I has no incentive to deviate within a market (i.e., $\frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N} = 0$). Next, consider the case of horizontally differentiated products ($b < 1$). Suppose firms set quantities in each market during collusion in order to maximize joint profit. I show that Condition 1 holds in this case in Appendix A.

[38] Note that some consumers still purchase product II (i.e., consumers located close to firm 2). In the airline industry, these are passengers which would purchase a connecting product despite the presence of a (superior) direct product. These customers may purchase the connecting product out of strong brand loyalty (perhaps due to frequent flyer programs). Alternatively, the connecting product's departure time may be more convenient for these consumers.

[39] This assumption follows (Häckner, 1994; Colombo, 2011) and reflects the practice, as mentioned in the DOJ complaint, of "offering connecting service at the same price as nonstop service."

[40] If airlines set capacity (e.g., number of seats, planes or airport gates) before setting prices, then airline competition may resemble quantity competition (Kreps and Scheinkman, 1983).

4 Data and Air Travel Demand

4.1 Data

Data on airline ticket prices, ticket characteristics, flight distance and the number of passengers are from the airline origin and destination survey (DB1B).[41] The DB1B is a 10% random sample of U.S. domestic airline tickets collected by the Bureau of Transportation Statistics. The DB1B does not contain information on ticket restrictions (weekend stay over requirements, advance purchase requirements) or departure times. I use DB1B data from 2011 through 2016 (three years prior and three years after the merger). For computational simplicity and tractability, I restrict attention to tickets which satisfy three main conditions. First, I consider tickets involving only the largest 100 U.S. airports, in terms of enplanements, as of 2018.[42] Second, following Berry, Carnall and Spiller (2006); Berry and Jia (2010), I drop any products involving airports in Alaska, Hawaii, or Puerto Rico. This results in a total of 94 airports in 79 metropolitan statistical areas. These airports serve approximately 91.4% of all domestic passengers in 2018. Third, I restrict the sample to itineraries involving 4 flights or fewer. Other sample restrictions are outlined in Appendix B.

A market is defined as directional travel between two metropolitan statistical areas. Markets can contain products involving different airports. Following Ciliberto and Williams (2014), I collapse all connecting products between an origin and destination airport to a single product. A product is defined by the origin airport, destination airport, ticketing carrier and service type (i.e., connecting or direct).[43] Following prior literature (Ciliberto and Williams, 2014; Berry, Carnall and Spiller, 2006; Berry and Jia, 2010), I define market size as the geometric mean of the population of the origin metropolitan statistical area and the population of the destination metropolitan statistical area.[44] As the merger was approved by the DOJ in November of 2013, I define the pre-merger period to be 2011-2013 and the post-merger period to be 2014-2016.[45] The final sample size is 583,227 products.

[41] https://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=125

[42] Aguirregabiria and Ho (2012) make a similar restriction and restrict to the top 75 cities. Ciliberto and Williams (2014) restrict to the top 200 airports. Ciliberto and Tamer (2009) use the top 100 metropolitan statistical areas. Berry (1992) uses the top 50 cities.

[43] For example, a connecting American Airlines itinerary from TPA to JFK constitutes a single product.

[44] Population data is from the U.S. Census (https://www2.census.gov/programs-surveys/popest/datasets/).

[45] Bilotkach (2011), when analyzing the US Airways and American West merger, used data from two years prior and two years after the merger. Bontemps, Remmy and Wei (2021) analyze data from the second quarter of 2011 and the second quarter of 2016.

4.2 Demand Model

In order to estimate an airline's incentives to collude, it is necessary to first obtain an estimate of air travel demand. Following prior literature,[46] air travel demand is modeled as a nested logit. The utility of consumer i in market m from consumption of air travel product j is

$$u_{ijm} = \alpha p_{jm} + x'_{jm}\beta + \xi_{jm} + v(\rho)_{im} + (1-\rho)\epsilon_{ijm}$$

where p_{jm} is price and x'_{jm} is a vector of other product characteristics. α and β are taste parameters. ξ_{jm} is a structural error term consisting of unobserved product characteristics including in-flight amenities, ticket restrictions and departure time. ϵ_{ijm} is a standard Type I extreme value error term that represents idiosyncratic differences in utility. $v_{im}(\rho)$ has a distribution such that $v_{im}(\rho) + (1-\rho)\epsilon_{ijm}$ generates a classic nested logit choice structure for each consumer where $\rho \in [0,1]$ is the nesting parameter. There are two nests: one consisting of all air travel products and one consisting of only the outside option (denoted product $j = 0$). I normalize the utility of the outside option to ϵ_{i0m}. $\delta_{jm} = \alpha p_{jm} + x'_{jm}\beta + \xi_{jm}$ is the mean utility or the portion of utility which is common to all consumers.

The unconditional probability of choosing product j is

$$s_{jm}(x_{jm}, p_{jm}, \xi_{jm}, \theta_d) = \frac{e^{\delta_{jm}/(1-\rho)}}{V_m} \frac{V_m^{1-\rho}}{1 + V_m^{1-\rho}} \tag{5}$$

where $V_{rm} = \sum_{j \in \mathcal{J}_m} e^{\delta_{rjm}/(1-\rho)}$ and $\mathcal{J}_m$ is the set of airline products in market m.

x_{jm} includes several variables relevant to airline demand. The nonstop distance (in 1000s of miles) between the origin and destination airport and the square of this distance are included to account for how trip length affects passenger utility. Connecting products involve flying some additional distance and traveling for a longer period of time. Connections that are more conveniently located between origin and destination yield shorter travel times. To account for this variation, I follow Ciliberto and Williams (2014) and include the ratio of the total itinerary distance to the nonstop distance between the two endpoint airports. A larger value of this ratio indicates a longer travel time relative to nonstop travel. The scope of a carrier's service from the origin and destination airport are also important determinants of airline demand (Ciliberto and Tamer, 2009; Berry, 1992; Berry and Jia, 2010) and are measured by the fraction of all destinations from the airport served by a particular carrier. Loyalty programs (such as frequent flyer programs) are more effective if accrued benefits can be used on a

[46] See Doi (2019); Peters (2006); Chen and Gayle (2019); White III (2019); Aguirregabiria and Ho (2012).

larger number of routes. Additionally, carriers with a large presence at an airport can offer superior airport amenities (e.g., business lounges). I also include dummy variables for Alaskan Airlines, Delta, Southwest, US Airways, and United (American represents the baseline). I aggregate smaller LCCs into a single group for simplicity. The group denoted *Other Low Cost Carriers* includes low cost carriers other than Southwest.[47] I also include year-quarter fixed effects.

4.3 Demand Estimation

$\theta_d = \{\alpha, \beta, \rho\}$ are the demand parameters to be estimated. To identify these parameters, I place further restrictions on the model in the form of moment conditions:

$$E\left[\xi_{jm} Z_{jm}^D\right] = 0$$

where Z_{jm}^D is a vector of instruments. Demand instruments include a number of excluded instruments and all observed product characteristics other than price. Prices and market shares are expected to be correlated with unobserved product characteristics ξ_{jm} and, therefore, are endogenous. To properly identify the demand parameters, I instrument for these endogenous variables. Instruments should be correlated with prices and market shares, but uncorrelated with unobserved product characteristics ξ_{jm}. I employ three sets of instruments (in addition to all observed product characteristics other than price and market share). The first set includes interactions of exogenous product characteristics. The second set includes BLP style instruments. These instruments are sums or averages of rival product characteristics (Berry, Levinsohn and Pakes, 1995). Specifically, I include the average distance of rival products, the number of direct rival products and the average origin and destination presence of rivals. Third, I include the number of products in a market, which prior literature has shown to be relevant for the identification of the nesting parameter ρ (Peters, 2006; Miller and Weinberg, 2017).

I estimate the model using the generalized method of moments. The estimation process proceeds as follows. Given an initial guess $\tilde{\theta}_D$, I recover, using the contraction mapping of Berry, Carnall and Spiller (2006), the vector $\xi_{jm}(\tilde{\theta}_D)$ which equates observed market shares $\bar{s}_{jm}$ with the predicted market shares in Equation (5),

$$\bar{s}_{jm} = s_{jm}(x_{jm}, p_{jm}, \xi_{jm}, \tilde{\theta}_D).$$

[47]The other low cost carriers are Allegiant Airlines (G4), Spirit Airlines (NK), Frontier Airlines (F9), JetBlue Airlines (B6), Airtran Airways (FL) and Sun Country Airlines (SY).

Next, I evaluation the GMM objective

$$G(\theta) = \xi(\theta)' Z_D W Z_D' \xi(\theta) \tag{6}$$

at $\tilde{\theta}_D$ where W is a consistent estimate of the efficient weighting matrix (using first stage estimates). I repeat this process to determine $\hat{\theta}_D = \text{argmin}_\theta G(\theta)$, the GMM demand estimate.

4.4 Demand Results

Table 7: Demand Results

Utility Parameters	Mean	SE
Intercept	-5.108***	(0.042)
Prices	-1.041***	(0.012)
Nonstop	0.666***	(0.006)
Nonstop Distance	0.555***	(0.014)
Nonstop Dist. Squared	-0.116***	(0.004)
Origin Presence	1.715***	(0.015)
Dest Presence	0.679***	(0.011)
$\frac{\text{Itinerary Dist.}}{\text{Nonstop Dist.}}$	-1.781***	(0.054)
$\left[\frac{\text{Itinerary Dist.}}{\text{Nonstop Dist.}}\right]^2$	0.438***	(0.018)
Delta	0.188***	(0.004)
US Airways	0.123***	(0.005)
United	-0.195***	(0.005)
Southwest	-0.343***	(0.008)
Other LCC	-0.404***	(0.009)
Other Major	0.306***	(0.013)
ρ	0.531***	(0.002)
Own. elasticity	-4.74	

Notes: Nested logit demand estimation results. Standard errors are in parentheses and are heteroskedasticity robust. Time fixed effects not reported. *** p<.01, ** p<.05, *p<.1.

