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Balancing Variety and Quality: Examining the Impact of Benefit-Linked Cross-Subsidization on Multisided Platforms

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ABSTRACT Multisided platforms face a fundamental trade-off: should they ease entry for a larger number of providers of complementary products or services (complementors) to join the platform and benefit from cross-side network externalities, or should they limit entry to maintain complementors' incentives to provide high-quality offerings? We contend that a specific cross-subsidizing pricing strategy – where the amount of subsidy to complementors is explicitly linked to the overall revenue they generate on the other side of the platform – may mitigate this trade-off. Using data from the airport industry, we demonstrate that following a reduction of airlines' entry barriers, airports that subsidize airlines, based on the aforementioned scheme, can boost their financial performance and maintain traffic composition in favour of legacy airlines, which bring passengers who spend more in airport shops. Our findings shed light on how cross-subsidization may balance the variety and quality of complementors and their offerings on multisided platforms.

Keywords: multisided platforms, network externalities, cross-subsidization pricing, gatekeeping strategies, variety vs. quality trade-off

INTRODUCTION

Multisided platforms serve as intermediaries, connecting distinct groups of participants, known as complementor[1] and users, to facilitate transactions and interactions. These platforms, such as Sony PlayStation, eBay, iOS App Store, or Airbnb, rely on cross-side network externalities that thrive on larger participant pools and transaction volumes

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between sides to ensure platform growth and success (Clements and Ohashi, 2005; Katz and Shapiro, 1992, 1994; Shapiro and Varian, 1999). However, beyond the sheer number of participants, the quality of participants and their offerings on the platforms are also of paramount importance (Fuentelsaz et al., 2015; Hagiu, 2009; McIntyre and Subramaniam, 2009; Zhu and Iansiti, 2012). As the success of platforms hinges on balancing between maximizing product variety and maintaining high-quality offerings, platform governance becomes a critical challenge.

Extant research has highlighted a fundamental trade-off confronted by platforms: balancing the provision of a vast array of diverse products by a large number of complementors while ensuring the high quality of their offerings (Chen et al., 2022; Hagiu, 2014; Rietveld et al., 2019; Skiti et al., 2022; Wareham et al., 2014). This trade-off arises from the inherent tension between positive cross-side network externalities and negative same-side network externalities (Belleflamme and Toulemonde, 2009). The adoption of less restrictive gatekeeping strategies (Dushnitsky et al., 2022; Zhang et al., 2022) to attract more complementors and expand product variety, thereby drawing in more users and enabling platform growth through positive cross-side network externalities, may potentially result in a decline in the quality of complementors and their product due to heightened competition among complementors or negative same-side network externalities (Boudreau, 2012; Chen et al., 2022; McIntyre et al., 2021). That very tension led to the well-known Atari shock in 1983 when the flood of poor-quality games on Atari resulted in the collapse of its market.

Research on platform governance has proposed strategies and mechanisms to increase the quality of complementors' offerings and 'weed out low-quality complementors' (Chen et al., 2022, p. 152), such as pecuniary and non-pecuniary rewards, recommendation, rating and certification systems (e.g., Claussen et al., 2013; Fu and Lyu, 2022; Liang et al., 2019; Rietveld et al., 2021; Skiti et al., 2022; Sun and Zhu, 2013; Wang, 2021). However, these strategies do not necessarily resolve the variety versus quality trade-off and the challenge of incentivizing complementors to provide high-quality products amid intense competition. In fact, quality-preserving strategies may exacerbate the trade-off by favouring incumbent complementors and deterring the entry of new complementors to the platform (Skiti et al., 2022).[2] Notwithstanding existing research successfully identifying the trade-off and its underlying rationale, it has yet to examine effective strategies to balance product variety and quality (Huang et al., 2022), and platform managers lack sufficient tools to tackle the tension between positive cross-side network externalities and negative same-side network externalities.

Our paper examines a novel type of cross-subsidization pricing strategy that alleviates the variety versus quality trade-off. The importance of a cross-subsidization strategy has been well-known since the seminal work of Armstrong (2006) and Rochet and Tirole (2003, 2006). Our study focuses on a specific type of cross-subsidization strategy that we call 'benefit-linked cross-subsidization', where complementors are subsidized *explicitly* based on the overall revenue they generate on the other side of the platform. For instance, in our empirical context, landing fees paid by airlines to (some) airports decrease as commercial revenue generated through passengers' expenditures in airport shops increases. By aligning the subsidy with the benefits complementors provide to the platform's other side participants, this strategy can foster the continued provision of high-quality contributions despite intensified competition. We empirically test this mechanism using data from airports as multisided platforms, with airline and passengers on the airside and commercial concessionaires in terminals as platform participants (Armstrong, 2007; Gillen, 2011; Ivaldi et al., 2011; Tavalaei, 2020). Some airports subsidize airlines' landing fees explicitly based on the concession revenue generated in terminals' commercial stores, while others do not employ cross-subsidization between the sides.

We demonstrate that even amidst a reduction in the barriers for new complementors to enter the platform – a shift triggered by a regulatory intervention in our context, which mandated airports with significant concentration by few dominant airlines to eliminate airlines' entry barriers – platforms utilizing a benefit-linked cross-subsidization may uphold the quality of complementors and their offering. Consequently, these platforms outperform those that do not use such a pricing strategy. Our quasi-natural experiment setting allows us to overcome endogeneity concerns related to platform governance and furnishes compelling evidence in support of the effectiveness of the proposed pricing strategy.

Our paper makes important contributions to research on multisided platforms. First, it introduces a potential solution for balancing variety and quality on platforms (Boudreau, 2012; Chen et al., 2022; Huang et al., 2022; Skiti et al., 2022; Wareham et al., 2014). We theorize and empirically demonstrate that implementing a pricing strategy that subsidizes complementors proportionally to their value creation on the platform may alleviate the trade-off between variety and quality. Second, we look into the impact of complementors' heterogeneity on platform performance and highlight the importance of directing complementors' composition toward high quality (McIntyre et al., 2021) or the 'right' type of complementors (Rietveld et al., 2021). Third, while extant literature has mostly analysed platform strategies separately from each other, our study analyses the combined effect of gatekeeping (governance) and pricing strategies, contributing to the understanding of the interconnected nature of strategic choices and platform strategy mixes (Cennamo and Santalo, 2013; Dushnitsky et al., 2022; Gawer, 2021; Jing et al., 2023).

THEORY AND HYPOTHESES DEVELOPMENT

Product Variety versus Quality and the Trade-off

Product variety denotes the range of products available within a given platform (Boudreau, 2012; Hagiu, 2009). Within the platform market literature, there has been a prevailing assumption that a high number of complementors is tightly linked with a broad spectrum of offerings (Boudreau, 2010; Boudreau, 2012; Skiti et al., 2022). Boudreau (2012) empirically finds a causal relationship between the number of producers on the platform and software varieties. Accordingly, a significant stream of research examines how platforms utilize governance and design strategies to effectively determine complementors accessibility and the breadth of product offerings (Boudreau, 2010; Chen et al., 2022; Dushnitsky et al., 2022; Wareham et al., 2014). Among the prominent approaches is opening up the platform to many complementors (Boudreau, 2012), characterized by a less restrictive gatekeeping strategy (Zhang et al., 2022). This approach can foster a broader spectrum of complementary products and drive user adoption through cross-side network externalities (Armstrong, 2006; Clements and Ohashi, 2005; Shankar and Bayus, 2003). An extensive user base translates into a larger market for complementors and initiates a cascade of positive reinforcing effects (Arthur, 1989). The intricate interplay of these network dynamics underscores a preference for the 'get big fast' strategy (Cennamo and Santalo, 2013; Lee et al., 2006; Sterman et al., 2007). This paradigm encourages the adoption of strategies by platforms focused on rapidly expanding their user base and complementors, thereby fostering mutually reinforcing benefits on the two sides of the market.

Although implementing less restrictive gatekeeping or 'open' strategies (Parker and Van Alstyne, 2018) drives up platform adoption and growth, on the flip side, providing broad access without adequate control can potentially yield adverse outcomes for platform performance. An increase in the number of complementors, leading to heightened within-platform competition among complementors and negative same-side externalities (Belleflamme and Toulemonde, 2009), can crowd out complementors' contribution and quality and innovation investments (Boudreau, 2010, 2012; Cennamo and Santalo, 2013; Ellison and Fudenberg, 2003; Zhang et al., 2022). Further, excessive growth in size may result in the platform being congested with low-quality complementors, fostering opportunistic and free-riding behaviours (Cennamo and Santalo, 2019; Geva et al., 2019). This can lead to unfavourable transactions (Chen et al., 2022) and user dissatisfaction (Cennamo and Santalo, 2019) and undermine the market identity of the platform (Cennamo, 2021). For instance, previous studies assert how such within-platform competition can hinder complementors' innovation (Boudreau, 2012) or knowledge-sharing incentives (Zhang et al., 2022).

The quality of a complementor or its offering entails the essential features that determine how it aligns with users' preferences and effectively fulfils their needs (Cennamo and Santalo, 2019). These defining features and attributes enhance the appeal of the complementor, which can be represented by the proportion of other side participants (users[3]) who show interest in and seek interaction with it (Hagiu, 2009, p. 1033). For instance, high-quality videogames or smartphone apps are those with superior programming and technical elements, as well as features that better match users' preferences (Cennamo and Santalo, 2019; Claussen et al., 2013). High-quality freelancers in crowdsourcing platforms, such as Upwork, are those who deliver superior service to clients and more effectively meet their needs (Gu and Zhu, 2021). On YouTube and social networking platforms, content creators with high impressions and viewer engagement are considered high-quality complementors for advertisers because they generate increased ad visibility and more likelihood of purchase. On the Eventbrite platform, which connects event organizers, attendees, and venue providers, event organizers with greater efficiency for organizing events and/or a stronger ability to attract upmarket and lucrative attendees – with a higher willingness to pay – could be more appealing and of higher quality for venue providers. In physical shopping malls, anchor stores can be considered as high-quality complementors (Eisenmann et al., 2006).

It is crucial to note that the defining characteristics of the quality of complementors and their offerings are often uncertain (Fan et al., 2023; Wang, 2021) and non-contractible ex-ante, prior to any potential transaction (Hagiu, 2009). This uncertainty introduces the possibility of asymmetric information among platform participants (Boudreau and Hagiu, 2009), which lies at the heart of the trade-off between variety and quality in platform markets, as explained later. Prior studies have identified different mechanisms that platforms can apply to preserve the quality of complementors' offerings. For instance, a few studies (e.g., Dewan et al., 2023; Rietveld et al., 2021) show how platforms, by applying performance certificates and reputation badges, can promote and benefit high-quality complementors. Claussen et al. (2013) point out rewarding high-performing complementors with additional technological features and opportunities, exemplified by permissions granted to Facebook app developers for notifications and enhanced user engagement. Other studies (e.g., Fleder and Hosanagar, 2009; Liang et al., 2019) highlight the role of recommendation systems in making highly rated products (and often in niche segments) stand out among their counterparts.

However, quality-preserving strategies can diminish the number of complementors and, hence, the variety of their offerings on the platform. For instance, Skiti et al. (2022) illustrate that while ranking sellers based on buyer ratings can lead to higher-quality sales, by lowering information asymmetries, it reduces product variety – highly rated sellers gain a strategic advantage, boosting their competitive position and deterring new entrants. The same mechanism may apply to certification systems (Dewan et al., 2023; Rietveld et al., 2021), such as 'Amazon's Choice' or 'Airbnb Plus' badging system, and 'Editor's Choice' or 'App of the Day' in the iOS App Store. Rewarding high-quality complementors with additional technological features (Claussen et al., 2013) may inadvertently lead to attrition among non-selected complementors or dampen the incentive for new complementors' participation. Some studies even show how platforms can benefit from deliberately limiting user choice and curbing the number of complementors on the platform (Casadesus-Masanell and Halaburda, 2014; Zheng and Kaiser, 2013).

In summary, platforms need to navigate the trade-off between product variety and quality, a decision influenced by the balance of positive cross-side and negative same-side network externalities (Dushnitsky et al., 2022; Gawer, 2021; Rietveld et al., 2019; Skiti et al., 2022). Notably, extant research highlights strategies to enhance complementor quality but offers limited insight into the variety versus quality trade-off and how to manage this tension (Huang et al., 2022). In this paper, we study how a specific cross-subsidization pricing strategy may mitigate the trade-off between the variety and quality of complementors and their offerings.

Benefit-Linked Cross-Subsidization to Balance Variety and Quality

The significance of cross-subsidization pricing has been extensively studied in prior research (Armstrong, 2006; Caillaud and Jullien, 2003; Hagiu, 2006; Parker and Van Alstyne, 2005; Rochet and Tirole, 2003, 2006; Seamans and Zhu, 2014; Weyl, 2010). This strategy entails reducing prices on one side of a multisided platform to stimulate participation, thereby enhancing the other side's willingness to pay and ultimately boosting platform profits. Such pricing strategies are commonplace across various multisided platforms. For instance, shopping malls often provide free amenities to attract consumers while generating revenue from merchant rent and royalties. Similarly, videogame consoles may be sold to consumers below production cost to entice gamers, with profits generated from game developers' royalties. Cross-subsidization serves as an effective approach, particularly in addressing the coordination problem encountered by platforms in their nascent stages, where there may be insufficient participation on both sides – often referred to as the 'chicken and egg' problem (Caillaud and Jullien, 2003).