Table 7 presents demand estimation results. As expected, consumers prefer lower prices and nonstop service. Results indicate an inverse U-shaped relationship between utility and distance. Consumers experience a greater utility from longer travel but at a diminishing rate. Utility is increasing in both origin and destination presence, which is consistent with prior studies (Berry and Jia, 2010; Ciliberto and Williams, 2014; Berry, Carnall and Spiller, 2006; Gayle, 2013). The coefficient on the distance ratio variable, the ratio of itinerary distance to nonstop distance, is negative. This indicates that, as expected, consumers prefer more convenient products with shorter travel times. The nesting parameter is statistically significant and equals 0.531, which implies that products other than air travel are somewhat substitutable for air travel. The coefficient on the other low cost carrier dummy variable is negative which suggests that, all else equal, consumers prefer to travel on an American Airlines flight, the baseline, than a low cost carrier flight. This reflects differences in customer service, in-flight experience and brand effects. The mean own-price elasticity is -4.74 which is consistent with prior literature.[48]

5 The Sustainability of Collusion

In this section, I present evidence which suggests the AA-US merger facilitated price coordination between legacy airlines. Specifically, I analyze an index which measures the sustainability of collusion within the airline industry and find that it increased significantly after the AA-US merger.

Ideally, an analysis of the sustainability of collusion would directly estimate the critical discount factor (such as the critical discount factor analyzed in Section 3) necessary to sustain collusion.[49] However, this would require specifying of the details of the underlying dynamic game and strategies employed by firms (e.g., the structure of the collusive agreement, punishments, information structure, public or private monitoring, timing and detection lags, beliefs regarding future payoffs etc.) which are unknown to the researcher. Considering these difficulties, prior literature (Brito, Ribeiro and Vasconcelos, 2018; Eizenberg, Shilian and Blanga, 2020; Igami and Sugaya, 2019; Davis and Huse, 2010; Ivaldi and Lagos, 2017) instead estimates an index, intended to measure the sustainability of collusion within an industry, that corresponds to the critical discount factor from a highly simplified and tractable dynamic game.[50] I follow this approach and estimate an index (hereafter, the sustainability index) which is based on the critical discount factor from a dynamic game similar to that of Section 3 (see Appendix C for details of the corresponding dynamic game). Next, I examine how this index

[48] Bontemps, Gualdani and Remmy (2020) find an elasticity of -4.69 in 2011 using a nested logit model. Ciliberto and Williams (2014) find an elasticity of -4.320 in 2006-2008. Gayle (2013), using a random coefficients logit with continuous heterogeneity, found an elasticity of -4.72 with data from 2006. Bet (2021*a*) finds an own price elasticity of -4.7 using a random coefficients nested logit.

[49] For collusion to be sustainable, firms must be sufficiently patient (i.e., must have a discount factor sufficiently close to 1) that they place a greater value on future profits from collusion than potential profits from defection in the current period. The critical discount factor represents the smallest discount factor (in other words, the minimal level of patience) necessary for collusion to be stable (i.e., no firm wishes to defect).

[50] See also Kovacic et al. (2007); Farrell and Baker (2021).

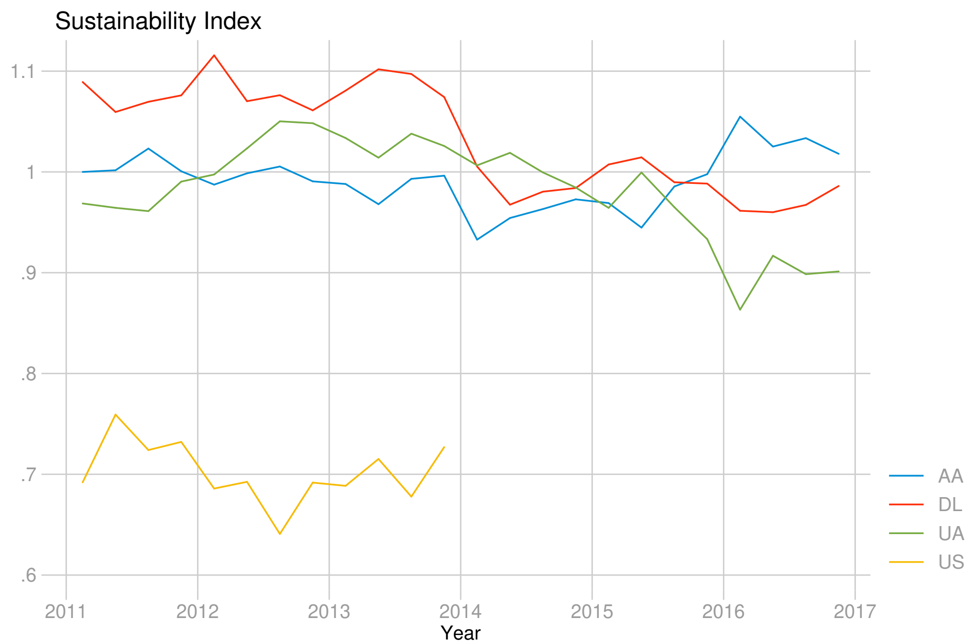

Figure 2: Sustainability Index by Carrier

Notes: This figure presents the sustainability index by carrier from 2011-2016. The index is normalized such that AA's index is 1 in 2011 Q1.

differs across firms and across time. Additionally, I examine the robustness of results to alternative indexes and assumptions.

The sustainability index for firm f at time t is

$$\lambda_{ft} = 1 - \frac{\sum_m \Pi^D_{fmt} - \sum_m \Pi^C_{fmt}}{\sum_m \Pi^D_{fmt} - \sum_m \Pi^N_{fmt}}.$$

Π^C_{fmt} denotes the collusive profit of firm f in market m at time t. Π^D_{fmt} denotes the defection profit of firm f in market m at time t. Defection prices are the prices that maximize their profits when all rivals set collusive prices (i.e., the best response of an airline to rivals' collusive prices). Π^N_{fmt} denotes the Nash equilibrium profit of firm f in market m at time t.

λ_{ft} is bounded between 0 and 1. Larger values of λ_{ft} suggest that collusion is more sustainable for firm f. In other words, firm f has weaker incentives to defect from the collusive agreement. λ_{ft} is increasing in $\sum_m \Pi^C_{fmt}$ which is the sum, across markets, of an airline's collusive profits. Intuitively, collusion is easier to sustain when it is more profitable. λ_{ft} is decreasing in $\sum_m \Pi^D_{fmt}$ which is the sum, across markets, of an airline's defection profits. Intuitively, collusion is more difficult to sustain when an airline earns large profits from defection. λ_{ft} is decreasing in $\sum_m \Pi^N_{fmt}$ which is the sum, across markets, of an airline's Nash equilibrium profits. Airlines which earn high profits in the Nash

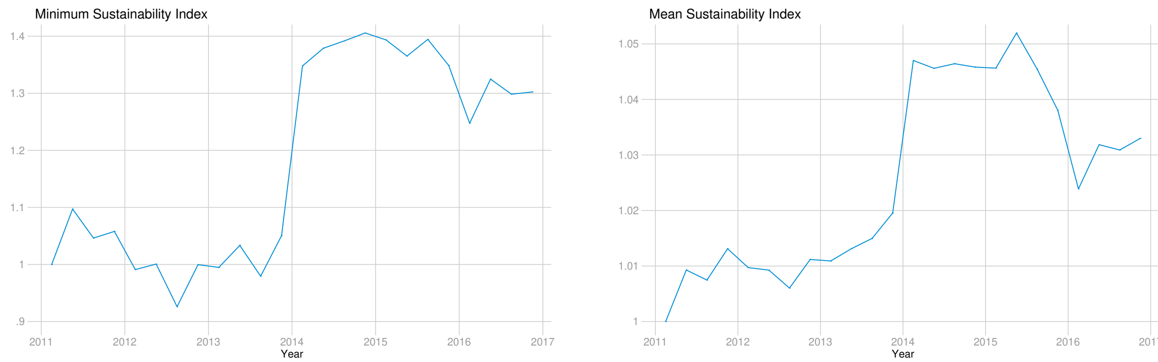

Figure 3: Min (left) and Mean (right) Sustainability Index

Notes: This figure presents the minimum sustainability index (left) across carriers and the mean sustainability index (right) across carriers from 2011-2016. The index is normalized such that it is 1 in 2011Q1.

equilibrium have weak incentives to collude because they can obtain high profits even in the absence of collusion.

The estimation of λ_{ft} requires specifying two inputs: the data generating process (DGP) and the collusive pricing strategy. The underlying data generating process (i.e., whether firms collude or compete in reality) must be specified in order to infer marginal costs (which are assumed to be constant). Second, the collusive pricing strategy (e.g., joint profit maximization, colluding on a common price) must be specified in order to determine collusive and defection profits.