Li and Penard (2014) emphasize the strategic importance of implementing pricing schemes that regulate the number of complementors and motivate them to offer diverse high-quality products. However, despite abundant studies on cross-subsidization, existing research has predominantly overlooked the quality implications and considerations associated with the cross-subsidization pricing strategy (Huang et al., 2022). As a notable exception, Hagiu (2009) discusses that when product quality is not contractible, and user demand for the platform is uncertain, the platform should charge complementors relatively lower, rather than higher, royalty fees. The more crucial the quality investments, the lower the royalty fees should be. That is, the heterogeneity and quality of complementors and their offering, which is essential in value creation for users on the other side, impact the platform's pricing decisions (Weyl, 2010). More recently, Huang et al. (2022), followed by Fu and Lyu (2022) and Lyu et al. (2024), show that offering a fixed amount of subsidy *only* to high-quality complementors, on certain occasions, can be an effective price discrimination strategy to deal with the variety versus quality trade-off.

Advancing this line of inquiry, we argue that a specific cross-subsidization pricing strategy – where cross-subsidies are explicitly linked to the total revenue that complementors generate on the other side of the platform – can alleviate the variety versus quality trade-off by maintaining (incumbent) complementors' incentive for quality as well as steering the platform's entry dynamics toward high-quality complementors. We call this specific type of cross-subsidization pricing 'benefit-linked cross-subsidization'. As described at the outset, implementing less restrictive gatekeeping strategies to boost the number of complementors and the variety of their products intensifies the tension between positive cross-side network externalities and negative same-side externalities. Intensive within-platform competition among complementors erodes their returns from quality investments (Aghion et al., 2005; Hagiu, 2014; Markovich and Moenius, 2009). Compensating complementors for their loss through subsidies proportionate to their revenue generation safeguards against the 'crowding out' of their quality incentives (Boudreau, 2012).

Opening up the platform can give rise to another issue, which can be mitigated through benefit-linked cross-subsidization. High-quality complementors contribute to an overall platform reputation, which benefits all complementors by increasing users' willingness to pay for platform-affiliated products. Accordingly, the number of complementors and the variety of their products generate a negative free-riding effect, diminishing the benefits of joint contributions to the collective and reducing complementors' incentives to make platform-specific investments that enhance user satisfaction (Cennamo and Santalo, 2019). When complementors' investments in quality generate positive spillovers for other complementors through their positive effect on the overall platform reputation, individual complementors cannot fully capture the returns from their investments. This leads to moral hazard problems arising from incentives to free ride on other complementors' efforts (Gupta et al., 1999) and, consequently, a value creation problem (Yalcin et al., 2013).

Lowering platform entry barriers and providing access to a larger pool of complementors eases the entry of low-quality and opportunistic complementors, thereby exacerbating the moral hazard problem and reducing individual contribution levels (Monge et al., 1998; Olson, 1965). Since the profits from a higher platform reputation are shared among all complementors, while complementors' efforts and contributions to the overall platform reputation are imperfectly assessed, free-riding incentives can increase. Platforms employing benefit-linked cross-subsidization strategies signal complementors that they will recoup quality investments by receiving a portion of platform revenue through lower royalty fees or higher subsidies. Consequently, complementors internalize some of the externalities they generate on the other side of the platform and capture value from high-quality contributions to the platform (Kretschmer et al., 2022). That is, *ex-ante* incentives to appropriate value can shape their *ex-post* contribution to value creation and quality investments (Chen et al., 2022).

This cross-subsidization also can make the platform more attractive to new high-quality entrants, preventing it from being overrun by low-quality products. Specifically, the entry of low-quality complementors potentially reduces overall revenue generated, leading to lower subsidies. Benefit-linked cross-subsidization, therefore, could discourage low-quality complementors from joining the platform and promote high-quality ones.

If royalty fees and subsidies are not linked to the revenue generated by complementors, the pricing scheme fails to compensate complementors for the challenges posed by heightened within-platform competition and negative same-side externalities (Belleflamme and Toulemonde, 2009). Consequently, these complementors are more likely to curtail their platform-specific coordination and investments when facing increased competition from new entrants (Boudreau, 2012; Markovich and Moenius, 2009), especially if they provide high-quality products. Additionally, such platforms become less attractive to new high-quality complementors since there are no rewards in the form of lower royalty fees or higher subsidies for providing high-quality products. Hence, we hypothesize:

> *Hypothesis 1:* When within-platform competition among complementors increases, platforms that employ a benefit-linked cross-subsidization strategy are more likely to experience an increase in the average quality of complementors and their offerings compared to platforms that do not employ such a strategy.

The platform literature has already shown how an increase in the number of platform participants leads to a cascade of positive effects characterized by positive cross-side network externalities. More users on one side attract more complementors on the other side in a reinforcing loop that generates higher transaction volume and drives up platform growth and profits (McIntyre and Srinivasan, 2017; Parker and Van Alstyne, 2005; Shankar and Bayus, 2003). Furthermore, higher within-platform competition among complementors reduces product prices, resulting in a higher transaction volume between the platform's sides, which can boost platform profits. The pursuit of these benefits has been behind the aggressive growth strategies (Sterman et al., 2007), which suggest expanding the user base and complementors and boosting the cross-side network externalities rapidly and benefit from the winner-takes-all outcome (Cennamo and Santalo, 2013; Katz and Shapiro, 1994; Lee et al., 2006; Schilling, 2002).

However, first, the entry of new competitors into the pool of existing complementors (i.e., incumbents) or the increased offering of lower-priced products induced by within-platform competition may be offset by a comparable decrease or pushback in the supply of incumbents' offerings, which means the net number of products and transaction volume could remain relatively unchanged. Second, even if the platform experiences significant growth in size, intensive within-platform competition can diminish complementors' quality investments (Boudreau, 2012; Markovich and Moenius, 2009). Platform success depends not only on the sheer size of the network (i.e., the participant pool) and transaction volume but also, critically, on the quality of products (Chen et al., 2022; Hagiu, 2009; Kim et al., 2014; McIntyre and Subramaniam, 2009; Rietveld et al., 2019; Zhu and Iansiti, 2012). Hence, if less restrictive gatekeeping strategies and increased competition among complementors lead to replacing high-quality products with low-quality ones, the platform's profits may not grow and may even fall.

This also relates to the platform's 'lemon market failure' (Akerlof, 1995; Hagiu, 2009). If high-quality and low-quality complementors are not effectively distinguishable, then high-quality complementors may be pushed out of the market. This is exemplified by the video game crash or Atari shock of 1983 in the video game industry. An influx of low-quality games eroded users' willingness to pay for video games, primarily due to the challenge of distinguishing low-quality games from high-quality titles before purchase (Boudreau and Hagiu, 2009). Dushnitsky et al. (2022) attest that the ultimate objective of platforms is to balance expansion strategies with curation strategies to maintain the quality of participants and offerings and generate valuable interaction between the multiple sides' participants.

As discussed earlier, the benefit-linked cross-subsidization pricing strategy can mitigate the potential adverse effects of same-side network externalities on platform performance. That is, making complementors aware that they will receive a portion of platform revenue through lower royalty fees preserves complementors' incentive for quality contributions (Kretschmer et al., 2022). It also shifts the platform's entry dynamics toward high-quality complementors. The benefit-linked cross-subsidization, therefore, can discourage low-quality complementors from joining the platform, promote high-quality complementors, and maintain a favourable mix of products despite an increase in within-platform competition. This higher value creation enables a higher value capture by the platform owner per complementor (Kretschmer et al., 2022).