I assume the data generating process involves legacy airlines setting prices to maximize joint profits after the merger and setting Nash prices before the merger. In Section 5.2, I show that results are highly robust to alternative data generating process including competition in all periods, collusion before and after the merger and intermediate degrees of collusion before or after the merger.[51] Following Eizenberg and Shilian (2019), I assume legacy airlines collude by setting monopoly prices (i.e., joint profit maximization). I show results are robust to alternative assumptions in Section 5.2.[52]

Figure 2 plots λ_{ft} by firm across time. I normalize the index such that $\lambda_{ft} = 1$ in quarter 1 of 2011 for American Airlines.[53] The sustainability index for US Airways is significantly less than other legacy airlines prior to the merger. This suggests that collusion among legacy airlines was, prior to the merger, hampered by the presence of US Airways–a firm disinclined to collude. Both the average and minimum sustainability index across firms increases after the merger (See Figure 3).[54] This suggests

[51] Eizenberg and Shilian (2019) follow a similar approach. Results are not dependent on assumptions regarding the DGP because the primary effects are driven by differences in airlines networks which are unaffected by DGP assumptions.

[52] For additional details of the numerical computation of collusion, defection and Nash equilibrium profit, see Appendix D.

[53] I normalize the sustainability index throughout the paper and focus on changes in the index across time or differences across firms.

[54] The minimum sustainability index, across firms, corresponds to the industry-level critical discount factor in the game theoretic model introduced in Appendix C.

that the merger, by eliminating US Airways as a competitor, facilitated collusion in the airline industry.

The results of this section do not imply that the merger caused collusion, only that the merger made it easier for firms to sustain collusion. Formally, this means that the merger expanded the set of discount factors wherein firms can sustain collusive equilibria in a repeated game. However, this does not speak to equilibrium selection (i.e., whether a collusive or a competitive equilibrium occurs when both are feasible).

5.1 Robustness: Alternative Indexes

To demonstrate that results are not dependent on the choice of index λ_{ft}, I consider two alternative indexes. The first index, hereafter the gains to defection index, is

$$r^D_{ft} = \frac{\sum_m \Pi^D_{fmt}}{\sum_m \Pi^C_{fmt}} - 1,$$

for firm f at time t. The gains to defection index is the ratio of defection profit to collusive profit minus 1. Intuitively, r^D_{ft} measures an airline's incentives to defect from a collusive agreement. Figure 4 plots r^D_{ft} normalized such that $r^D_{ft} = 1$ for American Airlines in quarter 1 of 2011, by firm across time. Prior to the merger, US Airways had greater incentives to defect than other legacy airlines. The merger reduced both the average and maximum values, across firms, of the gains to defection index.

The next index, proposed by Kovacic et al. (2007) and hereafter referred to as gains to collusion index, is

$$r^C_{ft} = \frac{\sum_m \Pi^C_{fmt}}{\sum_m \Pi^N_{fmt}} - 1$$

for firm f at time t. Intuitively, r^C_{ft} measures an airline's incentives to collude. If this ratio is large, an airline earns large profits from collusion relative to competition. Figure 5 plots r^C_{ft}, normalized such that $r^C_{ft} = 1$ for American Airlines in quarter 1 of 2011, by firm across time. US Airways's gains to collusion ratio is lower than other airlines (except in 2011) which suggests US Airways had weaker incentives to collude prior to the merger. Note that the gains to collusion for the merged entity (the blue line after the merger) lie between the gains to collusion index for US and AA in the pre-merger period. American Airlines inherits a large number of connecting markets from US Airways (which stand to gain relatively little from collusion) which reduces its gains to collusion. Conversely, US Airways inherits a large number of direct markets (in large markets) which increases its gains to collusion.

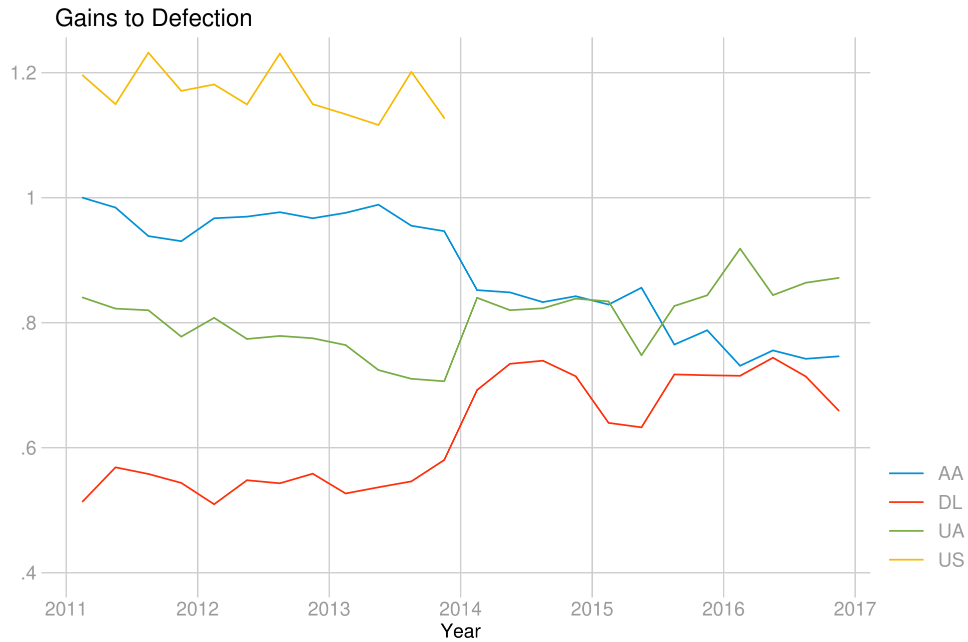

Figure 4: Gains to Defection Index (r^D_{ft}) by Carrier

Notes: This figure presents the gains to defection (the ratio of defection profits to collusive profits minus 1) for each legacy airline from 2011 to 2016. The gains to defection are normalized such that AA's gains to defection are 1 in 2011 Q1.

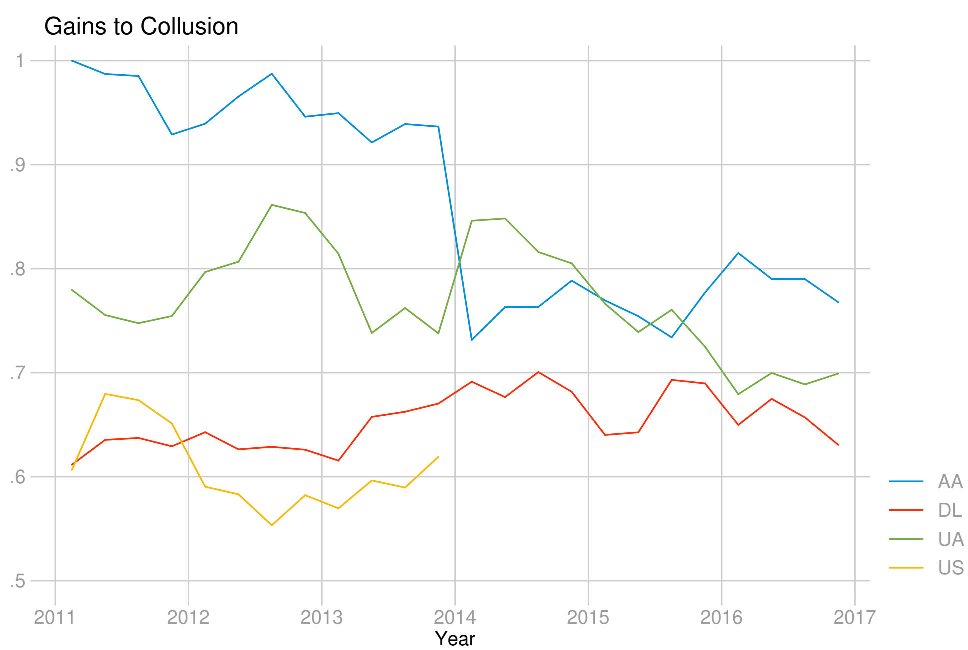

Figure 5: Gains to Collusion Index (r^C_{ft}) by Carrier

Notes: This figure presents the gains to collusion (the ratio of collusive profits to Nash profits minus 1) for each legacy airline from 2011 to 2016. The gains to collusion are normalized such that AA's gains to collusion are 1 in 2011 Q1.

5.2 Robustness: Alternative DGP and Collusive Pricing Assumptions

In this subsection, I explore the robustness of results to alternative assumptions regarding the data generating process and the collusive pricing strategy. Recall that in the main specification (as shown in Figure 2), I assume the data generating process involves legacy airlines setting prices competitively before the merger and setting prices to maximize joint profit after the merger. Table 8 Panel A presents results from a variety of alternative assumptions. Specifically, I allow for the data generating process to involve Bertrand Nash competition (denoted BN), full collusion (i.e., joint profit maximization, denoted Full Coll.) or partial collusion (denoted Partial Col.). Partial collusion involves legacy airlines partially internalizing the profits of rivals when setting prices (Miller and Weinberg, 2017; Michel and Weiergraeber, 2018). Legacy airlines maximize a weighted sum of their own profit and rival airlines' profits. Let $\mathcal{J}_{fm}$ denote the set airline f's products in market m. Let $\mathcal{F}_m$ denote the set of legacy airlines in market m. Airline f sets prices in market m to maximize

$$\sum_{j\in\mathcal{J}_{fm}} s_{jm}\left(p_{jm}-c_{jm}\right)+\kappa \sum_{g\in\mathcal{F}_m, g\neq f}\ \sum_{j\in\mathcal{J}_{gm},} s_{jm}\left(p_{jm}-c_{jm}\right) \tag{7}$$

where κ denotes the weight airline's place on their rivals' profits when setting prices. Specifically, I assume rival airlines internalize half of their rivals' profits when partially colluding. Results are robust to other degrees of partial collusion (e.g., internalizing $\frac{1}{4}$ of rival profits). Full collusion corresponds to airlines fully considering rival profit ($\kappa = 1$). I present the average, across years and quarters, of the sustainability index for each firm before and after the merger. Under all DGP process assumptions, results are very similar. US Airways is the firm with the lowest sustainability index in all specifications. Additionally, the minimum sustainability index, across carriers increases after the merger which is consistent with an increase in incentives to collude.