If royalty fees and subsidies are not linked to the revenue generated by complementors, the pricing scheme does not compensate complementors for suffering higher levels of within-platform competition. Consequently, these complementors are more likely to scale back their operations when facing increased competition from new entrants (Boudreau, 2010, 2012). Additionally, such platforms become less attractive to new high-quality complementors. In other words, even if the platform enjoys a large size, same-side network externalities can erode the benefits of cross-side externalities and diminish platform value to users (Cennamo and Santalo, 2019). Hence, we expect that the negative impact on the quality of complementors and platform performance due to higher within-platform competition will be lower if platforms have a benefit-linked cross-subsidization strategy, and we hypothesize:

> *Hypothesis 2:* When within-platform competition among complementors increases, platforms that employ a benefit-linked cross-subsidization strategy are more likely to experience higher financial performance compared to platforms that do not employ such a strategy.

RESEARCH CONTEXT

The Airport Industry

Our empirical context is the airport industry. According to Hagiu and Wright (2015), multisided platforms are primarily characterized by enabling *direct interactions* between two or more distinct groups that are *affiliated* with the platform on different sides. *Direct* interaction broadly means that key terms of interaction (such as the price and quality of products offered by the complementors) are at least partially controlled by the platform participants, as opposed to full control by the platform owner. Affiliation means that participants make platform-specific investments to be able to interact with other participants on the other side.

According to this definition, modern airports meet the criteria of a multisided platform (Gillen, 2011; Starkie, 2021), serving distinct participant groups – passengers, airlines, and third-party commercial concessionaires in airport terminals – and facilitating direct interaction among them. While airports may impose requirements for aeronautical operations and commercial activities within terminals, airlines and commercial concessionaires control key aspects of interaction with passengers, such as flight routes, ticket prices, in-terminal product offerings and pricing. Both airlines and commercial concessionaires also make airport-specific investments in operating in (i.e., affiliate with) the airport (Jacobides et al., 2018). Passengers also bear the opportunity cost of commuting to the airport and waiting time before boarding. They also, albeit indirectly through airlines, pay the passengers' facility charges to the airport. Commercial concessionaires and airlines are connected through passengers, while passengers interact with both groups.

Furthermore, cross-side network externalities exist since, ceteris paribus, commercial concessionaires value airports more when they serve airlines with higher passenger volumes or more *desirable* passengers – i.e., those who spend more in terminals (e.g., Fu and Zhang, 2010). Passengers benefit from a wider selection of airlines and flights. Airports gain revenue from two distinct sources: aeronautical revenue, which is based on airline-related activities such as landing fees; and non-aeronautical revenue from commercial tenants within terminals, parking, and car-rental concessions (Gillen, 2011). As multisided platforms, airports can subsidize airlines to appropriate higher rents from the commercial side (Zhang and Zhang, 1997). In line with some of the previous air transportation (e.g., Gillen, 2011; Ivaldi et al., 2011; Starkie, 2021) and management (Flores-Fillol et al., 2018; Tavalaei, 2020) studies, we consider airports as multisided platforms. Airlines and passengers participate on the airside, while commercial concessionaires participate on the commercial side of the platform (Czerny, 2006; Fu and Zhang, 2010).[4]

Airport Pricing for Airlines and the Internalization of Externalities

Airport pricing for airlines depends on whether the airlines are signatory or non-signatory. Signatory airlines have bilateral agreements with airports (the so-called 'airport and airline use and lease agreement'), while non-signatory airlines operate seasonally without such agreements. In the USA, two main types of agreements determine the use and leasing conditions for airfield and terminal facilities for signatory airlines. These agreements are typically long-term; Sabel (2004) mentions 15–30 years.

Under the *residual* approach (known in Europe as 'single-till'), airlines pay airports the difference between airport costs and non-aeronautical revenue, meaning their fees decrease as non-aeronautical revenue increases (Ashford and Moore, 1992). Hence, the fees paid by airlines fall as non-aeronautical revenue rises (Ashford and Moore, 1992). In this model, part of the total net revenue obtained from the commercial side of the airport (apart from a portion reserved as a cushion to pay off bonds in case of downturns and other eventualities) is used to subsidize signatory airlines. Consequently, the higher (non-aeronautical) revenue generated on the commercial side of the airports, the airport charges airlines lower landing fees. In return, signatory airlines pledge to cover potential airport deficits not covered by airport revenues. The residual pricing is consistent with our proposed benefit-linked cross-subsidization strategy. That is, the subsidies provided to airlines are directly tied to the revenue they generate through their passengers' spending in the terminals' commercial stores. The higher the revenue generated, the more benefits airlines obtain in terms of lower landing fees.

In the *compensatory* approach (known in Europe as 'dual-till'), airports keep non-aeronautical (commercial) revenues separate and do not subsidize airlines with them (Crider et al., 2011; Doganis, 1992; Graham, 2008). This method splits aeronautical and non-aeronautical finances into distinct accounts, with airlines paying landing fees solely based on their airside costs and facility usage. As a result, in the compensatory regime, airlines neither receive subsidies nor face overcharges, and non-aeronautical revenues do not offset airline landing fees. While residual agreements offer lower landing fees to airlines in exchange for assuming airport financial risks, compensatory agreements typically mean higher landing fees but no financial risk for airlines.

A third type of agreement, called the *hybrid* approach, combines elements of both compensatory and residual approaches. It allows for compensatory rate-setting while incorporating some non-aeronautical revenue sharing to maintain reasonable airline fees, typically involving specific non-aeronautical revenues like parking shared with signatory airlines (Faulhaber et al., 2010).

Increase of Airline Competition within US Airports

The Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (AIR-21), passed by Congress in year 2000 and enacted in 2001, aimed to address concerns over high entry barriers and limited competition in the airline industry. It mandated highly concentrated airports in the USA to develop competition plans facilitating entry for new airlines. Compliance with AIR-21, including the submission of satisfactory competition plans, was tied to receiving federal funds. 'Covered' airports had to ensure fair access to essential facilities for all airlines. 'Covered' airports were those that (1) accounted for more than 0.25 per cent of enplanements at US primary airports and (2) had more than half their boarding passengers accounted for by the top two airlines. Approval of federal funds for these airports depended on satisfying competition plan requirements and reducing entry barriers, with the FAA overseeing the process.

Notable examples of pro-competitive measures implemented by covered airports were improving the passengers' boarding gates accessibility for all airlines, promoting *common use* approach in leasing gates to airlines as opposed to a *preferential* or *exclusive* basis, oversighting fees in sublease agreements between the gate controlling airlines and the lessees, eliminating access protections for specific airlines, developing marketing plans encouraging the entry of new (low-cost) carriers, and applying 'more entry-friendly' contractual terms (Snider and Williams, 2015, pp. 1005–1006). Studies have reported that AIR-21 successfully erased entry barriers and fostered competition among airlines in the covered airports (Ciliberto and Williams, 2010; Snider and Williams, 2015).

METHOD

Data

We collected longitudinal data on 66 major US airports from 1996 to 2005. We based our initial sample on these 66 for two reasons. First, they are all medium and large hubs (each accounting for at least 0.25 per cent of total domestic enplanements); smaller airports are not covered by AIR-21 regardless of their concentration, and financial data are unavailable for many of them. Second, as we captured the AIR-21 coverage data from Snider and Williams (2015), we were using precisely the same sample of airports they analysed.

According to Snider and Williams (2015), 43 airports were immediately covered by AIR-21 and are considered the treatment group in our quasi-natural experiment. The other 23 were not required to implement any mandatory competition plan (at least until 2005) and thus constitute the control group. The aeronautical and non-aeronautical revenues of the airports, as well as hub status, came from the Federal Aviation Administration (FAA) database. We also used the US Department of Transportation's (DOT) T-100 database for passenger and flight traffic data. We obtained ticket prices (in USD) from DOT's DB1B database.

To determine airports' pricing approaches, we first used the results of a 1998 survey conducted by the Airports Council International-North America (ACI-NA 1998; see FAA/OST Task Force, 1999) that specifies the type of agreement between the airport and signatory airlines for 39 airports of our sample, along with the expiration dates of these agreements. To recover these data for the missing airports, we used another survey conducted by ACI-NA for the year 2003 and the available competition plans on the airports' websites. By doing so, we increased the number of airports with data on the pricing approach available to 62 (16 airports with compensatory, 23 with residual, and 23 with hybrid pricing) so that our final sample comprises 620 airport-year observations. The lease agreements average 20 years in our sample. According to ACI-NA 1998, the expiration dates of most agreements extend beyond 2005 – an average of eight years elapsed between the enactment of AIR-21 and the expiry of agreements. For a few exceptions, we cross-referenced the type of agreement with information from ACI-NA 2003 and the airports' competition plans in the years following the expiration date (when available), as well as with another source (LeighFisher, 2016). We observed no shift from residual- to compensatory-based agreements or vice versa.[5] Finally, the data on income per capita in each metropolitan statistical area came from the US Bureau of Economic Analysis.

Measurements

Dependent variables. To test the first hypothesis, we measure the quality of complementors and their offerings with the (natural logarithm of) the airport's *commercial revenue per passenger*. Commercial revenue is obtained from concessions in terminals such as food and beverage sales, bookstores, gift shops, and duty-free shops. According to Cennamo and Santalo (2019) and Hagiu (2009), high-quality complementors have features and attributes that more closely align with the needs and preferences of participants on the other side of the platform, making them more appealing to these participants to interact with. In our context, airlines that draw passengers with higher spending profiles in terminals have features that make them more desired by commercial concessionaires, hence, regarded as higher quality for concessionaires – the participants on the other side of the platform. Non-low-cost or premium passengers who fly with legacy (non-low-cost) airlines/flights individually spend more in airport stores (Castillo-Manzano, 2010; Graham, 2008; Lei and Papatheodorou, 2010) and are associated with higher commercial revenue *per passenger* as a measure of passenger spending (Fasone et al., 2016). Hence, we consider legacy airlines as high-quality complementors and their flights as high-quality products in our setting: by bringing premium passengers, they are more appealing to commercial concessionaires. A high commercial revenue per passenger indicates a high percentage of legacy airlines and passengers flying with those airlines, on average. In other words, a high commercial revenue per passenger implies that the composition of the airside is toward the high-quality complementors (i.e., legacy airlines).

To test the second hypothesis, we measure airport financial performance by *operating income per passenger*[6] and return on sales from operating revenue (*operating ROS*),[7] which have been used in previous airport studies as financial performance indicators (e.g., Fasone et al., 2014;

Francis et al., 2002; Humphreys and Francis, 2002; Vogel, 2006). Operating revenue consists of aeronautical and non-aeronautical revenue. The former consists mainly of landing revenue from airlines, rent from terminal arrival areas such as check-in and ticket counters, fuel sales, and fees for aircraft parking or 'tiedown' (facilities for securing parked aircraft). Non-aeronautical revenue includes revenue from concessions and retail in terminals (what we term 'commercial revenue') and rental revenue for land, non-terminal facilities, and hire-car lots. Airports' operating costs include all expenses related to activities in the aeronautical and non-aeronautical operations of the airport, such as personnel compensation, contractual services, supplies, and materials.

Independent variables

AIR-21 intervention. We build two dummy variables: one to distinguish the treatment from the control group (*Treat* = 1 if the airport is covered by AIR-21; 0 otherwise) and one (*Post*) to distinguish years before (1996–2000) and after (2001–2005) AIR-21 enactment in 2001. AIR-21 mandated lower entry barriers for new entrant airlines in covered airports, increasing competition in the airside. As noted above, the entry of more complementors is linked with a higher product variety (Boudreau, 2010; Boudreau, 2012; Skiti et al., 2022). Additional analysis (as reported in Table A12 of Appendix B) shows that lower entry barriers to airlines resulted in more available destinations and a total number of flights – i.e., higher product variety – for both the residual- and compensatory-based airports after AIR-21.

Airports' pricing approach. We use the *Residual* dummy variable to distinguish the two subsamples: first, airports that implement residual, i.e., benefit-linked cross-subsidizing pricing (23 airports); second, airports that implement compensatory, i.e., non-subsidizing pricing (16 airports). For simplicity, we refer to the first (and second) group as *cross-subsidizing* (and *non-subsidizing*) airports. We exclude hybrid-pricing airports from our analysis.[8]

Control variables. We include the (natural logarithm of the) *yearly average ticket price* at each airport to rule out any direct effect of change in the ticket price on consumers' expenditure in the terminals as a control variable. Also, the model contains (the natural logarithm of) *income* per capita for the metropolitan statistical area in which each airport is located. Other time-invariant control variables, such as location, state fixed effects, hub status, or being a monopolist or competing with other airports located in the same city – associated with the airport market power and airport-airlines bargaining power – are absorbed by airport fixed effects in all our models.

Empirical Strategy

We build a triple difference or difference-in-difference-in-differences (hereafter, 'DDD') model as follows (Angrist and Pischke, 2008; Olden and Moen, 2022):

$$Y_{it} = \psi \ Resdiual_i \times Treat_i \times Post_t + \varphi \ Treat_i \times Post_t + \rho \ Residual_i \times Post_t + A_i + B_t + \phi \ X_{it} + \epsilon_{it,} \quad (1)$$

where Y_{it} denotes the dependent variable at time t for airport i. $Treat_i$ and $Post_t$ are the indicators of belonging to the treatment group (being covered by AIR-21 regulation) and postdating the AIR-21 intervention, respectively. $Residual_i$ equals one (or zero) if the airport employs a residual (or compensatory) pricing approach. The interaction of these three dummy equals one only if the airport is residual-based, covered by AIR-21, and the year is later than 2000 (i.e., post-AIR-21 enactment). A_i and B_t are airport and year fixed effects. X_{it} is a vector of control variables, and ϵ_{it} is the error term. The effects of $Treat_i$, $Residual_i$, and their interaction are absorbed by the airport fixed effects. The effect of $Post_t$ is absorbed by the year fixed effects. Hence, they are not directly incorporated into the model. Our main goal is to estimate the impact of AIR-21 (ψ) on airports with the benefit-linked cross-subsidization pricing approach (residual) compared to airports with no cross-subsidization (compensatory). Specifically, it shows whether or not the AIR-21 intervention causes a different trend in covered airports (treatment group) than in non-covered ones (control group) for residual-based compared to compensatory-based airports.