Table 8 Panel B presents results from alternative assumptions regarding the collusive pricing strategy. I assume airlines maximize 7 when colluding. I consider four values for κ: .25, .5, .75 and 1 (the baseline). Under each collusive pricing strategy, US Airways is the airline least inclined to collude prior to the merger. In all specifications, the merger increases the minimum sustainability index which suggests the merger elevated incentives for legacy airline to collude. Note that the sustainability index is higher for smaller values of κ. Additionally, the increase in the sustainability index is more modest for smaller levels of kappa. This is the case because smaller values of kappa imply lower collusive prices. Collusion with lower collusive prices is easier to sustain in a repeated game because profits from defection are relatively low.

Table 8: DGP and Collusive Pricing Robustness: Sustainability Index

Panel A: DGP Robustness

		Pre-Merger				Post-Merger			Per. Inc.
Pre-Merger DGP	Post-Merger DGP	AA	DL	UA	US	AA	DL	UA	in Min
BN	BN	.524	.569	.531	.37	.522	.528	.506	33.8%
BN	Partial Col.	.524	.569	.531	.37	.52	.518	.502	33%
BN	Full Col. (Baseline)	.524	.569	.531	.37	.515	.505	.495	31.7%
Partial Col.	BN	.516	.559	.522	.377	.522	.528	.506	31.2%
Partial Col.	Partial Col.	.516	.559	.522	.377	.52	.518	.502	30.4%
Partial Col.	Full Col.	.516	.559	.522	.377	.515	.505	.495	29.1%
Full Col.	BN	.507	.544	.511	.386	.522	.528	.506	28.1%
Full Col.	Partial Col.	.507	.544	.511	.386	.52	.518	.502	27.4%
Full Col.	Full Col.	.507	.544	.511	.386	.515	.505	.495	26.1%

Panel B: CP Robustness

	Pre-Merger				Post-Merger			Per. Inc.
Collusive Pricing Parameter κ	AA	DL	UA	US	AA	DL	UA	in Min
.25	.895	.905	.896	.841	.891	.888	.887	5.07%
.5	.781	.802	.784	.683	.775	.768	.765	11.2%
.75	.657	.69	.662	.526	.649	.641	.634	19.2%
1 (Baseline)	.524	.569	.531	.37	.515	.505	.495	31.7%

Notes: Panel A presents the sustainability index and the percentage change in sustainability index under alternative DGPs. BN denotes a κ value of 0, Partial Col. denotes a κ value of .5 and Full Col. denotes a κ value of 1. Panel B presents results under alternative collusive pricing schemes.

5.3 Robustness: Southwest Airlines

The DOJ's concerns regarding coordinated effects in the AA-US merger primarily concerned coordination between remaining legacy airlines (i.e., American Airlines, Delta Airlines and United Airlines).[55] However, recent antitrust litigation[56] and empirical studies (Bet, 2021*a*) suggest that price coordination may also involve Southwest Airlines. In this subsection, I analyze the sustainability of collusion between legacy airlines and Southwest Airlines, both before and after the merger.

Southwest airlines differs from traditional legacy airlines in that it operates a point-to-point network rather than a hub and spoke network. This means that Southwest's network does not involve connecting passengers through hub and instead flies passengers directly between their initial and final destination. Additionally, Southwest airlines is a low cost carrier. Southwest attains lower costs due to greater cross utilization of employees, its use of secondary airports and low labor costs (Doganis, 2019). Thus, Southwest competes against legacy airlines with direct service in the majority of its markets. The analysis of Section 3 suggests that firms offering a direct service in a high proportion of markets have large incentives to collude.[57] Figure 6 presents the sustainability index from collusion between all legacy airlines and Southwest. The sustainability index is high for Southwest Airlines and US Airways remains the firm least inclined to collude prior to the merger. The results of this section do not speak to whether Southwest Airlines coordinated prices. However, results suggest that if Southwest airlines was to collude, the sustainability of collusion would not be an impediment to successful price coordination.

Note that the sustainability index of Delta Airlines increases substantially if Southwest Airlines joins the set of colluding firms. This is the case because Delta and Southwest Airlines interacted heavily on routes to and from Delta's largest hub in Atlanta.[58] Due to its presence in Atlanta, Southwest is well positioned to effectively punish any defection by Delta Airlines from the collusive agreement. Additionally, the involvement of Southwest Airlines increases Delta's profits from collusion due to the large number of markets where it competes against Southwest.

6 The Cause of Coordinated Effects

The results of Section 5 imply the AA-US merger increased incentives to collude. In this section, I provide evidence suggesting that this result is caused by the effect illustrated theoretically in Section

[55] "Traditionally, Southwest and other smaller carriers have been less likely to participate in coordinated pricing or service reductions" (DOJ Complaint).

[56] "Domestic Airline Travel Antitrust Litigation" case, numbered 1:15-mc-01404 in the US District Court, DC.

[57] Mathematically, Southwest's network corresponds to a negative value for x in the theoretical model of section 3 which results in a low critical discount factor.

[58] Southwest Airlines inherited a large presence at Atlanta after it merged with AirTran Airways.

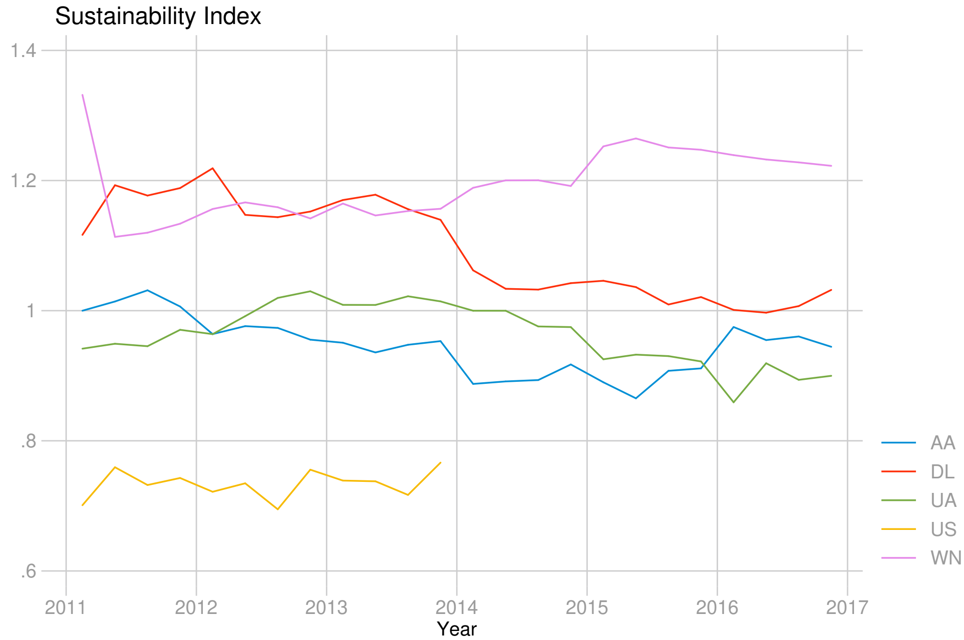

Figure 6: Sustainability Index by Carrier including Southwest

Notes: This figure presents the sustainability index by carrier (including Southwest Airlines) from 2011-2016. The index is normalized such that AA's index is 1 in 2011 Q1.

3. Specifically, I provide evidence suggesting US Airways was disinclined to collude prior to the merger due to its network structure, as argued by prior literature (Olley and Town, 2018; Porter, 2020).[59] By combining the networks of US Airways and American Airlines, the merger increased incentives to collude.

6.1 Changing US Airways's Network

I analyze the effect of the merger on the sustainability index in a counterfactual scenario where US Airways's network is changed. These simulations demonstrate that he observed increase in the sustainability of collusion was a result of US Airways's unique network structure which was highly dependent on connecting products.

I conduct two related counterfactual simulations. The first simulation proceeds as follows. I randomly select a fraction markets where US Airways faces a competitive disadvantage prior to the merger (i.e., US Airways offers only connecting service while a rival legacy airline offers direct service). I then drop US Airways products in these markets and re-compute the minimum sustainability index.[60]

[59] Also, see U.S. vs. US Airways Group, Inc. and AMR Corporation (D.D.C. Pa., No. 1:13-cv-01236-CKK 9/5/13) Amended Complaint.