For simplicity of the effect size interpretation, we also apply a difference-in-differences model (hereafter, 'DD'), as follows, for residual- and compensatory-based subsamples separately. We are particularly interested in the coefficient of the $Treat_i$ and $Post_t$ interaction in each regression. As above, $Treat_i$ and $Post_t$ main effects are absorbed by the airport and year fixed effects, respectively.

$$Y_{it} = \psi \ Treat_i \times Post_t + A_i + B_t + \phi \ X_{it} + \epsilon_{it}, \tag{2}$$

Imbens and Wooldridge (2007) suggest that when the number of clusters is small, using clustered-robust inference produces poor inference. Note that in the regressions with residual airports, we have only 23 clusters, while in the regressions with compensatory airports, we have only 16 clusters. This means that in our case, it is not that clear that we should use airport-clustered standard errors. Therefore, we run an Ordinary Least Squares (OLS) regression with robust to heteroscedasticity standard errors. To address potential selection problems or lack of homogeneity between control and treatment groups before the AIR-21 intervention, we apply a regression discontinuity design, among other robustness tests.

In our DDD and DD settings, where AIR-21 is exogenous to our model, we circumvent endogeneity problems related to platform gatekeeping strategy. With this in mind, it is important to stress that airport-airline bilateral agreements tend to be long-term, and airports facing the shock of AIR-21 could not simply switch between pricing regimes. In fact, as noted earlier, we have not observed a single case in which an airport has switched from compensatory to the residual approach or vice versa as a result of AIR-21. Since the pricing regime selections are made or 'grandfathered in' years before the AIR-21, they are 'intrinsically exogenous' to our model and do not confound the AIR-21 impact (Karanki and Lim, 2020, p. 8). It is also worth noting that, as noted earlier, residual-based airports, in exchange for sharing commercial revenue with airlines, also transfer the risk of revenue deficits to the airlines. In contrast, compensatory-based airports assume the full risk of any shortfall in revenue and retain all commercial revenue for themselves. Yet, the difference between the risk transfer and bearing should not affect our analyses. First, the impact of pricing schemes on airport performance is inconclusive in the literature as each method has advantages and disadvantages (e.g., Fu et al., 2011; Karanki and Lim, 2020; Oum et al., 2008). Moreover, as shown in the following section, we can assume homogeneity between residual- and compensatory-based airports before AIR-21 regarding financial performance and other observable factors such as total number of passengers and airside concentration. Additionally, including airport fixed effects in our models accounts for any time-invariant factors such as location and airport infrastructure.[9]

FINDINGS

Tables I and II present the descriptive statistics and correlations of the variables. Pairwise correlations in Table I show no evidence of multicollinearity.[10] It is worth noting that the pairwise correlations between Airside HHI (Herfindahl Hirschman Index) – the concentration of airlines in a given airport in terms of the number of each airline's passengers – and both airport financial performance and commercial revenue per passenger should be considered cautiously. These correlations are confounded by factors such as the airport pricing scheme, gatekeeping strategy, and whether the airport is covered by AIR-21. However, the negative values could be explained by the potentially higher bargaining power of airlines against airports when the airside is more concentrated (i.e., higher HHI).

To better overview the final sample, Table II shows the summary statistics for the different subsamples of airports with compensatory and residual pricing regimes. Table III shows similar statistics while distinguishing between each subsample's control and treatment groups. Applying t-tests to compare all variables in Table II (as well as the total number of passengers, flights and available destinations, the percentage of legacy airlines and the total number of legacy airlines) for residual-based and compensatory-based airports, year by year before AIR-21, (not reported here but available upon request) shows that that the two types of airports were homogeneous before the AIR-21 intervention (all p-values > 0.5, except for operating ROS in 1997 with p-value $= 0.035$). Furthermore, as

Table I. Correlation matrix

Variables	*1*	*2*	*3*	*4*	*5*	*6*
1. Operating income per passenger	**1.000**					
2. Operating ROS	**0.671**					
3. Ln (Commercial revenue per passenger)	**0.468**	0.029				
4. Ln (Income per capita)	**0.179**	**−0.108**	**0.284**			
5. Ln (Ticket price)	**0.194**	**0.161**	**0.235**	**0.177**		
6. Ln (Total passengers)	−0.006	0.070	**0.298**	**0.258**	**0.408**	
7. Airside HHI	**−0.348**	−0.079	**−0.392**	**−0.148**	−0.160	**0.114**

Note: N = 380 (residual or compensatory). Correlations in bold text are coefficients with p-value < 0.05.

Table II. Descriptive statistics

	Operating income per passenger	*Operating ROS*	*Ln (Commercial revenue per passenger)*	*Ln (Income per capita)*	*Ln (Ticket price)*	*Ln (Total passengers)*	*Airside HHI*
Compensatory							
N	160	160	160	160	160	160	160
mean	3.150	0.402	−0.169	10.398	5.893	16.601	0.269
min	−0.665	−0.100	−3.385	10.013	3.976	14.777	0.078
max	8.923	0.732	1.546	10.791	6.272	18.262	1.000
Residual							
N	230	221	220	230	230	230	230
mean	2.544	0.334	−0.186	10.387	5.931	16.509	0.311
min	−0.651	−0.151	−1.846	9.928	5.325	15.068	0.090
max	10.540	0.745	1.913	10.917	6.373	18.124	0.875
Total							
N	390	381	380	390	390	390	390
mean	2.793	0.363	−0.179	10.391	5.915	16.546	0.294
min	−0.665	−0.151	−3.385	9.928	3.976	14.777	0.078
max	10.540	0.745	1.913	10.917	6.373	18.262	1.000

expected, Table III shows how the airside concentration is much higher in airports that belong to the treatment (i.e., covered by AIR-21) group.

Figure 1 shows the concentration of airlines at all airports before and after AIR-21. We can see a clear decline in the concentration for covered airports after AIR-21, while only a slight decrease for non-covered airports. This corroborates the expectation that AIR-21 successfully forced covered airports to lower barriers to entry for new airlines (Snider and Williams, 2015).

Before running the regressions, we check the validity of the parallel (common) trend assumption for our DDD and DD models, following the process suggested by Mora and Reggio (2015: 'didq' command in Stata software). Specifically, we test if we can reject the parallel trend assumption in all pre-treatment periods (H0: Common pre-dynamics) and if we can reject the assumption between a given period and the previous period (H0: $q = q-1$) before the AIR-21 enactment year in 2001. The former test results are reported in Table IV, and the latter test results are reported in Table A1 of Appendix B. All results show that we cannot reject the parallel trend assumption for any dependent variables in compensatory or residual subsamples or the full sample (all p-values > 0.05). Furthermore, by applying the relative time model (Autor, 2003; Burtch et al., 2018), we estimate the effect of AIR-21 intervention (i.e., treatment vs. control groups) across different years. Specifically, in our DDD (or subsample DD) model, we replace the *Post* dummy with a series of dummies that indicate leads or lags (in years) in reference to the AIR-21 enactment year in 2001. Figure 2 depicts these yearly effects on our three dependent

Table III. Descriptive statistics for treatment and control groups

	Compensatory				*Residual*			
	N	*mean*	*min*	*max*	*N*	*mean*	*min*	*max*
Control								
Operating income per passenger	90	3.487	−0.665	8.646	50	3.152	0.157	8.331
Operating ROS	90	0.387	−0.100	0.683	50	0.389	0.037	0.745
Ln (Commercial revenue per passenger)	90	−0.095	−3.385	1.546	50	0.528	−0.591	1.913
Ln (Income per capita)	90	10.422	10.067	10.791	50	10.373	10.041	10.692
Ln (Ticket price)	90	5.930	5.383	6.264	50	5.940	5.386	6.373
Ln (Total passengers)	90	16.404	14.777	17.996	50	16.613	15.186	17.331
Airside HHI	90	0.126	0.078	0.252	50	0.143	0.090	0.180
Treatment								
Operating income per passenger	70	2.715	0.136	8.923	180	2.375	−0.651	10.540
Operating ROS	70	0.422	0.052	0.732	171	0.317	−0.151	0.725
Ln (Commercial revenue per passenger)	70	−0.264	−1.190	1.219	170	−0.396	−1.846	1.672
Ln (Income per capita)	70	10.366	10.013	10.746	180	10.391	9.928	10.917
Ln (Ticket price)	70	5.845	3.976	6.272	180	5.928	5.325	6.262
Ln (Total passengers)	70	16.854	15.051	18.262	180	16.480	15.068	18.124
Airside HHI	70	0.453	0.133	1.000	180	0.358	0.140	0.875

Note: The airport is in the treatment group if it is covered by AIR-21 and in the control group otherwise.

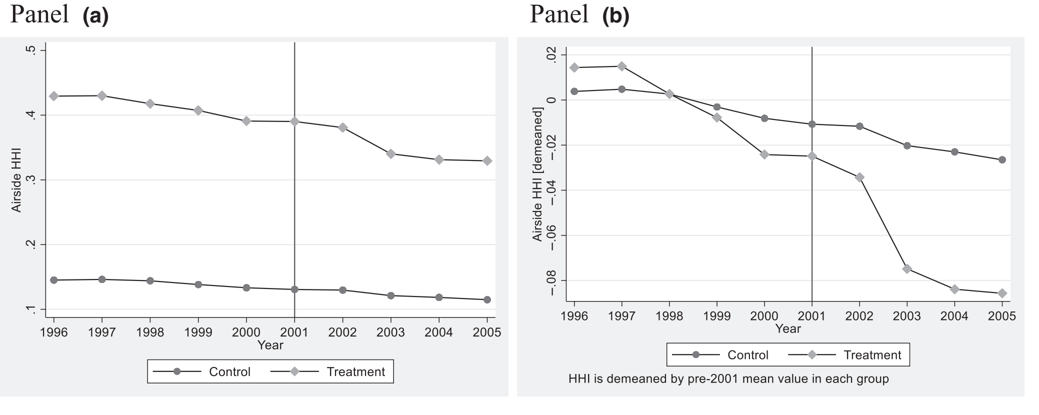

Figure 1. Effect of AIR-21 on the airside competition for control and treatment groups. Airside HHI is measured by the Herfindahl–Hirschman Index (HHI) of airlines in a given airport, considering the number of passengers flying on each airline. A higher HHI means higher concentration and lower competition on the airside. The airports covered by AIR-21 constitute the treatment group. Airports not covered by AIR-21 constitute the control group. AIR-21 was enacted in the year 2001. In Panel b, the HHI values are demanded by the mean value of HHI pre-AIR-21 enactment (i.e., pre-2001) in each control or treatment group.

Table IV. Testing parallel trend assumption

	Ln (Commercial revenue per passenger)	*Operating income per passenger*	*Operating ROS*
Compensatory	0.671	0.150	0.217
	[0.954]	[0.997]	[0.994]
Residual	0.419	0.305	0.249
	[0.980]	[0.989]	[0.992]
Compensatory or Residual	0.769	0.671	0.810
	[0.943]	[0.955]	[0.938]

Note: Wald test for H0: Common pre-dynamics; p-values in brackets. Sample Period: 1996–2005. Treatment Period: 2001–5.

variables for residual-based, compared to compensatory-based airports (or in residual and compensatory subsamples separately), along with upper and lower bounds for 95% confidence intervals. The graphs show no clear evidence of upward or downward trends before the AIR-21 enactment in either the residual or compensatory airports. Moreover, we see a clear upward trend after the AIR-21 for the three dependent variables only in residual airports (and not in the compensatory airports), as hypothesized.

Table V shows the results of the regressions. Based on our hypotheses, post-AIR-21, legacy airlines are predicted to dominate new entries at residual-based airports, motivated by the benefits of benefit-linked cross-subsidization, where their passengers' higher commercial spending leads to more airline subsidies through lower landing fees. Moreover, this pricing scheme could encourage legacy airlines to maintain operations at these airports. Consequently, cross-subsidizing (i.e., residual-based) airports are more likely to experience higher commercial revenue per passenger (Hypothesis 1) and improved financial performance (Hypothesis 2) compared to their non-subsidizing (i.e., compensatory-based) counterparts. Assessing Hypothesis 1, the coefficient of *Residual* × *Treat* × *Post* is positive (β = 0.728, p-value = 0.000, 95% C.I. = [0.462, 0.994]), which attests AIR-21 seems to have a stronger positive effect on commercial revenue per passenger of residual- versus compensatory-based airports. Looking at the subsample DD models, AIR-21 appears to have a positive effect (β = 0.540, p-value = 0.000, 95% C.I. = [0.369, 0.710]), indicating that AIR-21 leads to a 71 per cent[11] increase in commercial revenue per passenger in residual-pricing (cross-subsidizing) airports, compared to the control (i.e., counterfactual) group, based on our sample. However, its effect on commercial revenue per passenger in compensatory-pricing (non-subsidizing) airports seems to be negative (β = −0.226, p-value = 0.044, 95% C.I. = [−0.445, −0.006]). Applying a t-test to compare the coefficients of *Treat* × *Post* in the residual and compensatory subsample attests that the coefficients statistically differ across subsamples (p-value = 0.000). These results are consistent with Hypothesis 1: commercial revenue per passenger is more likely to increase in airports with residual pricing (i.e., cross-subsidizing airports).