[60] This involves computing counterfactual prices and shares after the removal of US Airways products in the selected markets. These counterfactual prices and shares must be re-computed for both the Nash equilibrium, collusive and

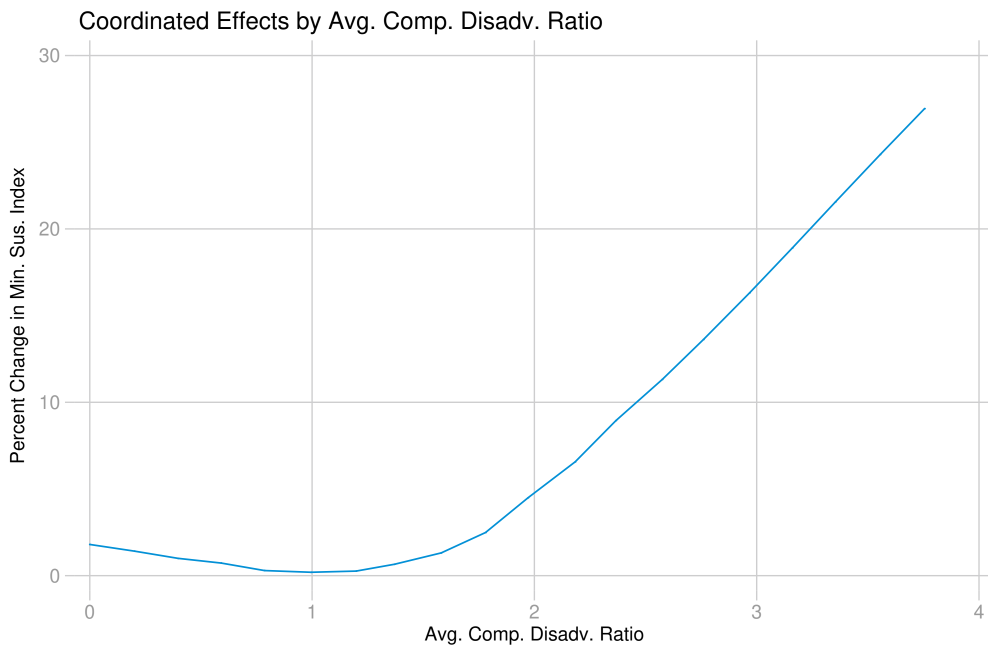

Figure 7: Coordinated Effects by Avg. Comp. Disadv. Ratio

Notes: This figure presents results from a counterfactual simulation where markets where US faces a competitive disadvantge prior to the merger are randomly dropped. The percentage change in the minimum (across carriers) of the sustainability index (the magnitude of coordinated effects) is plotted over US's average (across rival legacy airlines) competitive disadvantage ratio.

This simulation is repeated for 50 different random selections of markets and I take the average minimum sustainability index across simulations. I also repeat this simulation while selecting an increasingly large number of competitively disadvantaged markets. Intuitively, this simulation involves reducing US Airways's reliance on connecting products by removing these products from its network and re-estimating the sustainability of collusion. As the number of selected markets increases (i.e., as more US Airways products which face a competitive disadvantage are removed), US Airways's average competitive disadvantage declines (averaging across its three rival legacy airlines). This is the case because US Airways's network becomes less reliant on connecting products and increasingly balanced relative to its rivals. In the theoretical model of Section 3, this simulation corresponds to reducing the ratio $\frac{N+x}{N-x}$, which the model predicts will reduce the magnitude of the merger's effect on the sustainability of collusion.

Figure 7 depicts the results from this simulation. Figure 7 plots the percentage increase in the minimum sustainability index from the merger (i.e., the magnitude of coordinated effects) relative to US Airways's average competitive disadvantage ratio. As the figure shows, the magnitude of the merger's coordinated effects declines as the average competitive disadvantage ratio falls. When the average competitive disadvantage ratio is 1, the merger has no significant effect on the sustainability of collusion. The results of this simulation suggest that the merger would not have increased the sustainability of collusion if US Airways's network was more balanced relative to its rivals before the merger.

To further examine the impact of US Airways's network on the observed increase in the sustainability of collusion, I conduct a second simulation. In this simulation, I randomly select markets where US Airways faced a competitive disadvantage prior to the merger. From these markets, I drop US Airways products and recompute the counterfactual minimum sustainability index (as in the previous simulation). However, I only consider the random selection markets if it results in a balanced network for US Airways. I define US Airways's network as highly balanced if each of US Airways's competitive disadvantage ratios with its three rival airlines are between .95 and 1.05. In other words, if r_f^s denotes US Airways competitive disadvantage ratio with airline f for simulation s, then simulation s is considered if $.95 \leq r_f^s \leq 1.05$ for all $f \in \{AA, DL, UA\}$. If $.95 \leq r_f^s \leq 1.05$ does not hold for at least one f, the simulation is discarded. This simulation is intended to analyze the impact of the merger on the sustainability of collusion in a counterfactual setting where US Airways's network is highly balanced and US Airways is not dependent on connecting products.[61]

defection phases in order to estimate the sustainability index. See Appendix ___ for additional details regarding this simulation.

[61] The second simulation differs from the first simulation in that I require all competitive disadvantage ratios to lie

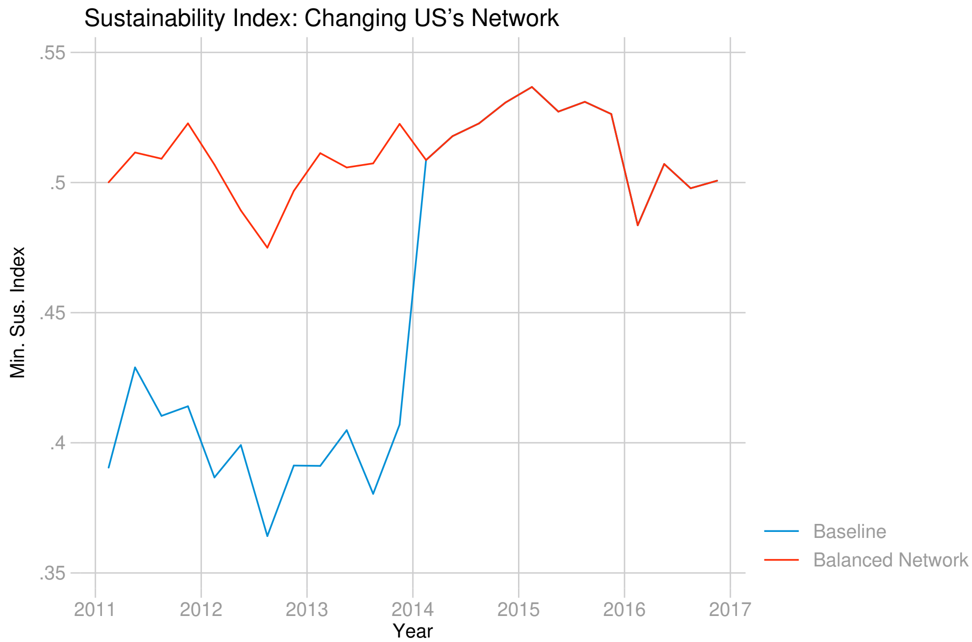

Figure 8: Balancing US's Network

Notes: This figure presents results from a counterfactual simulation where US Airways's network is balanced with other legacy Airlines. The figure presents the minimum sustainability index (across legacy airlines) in the baseline setting (blue) and counterfactual setting (red).

Figure 8 presents results. The blue line denotes the baseline (i.e., the observed minimum sustainability index). The red line denotes the counterfactual minimum sustainability index when US Airways's network is balanced. The merger has no significant effect on the minimum sustainability index in the counterfactual setting. The counterfactual setting corresponds to the case of $x = 0$ in the theoretical model of Section 3. As Theorem 1 predicts, the merger has no impact on the sustainability of collusion when $x = 0$ (i.e., a balanced network). This suggests that the coordinated effects of the merger were driven by US Airways's unique network structure prior to the merger. If US Airways's network resembled its rivals prior to the merger, then the merger would not have resulted in coordinated effects.

6.2 Equal Market Size

In this subsection, I consider a counterfactual simulation where all markets have equal sizes (i.e., the population of every metropolitan statistical area is identical). US Airways's network was highly dependent on connecting products because its direct markets were relatively small (as shown in Subsection

between .95 and 1.05 in the second simulation. In the first simulation, I simply drop markets at random, not requiring that US Airways's network is balanced with each of its rivals.

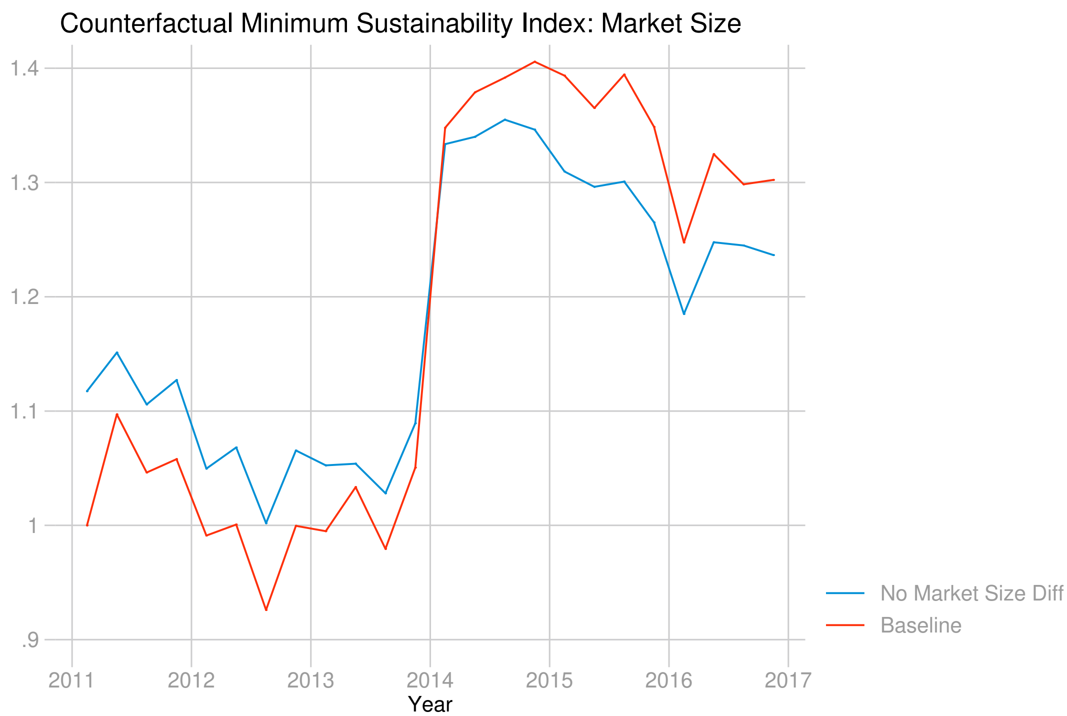

Figure 9: Counterfactual Sustainability Index for Equal Market Sizes

Notes: This figure presents results from a counterfactual simulation where all markets have the same size. The figure presents the minimum sustainability index (across legacy airlines) in the baseline setting (red) and counterfactual setting (blue).

2.2) and, as a result, it stood to benefit less from collusion than other legacy airlines. To examine the impact of market size differences on the magnitude of coordinated effects, I recompute the sustainability index assuming $M_m = M$ for all m both before and after the merger. As market sizes cancel out of the sustainability index (because they are identical across markets), the value of the constant M does not affect results. Figure 9 presents the results. When market sizes are equal, the magnitude of coordinated effects is reduced. However, the sustainability index still increases significantly after the merger. This suggests that market size differences only partly explain the observed increase in the sustainability of collusion.

7 Conclusion

This study has examined changes in airlines' incentives to collude before and after the American Airlines and US Airways merger. I present evidence that the merger enhanced the sustainability of collusion within the airline industry. Specifically, I find that US Airways was disinclined to collude prior to the merger. This was the case because US Airways operated a unique route structure, prior to the merger, which emphasized connecting products.[62] US Airways's network was highly dependent on connecting products because its hubs were well positioned for connecting service (and therefore offered connecting service in many markets) but were located in small markets with weak direct demand. As a result, US Airways's gains from collusion were small and incentives to defect from collusion were large. By merging with American Airlines, a firm more inclined to collude, the sustainability of collusion in the airline industry increased after the merger. The merger, by combining the networks of American Airlines and US Airways, homogenized the industry and facilitated collusion.

Two caveats warrant brief mention. First, while I present evidence which suggests the merger facilitated collusion, my findings do not imply that collusion increased. My findings suggest the merger made collusion easier to sustain in a repeated game but do not imply that firms selected a more collusive equilibrium post-merger. Second, this study focuses on price coordination and does not analyze the aggregate welfare effect of the merger. Such an analysis would involve accounting for unilateral effects, entry decisions, changes in product selections, price coordination and merger synergies.[63] Therefore, the results of this study do not suggest the AA-US merger harmed consumers (even if an increase in price coordination occurred), only that it resulted in increased incentives to collude.

[62] This is the argument of prior literature (Porter, 2020; Olley and Town, 2018) and the DOJ in U.S. vs. US Airways Group, Inc. and AMR Corporation (D.D.C. Pa., No. 1:13-cv-01236-CKK 9/5/13) Amended Complaint.

[63] See Das (2019); Bontemps, Gualdani and Remmy (2020) for other analyses of the AA-US merger.

The results of this study suggest that a firm's network, and differences between a firm's network and its rivals' networks, should be closely analyzed during merger review. Differences in the markets a firm serves, and the size of those markets, can hinder collusion. Mergers which tend to reduce this asymmetry should be treated with caution as they can potentially result in coordinated effects.

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A Theoretical Examples

A.1 Example 1: Bernheim and Whinston (1990)

For a firm offering Product I, $\Pi_I^C = \Pi_I^D = r$ and $\Pi_I^N = c + \Delta$. Thus, $\frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N} = 0$. For a firm offering Product II, $\Pi_I^C = 0$, $\Pi_I^D = r - \Delta$ and $\Pi_I^N = 0$. Thus, $\frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N} = \frac{r-\Delta}{r-\Delta} = 0$. Clearly, Condition 1 holds as

$$\frac{\Pi_{II}^D - \Pi_{II}^C}{\Pi_{II}^D - \Pi_{II}^N} = 1 > 0 = \frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N}.$$

A.2 Example 2: Singh and Vives (1984) Demand

Lee and Turner (2022) show that $\frac{\Pi_{II}^D - \Pi_{II}^C}{\Pi_{II}^D - \Pi_{II}^N} > \frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N}$ if $c_{II} > c_I - \Delta$ which holds in this setting as $\Delta > 0$ and $c_{II} > c_I$.

A.3 Example 3: Hotelling (1929) Linear City Model

Colombo (2011)'s Proposition 3 shows that condition 1 is satisfied in this setting.

A.4 Example 4: Quantity Competition

Condition 1 holds trivially when products are homogenous as joint profit maximization implies all production is allocated to the firm offering product I. Thus, the firm offering product I has no incentive to defect and $\Pi_I^C = \Pi_I^D$ which implies $\frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N} = 0$. Additionally, the firm offering product II earns 0 profits during collusion which implies $\frac{\Pi_{II}^D}{\Pi_{II}^D - \Pi_{II}^N} \geq 1$. When products are differentiated, Lee and Turner (2022) show that $\frac{\Pi_{II}^D - \Pi_{II}^C}{\Pi_{II}^D - \Pi_{II}^N} > \frac{\Pi_I^D - \Pi_I^C}{\Pi_I^D - \Pi_I^N}$ if $c_{II} > c_I - \Delta$ which holds in this setting as $\Delta > 0$ and $c_{II} > c_I$.

B Data Restrictions

First, raw DB1B data is restricted to only those tickets which involve the chosen sub-sample of airports, are round-trip and consist of no more than 1 connection in each direction. Next, any products with a reported fare that is deemed questionable (a dollarcred value of 0) are dropped. Any products involving fares greater than \$1500 or less than \$20 are dropped as these are likely the result of key punch errors or the use of frequent flier miles. Any tickets involving ticketing carriers other than $AA, AS, B6, DL, FL, F9, G4, NK, SY, UA, US, VX$ or WN are excluded. Code sharing or the use of regional airlines may result in the carrier who operates a flight (the operating carrier) differing from the carrier who issues the ticket (ticketing carrier). I attribute ownership of products to the ticketing carrier. I drop any tickets involving multiple ticketing carriers. Next, I collapse tickets to the carrier-itinerary level, taking the average price and summing the passengers. Lastly, any products which are not purchased by at least 100 passengers (10 DB1B passengers) in quarter 3 of 2018 are dropped as they do not represent a competitive presence in the market.

C Game Theoretic Foundation of the Sustainability Index

I next describe the underlying dynamic game wherein the critical discount factor equals 1 minus the sustainability index. Firms employ grim trigger strategies where each firm charges its collusive prices in each market unless any firm deviates in any prior period. If any firm deviates and does not charge collusive prices in any period, all firms revert to Nash competition in all markets in perpetuity. Firms punish deviations in all markets simultaneously as in Bernheim and Whinston (1990). This assumption is motivated by a substantial literature finding evidence of multi-market contact based collusion in the airline industry (Evans and Kessides, 1994; Ciliberto and Williams, 2014) I assume that collusive prices maximize joint collusive profits in each market. Defection from the collusive agreement occurs for one quarter. I assume each firm expects collusive profit, defection profit and Nash equilibrium profit in all future periods to equal their values in the current period.[64] Let π^C_{fmt} denote collusive profit, π^D_{fmt} denote defection profit and π^N_{fmt} denote Nash equilibrium profit in market m and time t. Let δ denote the common discount factor of all firms. Firm f does not wish to defect from the collusive agreement if the payoff from collusion, summing over markets, exceeds the payoff from defection:

$$\frac{1}{1-\delta}\sum_m \pi^C_{fmt} \geq \sum_m \pi^D_{fmt} + \frac{\delta}{1-\delta}\sum_m \pi^N_{fmt}.$$

Equivalently, firm f does not wish to defect at time t if

$$\delta \geq \delta_{ft} = \frac{\sum_m \pi^D_{fmt} - \sum_m \pi^C_{fmt}}{\sum_m \pi^D_{fmt} - \sum_m \pi^N_{fmt}}$$

where δ_{ft} denotes firm f's critical discount factor at time t. The sustainability index is $\lambda_{ft} = 1 - \delta_{ft}$. The industry critical discount factor is

$$\delta_t = \max_{f \in \mathcal{F}_L} \{\delta_{ft}\}$$

where $\mathcal{F}_L$ denotes the set of colluding airlines.

[64] Duarte and Chaves (2021) make a similar assumption.

Note that results are not dependent on the assumption of a one period detection lag and an infinite reversion to Nash equilibrium play (as opposed to finite punishment periods consisting of Nash equilibrium play followed by a return to collusion). Miller, Sheu and Weinberg (2021)'s Proposition 2 implies that the ordering of the critical discount factors (across time or firm) is unaffected by these assumptions. This is the case because a change in the detection lag or punishment length results in a monotonic transformation of each firm's critical discount factor. Thus, both the result that US Airways is the firm least inclined to collude pre-merger and the result that the sustainability index increases after the merger are robust to alternative assumptions regarding the punishment length and detection lag.

Specifically, let δ_{τ_1,τ_2} denote the critical discount factor when the detection lag is $\tau_1 \geq 1$ periods and the punishment length is $\tau_2 \geq 1$ periods. Let $\delta_{1,\infty} = \frac{\pi^D - \pi^C}{\pi^D - \pi^N}$ denote the critical discount factor under an assumption of a one period detection lag and infinite punishments (as in the main text). Miller, Sheu and Weinberg (2021)'s Proposition 2 shows that

$$\delta_{1,\infty} = f(\delta_{\tau_1,\tau_2}) = \frac{(\delta_{\tau_1,\tau_2})^{\tau_1} - (\delta_{\tau_1,\tau_2})^{\tau_1+\tau_2}}{1 - (\delta_{\tau_1,\tau_2})^{\tau_1+\tau_2}}$$

where $f(\delta_{\tau_1,\tau_2})$ is increasing in δ_{τ_1,τ_2}. Thus, the critical discount factor under an assumption of $\tau_1 = 1$ and $\tau_2 = \infty$ is a monotonic (one-to-one) transformation of the true critical discount factor. As a result, the ordering of critical discount factors across time and firm are unchanged by the assumption of a one period detection lag and infinite punishments, even if the underlying repeated game involves another punishment length and/or detection lag.

D Computation of the Sustainability Index

The computation of the sustainability index λ_{ft} involves 6 steps. Throughout, counterfactual prices are computed using the contraction mapping of Morrow and Skerlos (2011).[65]

Let $\mathcal{J}_{fm}$ denote the set of products firm f offers in market m. Let $\mathcal{F}_m$ denote the set of colluding firms in market m (i.e., legacy airlines in the main specification).

1. First, I compute the marginal costs implied by the first order conditions that result from the maximization of joint profits in the post-merger period and Nash equilibrium play in the pre-merger period. This yields marginal costs in the pre and post merger period for all firms. To illustrate, consider the post merger period. The first order condition associated with the price

[65] Computations are done using pyblp (Conlon and Gortmaker, 2020).

of a product j owned by a firm $g \in \mathcal{F}_m$ is

$$0 = s_{jm} + \sum_{f \in \mathcal{F}_m} o_{fg} \sum_{j' \in \mathcal{J}_{fm}} \frac{\partial s_{j'm}}{\partial p_{jm}} (p_{j'm} - c_{j'm}) \tag{8}$$

where $o_{fg} = 1$ if $f, g \in \mathcal{F}_m$ and is 0 otherwise. The first order condition associated with the price of a product j owned by firm $g \notin \mathcal{F}_m$ is

$$0 = s_{jm} + \sum_{j' \in \mathcal{J}_{gm}} \frac{\partial s_{j'm}}{\partial p_{jm}} (p_{j'm} - c_{j'm})$$

2. Stacking the first order conditions of each product j in market m yields the matrix equation

$$0 = [O_m \cdot D_m] [p_m - c_m] + s_m \tag{9}$$

where p_m is a vector of prices, s_m is a vector of shares and c_m is a vector of marginal costs. D_m is the jacobian of market shares s_m with respect to p_m. O_m is a matrix where element (i, j) is 1 where product i and j are owned by firm $f \in \mathcal{F}_{col}$ and $g \in \mathcal{F}_{col}$ respectively and 0 otherwise. Rearranging equation (9) yields the implied marginal costs c_m:

$$c_m = p_m + [O_m \cdot D_m]^{-1} s_m. \tag{10}$$

c_m is the vector of marginal costs consistent with both observed prices and maximization of joint profits. Similar computations show how marginal costs are inferred in the pre-merger period. In the pre-merger period, O_m is a matrix where element (i, j) is 1 where product i and j are owned by the same firm and 0 otherwise.

3. I compute collusive prices and market shares under the counterfactual assumption that firms collude by maximizing joint profit. Firm $g \in \mathcal{F}_m$ maximizes

$$\max \sum_{f \in \mathcal{F}_m} o_{fg} \sum_{j \in \mathcal{J}_{fm}} s_{jm}(\hat{\theta}_d) (p_{jm} - c_{jm}).$$

4. I compute prices and shares under the counterfactual assumption that firms engage in Bertrand-Nash competition: Firm g maximizes

$$\max \sum_{j \in \mathcal{J}_{gm}} s_{jm}(\hat{\theta}_d) (p_{jm} - c_{jm}).$$

I employ the contraction mapping of Morrow and Skerlos (2011).[66]

5. I compute defection prices and shares. Defection prices are the best response prices to the collusive prices. Specifically, defection prices maximize a firms own profit conditional on rivals charging the collusive price.

6. I compute collusive (π^C_{fmt}), defection (π^D_{fmt}) and Nash equilibrium (π^D_{fmt}) prices for each firm in each market.

7. Lastly, I compute the sustainability index $\lambda_{ft} = 1 - \frac{\sum_m \pi^D_{fmt} - \sum_m \pi^C_{fmt}}{\sum_m \pi^D_{fmt} - \sum_m \pi^N_{fmt}}$ for each firm in each time t.

The alternative indexes discussed in the main text are computed with similar steps.

E Additional Analysis

E.1 Checking Condition 1

In this subsection, I demonstrate that Condition 1 holds in the airline industry when firms maximize joint profits. Condition 1 states that the market level critical discount factor (i.e., the critical discount factor if collusion occurs only in a specific market) for the firm offering only connecting products (Product II) exceeds the market level critical discount factor of firms offering direct products (Product I). Put differently, the sustainability of collusion within a market, if collusion was to occur only in that specific market, is lowest for the firm offering a connecting product. To test this condition, I compute the market-level critical discount factor for each legacy airline in each market. Specifically, I compute

$$\gamma_{f,m} = \frac{\sum_j \Pi^D_{j,m} - \sum_{j,m} \Pi^C}{\sum_{j,m} \Pi^D - \sum_{j,m} \Pi^N}$$

for each firm in each market. Next, I determine the percentage of markets where the largest market-level critical discount factor, across firms, belongs to a firm offering only connecting products in that market (i.e., the highest value $\gamma_{f,m}$ belongs to a firm offering only connecting service). Table 9 presents results for a number of entry thresholds. For all entry thresholds an sample years, Condition 1 holds in approximately 90% of markets.

[66]Computations use the package pyblp (Conlon and Gortmaker, 2020).

Table 9: Checking Condition 1

Year	Entry Condition			
	>= 50 Passengers	>= 100 Passengers	>= 150 Passengers	>= 200 Passengers
2011	91.4	88.4	84.9	81.1
2012	90.5	88.1	85.2	82.5
2013	90.8	88.8	86.5	84
2014	93.5	91.6	88.8	86.2
2015	93.9	91.5	87.5	83.4
2016	93.3	89.5	84.7	79.6

Notes: Percentage of markets where condition 1 holds for a variety of entry conditions. Excludes monopoly markets. This table uses 2014-2016 data.

Table 10: Competitive Disadvantage Ratio for American Airlines

Entry Condition	AA-DL	AA-UA
$\geq$ 50 Passengers	.953	1.17
$\geq$ 100 Passengers	.928	1.64
$\geq$ 150 Passengers	.908	2.07
$\geq$ 200 Passengers	.85	2.44

Notes: Competitive disadvantage ratio for AA for a variety of entry conditions. Uses 2014-2016 data.

E.2 American Airlines's Network Post-Merger

Table 10 presents the competitive disadvantage ratio for American Airlines after the merger. Specifically, Table 10 reports the ratio of the number of markets where American Airlines has a competitive disadvantage relative to the number of markets where American Airlines has a competitive disadvantage for each rival legacy airline, after the merger. AA's competitive disadvantage ratios after the merger are lower than US Airways's competitive disadvantage ratios before the merger (See Table 2). In fact, American Airlines has a competitive advantage against Delta Airlines in more markets than it faces a competitive disadvantage. This is consistent with the merger balancing the networks of remaining legacy airlines.

Table 11 presents, for multiple entry conditions and for each rival legacy airline, the average size (in millions of people) of markets where American Airlines faced a competitive advantage or disadvantage

Table 11: Market Sizes and Competitive Advantage for American Airlines (Post-Merger)

Entry Condition		DL	UA
≥ 50 Passengers	AA Comp. Adv.	3.49	3.54
	AA Comp. Disadv.	2.87	3.36
≥ 100 Passengers	AA Comp. Adv.	3.49	3.83
	AA Comp. Disadv.	2.96	3.47
≥ 150 Passengers	AA Comp. Adv.	3.45	4.07
	AA Comp. Disadv.	3.07	3.59
≥ 200 Passengers	AA Comp. Adv.	3.43	4.25
	AA Comp. Disadv.	3.18	3.7

Notes: Market sizes for AA comp. adv. markets and comp. disadv. markets for a variety of entry conditions. Uses 2014-2016 data.

after the merger. Prior to the merger (see Table 4), markets where US Airways faced a competitive advantage were, on average, smaller than markets where it faced a competitive disadvantage. After the merger, the average size of markets where the merged entity (i.e., AA after the merger) faced a competitive disadvantage is similar to the average size of markets where the merged entity faced a competitive advantage. In fact, the average size of markets where the merged entity competes against rivals with a competitive advantage are, on average, slightly larger than markets where it faces a competitive disadvantage. This suggests the merger balanced the sizes of legacy airline's markets.

E.3 Competitive Disadvantage Ratio

Table 12 presents additional information used to calculate US Airways's competitive disadvantage ratio from Table 2 in the main text. Specifically, Table 12 presents the number of pre-merger markets where US Airways faced a competitive disadvantage or advantage against each rival legacy airline, for multiple entry conditions.

F Counterfactual Simulation Details

In this section, I provide additional details regarding the counterfactual simulations in Section 6.1. The first simulation (depicted in Figure 7) proceeds as follows. First, I randomly select 100 markets where US Airways faces a competitive disadvantage prior to the merger (i.e., US Airways offers only

Table 12: Competitive Disadvantage Ratio: Additional Information

Panel A: US Airways Pre-Merger

	US Comp. Disadv.		US Comp. Adv.	
Entry Condition	AA	UA	AA	UA
≥ 50 Passengers	2699	3782	1926	1153
≥ 100 Passengers	2553	3602	1201	709
≥ 150 Passengers	2346	3296	823	477
≥ 200 Passengers	2111	2978	618	353

Panel B: American Airlines Post-Merger

	AA Comp. Disadv.		AA Comp. Adv.	
Entry Condition	DL	UA	DL	UA
≥ 50 Passengers	5589	3831	5867	3280
≥ 100 Passengers	4716	3289	5082	2007
≥ 150 Passengers	3908	2782	4306	1341
≥ 200 Passengers	3161	2331	3717	955

Notes: This table presents the raw number of comp. adv. and disadv. markets for US pre-merger (Panel A) and AA post-merger (Panel B). Panel A uses 2011-2013 data. Panel B uses 2014-2016 data.

connecting service while a rival legacy airline offers direct service) and drop the US Airways products in these markets. Next, I compute the counterfactual prices and shares after the removal of US Airways products in the selected markets. These counterfactual prices and shares must be re-computed for both the Nash equilibrium, collusive and defection phases in order to estimate the sustainability index. I use the counterfactual prices and shares are computed using the contraction mapping of Morrow and Skerlos (2011).[67] These are the prices and shares which would occur if US Airways's did not offer service in the selected markets. Finally, I recompute the minimum sustainability index (using the counterfactual prices and shares) across firms in the counterfactual setting. I also compute the average competitive disadvantage ratio of US Airways (averaging across its three rival legacy airlines) prior to the merger after US Airways has been removed from the selected markets. These steps are repeated for 50 different simulations (randomly selecting a different 100 markets in each simulation) and I take the average minimum sustainability index across simulations. The percentage increase in the minimum sustainability index is the percent increase in the average value of the minimum sustainability index before the merger relative to the average value of the minimum sustainability index after the merger. Additionally, I repeat this entire simulation a number of times while selecting 200,300...8000 US Airways competitively disadvantaged markets. Each simulation yields a pair of values: an average competitive disadvantage ratio of US Airways and a percentage increase in the minimum sustainability index. These values are depicted in Figure 7.

The second simulation (depicted in Figure 8) proceeds as follows. I randomly select a subset of markets[68] where US Airways faces a competitive disadvantage prior to the merger (i.e., US Airways offers only connecting service while a rival legacy airline offers direct service). Next, I compute US Airways's competitive disadvantage ratio with firm $f \in \{AA, DL, UA\}$ for simulation s (r_f^S). This simulation is accepted $.95 \leq r_f^s \leq 1.05$ for all $f \in \{AA, DL, UA\}$ (i.e., US Airways network is balanced). If $.95 \leq r_f^s \leq 1.05$ does not hold for at least one f, the simulation is discarded and the algorithm proceeds to the next random draw of markets. If a simulation is accepted, then I re-compute the minimum sustainability index under the counterfactual network. As in the previous simulation, counterfactual prices and shares must be recomputed once US Airways's product is dropped from a market. I continue the procedure until 100 simulations are accepted. Next, I take the average of the minimum sustainability index, in each quarter, across simulations. This average is denoted "Balanced Network" (the red line) in Figure 8.

[67] Computations are done using pyblp (Conlon and Gortmaker, 2020).

[68] Through trial and I error, I have found that a higher number of markets where US Airways competes against United need to be selected in order to balance US Airways network. This is the case because US Airways competes against United with a competitive disadvantage in a large number of markets (see Table 2). About 40% of US Airways's competitively disadvantaged products need to be dropped in order to balance its network.

G Proofs

Lemma 1. $\frac{(N-x)\left(\Pi_I^D-\Pi_I^C\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(N-x)\left(\Pi_I^D-\Pi_I^N\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^N\right)}$ *is increasing in* x *if* $\frac{\Pi_{II}^D-\Pi_{II}^C}{\Pi_{II}^D-\Pi_{II}^N} > \frac{\Pi_I^D-\Pi_I^C}{\Pi_I^D-\Pi_I^N}$.

Proof. Note that

$$\frac{(N-x)\left(\Pi_I^D-\Pi_I^C\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(N-x)\left(\Pi_I^D-\Pi_I^N\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^N\right)} = \frac{\left(\Pi_I^D-\Pi_I^C\right)+\frac{N+x}{N-x}\left(\Pi_{II}^D-\Pi_{II}^C\right)}{\left(\Pi_I^D-\Pi_I^N\right)+\frac{N+x}{N-x}\left(\Pi_{II}^D-\Pi_{II}^N\right)}.$$

Thus, it suffices to show that

$$\frac{a+bx}{c+dx}$$

is increasing in x where $a=\Pi_I^D-\Pi_I^C$, $b=\Pi_{II}^D-\Pi_{II}^C$, $c=\Pi_I^D-\Pi_I^N$ and $d=\Pi_{II}^D-\Pi_{II}^N$. This is case if $(c+dx)b-(a+bx)d = cb-ad > 0$ or $\frac{b}{d} > \frac{a}{c}$. Thus, $\frac{(N-x)\left(\Pi_I^D-\Pi_I^C\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(N-x)\left(\Pi_I^D-\Pi_I^N\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^N\right)}$ is increasing in x if and only

$$\frac{\Pi_{II}^D-\Pi_{II}^C}{\Pi_{II}^D-\Pi_{II}^N} > \frac{\Pi_I^D-\Pi_I^C}{\Pi_I^D-\Pi_I^N}.$$

□

Proof of Theorem 1. If $x=0$, all firms have a critical discount factor of $\frac{N\left(\Pi_I^D-\Pi_I^C\right)+N\left(\Pi_{II}^D-\Pi_{II}^C\right)}{N\left(\Pi_I^D-\Pi_I^N\right)+N\left(\Pi_{II}^D-\Pi_{II}^N\right)}$, both before and after the merger, which implies $\delta_{pre}^* = \delta_{post}^*$.

Part (i): First, note that $\delta_{3,pre}^* > \delta_{2,pre}^* = \delta_{1,pre}^*$ and $\delta_{1,post}^* > \delta_{2,pre}^*$ follow from Lemma 1. Part (i) follows from

$$\begin{aligned}
\delta_{1,post}^* &= \frac{(2N-x)\left(\Pi_I^D-\Pi_I^C\right)+(2N+x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(2N-x)\left(\Pi_I^D-\Pi_I^N\right)+(2N+x)\left(\Pi_{II}^D-\Pi_{II}^N\right)} \\
&= \frac{(N-\frac{x}{2})\left(\Pi_I^D-\Pi_I^C\right)+(N+\frac{x}{2})\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(N-\frac{x}{2})\left(\Pi_I^D-\Pi_I^N\right)+(N+\frac{x}{2})\left(\Pi_{II}^D-\Pi_{II}^N\right)} \\
&< \frac{(N-x)\left(\Pi_I^D-\Pi_I^C\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(N-x)\left(\Pi_I^D-\Pi_I^N\right)+(N+x)\left(\Pi_{II}^D-\Pi_{II}^N\right)} = \delta_{3,pre}^*
\end{aligned}$$

where the last inequality follows from Lemma 1. Thus, the merger reduces the industry critical discount factor.

Part (ii): Note that

$$\delta_{1,pre}^* = \frac{(2N+x)\left(\Pi_I^D-\Pi_I^C\right)+(2N-x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(2N+x)\left(\Pi_I^D-\Pi_I^N\right)+(2N-x)\left(\Pi_{II}^D-\Pi_{II}^N\right)} < \frac{(2N-x)\left(\Pi_I^D-\Pi_I^C\right)+(2N+x)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{(2N-x)\left(\Pi_I^D-\Pi_I^N\right)+(2N+x)\left(\Pi_{II}^D-\Pi_{II}^N\right)} = \delta_{1,post}^*$$

holds if and only if

$$\frac{\left(N+\frac{x}{2}\right)\left(\Pi_I^D-\Pi_I^C\right)+\left(N-\frac{x}{2}\right)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{\left(N+\frac{x}{2}\right)\left(\Pi_I^D-\Pi_I^N\right)+\left(N-\frac{x}{2}\right)\left(\Pi_{II}^D-\Pi_{II}^N\right)}<\frac{\left(N-\frac{x}{2}\right)\left(\Pi_I^D-\Pi_I^C\right)+\left(N+\frac{x}{2}\right)\left(\Pi_{II}^D-\Pi_{II}^C\right)}{\left(N-\frac{x}{2}\right)\left(\Pi_I^D-\Pi_I^N\right)+\left(N+\frac{x}{2}\right)\left(\Pi_{II}^D-\Pi_{II}^N\right)}$$

which holds by Lemma 1.

Part (iii): $\delta^*_{2,pre}=\delta^*_{2,post}$ follows immediately as firm 2's network is unchanged. $\square$