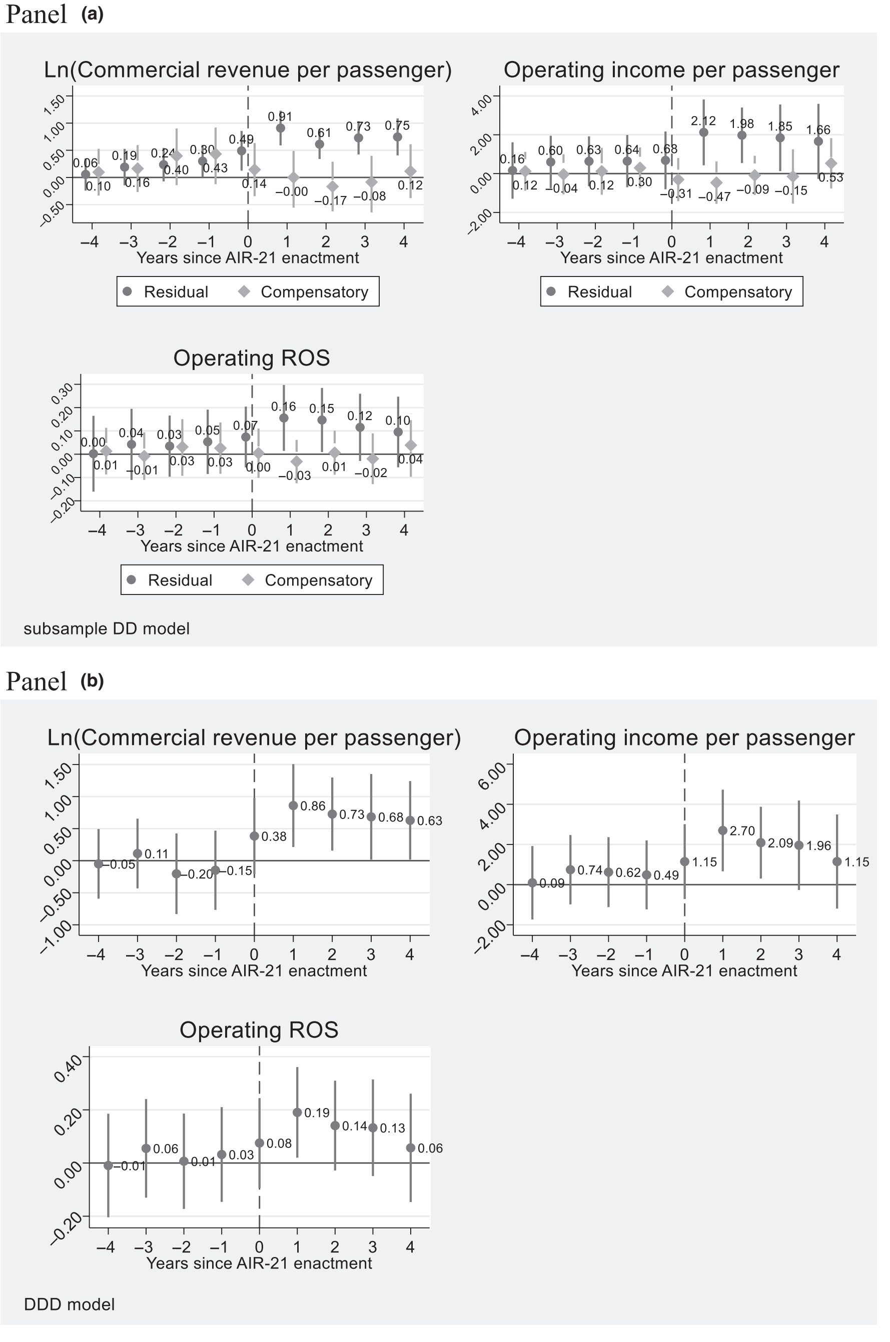

Figure 2. Yearly effect of AIR-21 on commercial revenue per passenger and financial performance. In Panel a, each point denotes the estimated difference between the treatment and control groups in each year (as in the subsample DD model) in reference to the AIR-21 enactment in 2001, along with upper and lower bounds for 95% confidence intervals. In Panel b, each point denotes the estimated difference between the treatment and control groups in each year for residual- versus compensatory-based airports (as in the DDD model), in reference to the AIR-21 enactment in 2001, along with upper and lower bounds for 95% confidence intervals.

Table V. DDD and DD analysis for financial performance and commercial revenue per passenger

	H1			*H2*					
	Ln (Commercial revenue per passenger)			*Operating income per passenger*			*Operating ROS*		
	DDD	*Compensatory*	*Residual*	*DDD*	*Compensatory*	*Residual*	*DDD*	*Compensatory*	*Residual*
Residual × Treat × Post	0.728***			1.394**			0.102**		
	(0.135)			(0.438)			(0.039)		
Treat × Post	−0.198^{+}	−0.226*	0.540***	−0.196	−0.197	1.239**	−0.012	−0.013	0.091**
	(0.112)	(0.111)	(0.086)	(0.252)	(0.253)	(0.374)	(0.026)	(0.026)	(0.030)
Residual × Post	−0.572***			−0.809*			−0.029		
	(0.106)			(0.388)			(0.033)		
Ln (Income per capita)	−2.957**	−7.678**	−1.270	1.408	−3.035	3.016	−0.102	−0.322	−0.058
	(0.990)	(2.293)	(0.911)	(2.924)	(4.747)	(3.666)	(0.308)	(0.661)	(0.362)
Ln (Ticket price)	0.060	0.360**	−0.410*	0.262	0.295	0.524	0.048	0.060	0.062
	(0.113)	(0.119)	(0.166)	(0.245)	(0.202)	(0.515)	(0.033)	(0.128)	(0.317)
Year FE	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Airport FE	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Constant	30.281**	77.590**	15.246	−13.402	33.008	−32.376	1.134	3.403	0.534
	(10.134)	(23.600)	(9.299)	(30.107)	(49.278)	(37.513)	(3.187)	(6.875)	(3.700)
Observations	379	160	219	390	160	230	380	160	220
R^2	0.862	0.842	0.897	0.830	0.838	0.825	0.770	0.792	0.754
Adjusted R^2	0.841	0.81	0.88	0.803	0.80	0.79	0.735	0.75	0.71
Statistical power	1.000	0.810	1.000	1.000	0.697	1.000	0.509	0.053	0.269

Note: Treat equals 1 if the airport is covered by AIR-21 and 0 otherwise. Post equals 1 for years after AIR-21 enactment (2001 to 2005) and 0 otherwise (1996 to 2000). In DDD models, Residual equals 1 if the airport pricing is residual-based and 0 if compensatory-based. Statistical power is computed for Residual × Treat × Post effect (in DDD models) or Treat × Post effect (in subsample DD models). Robust standard errors in parentheses.
$^{+}p<0.10$; *$p<0.05$; **$p<0.01$; ***$p<0.001$.

Testing the second hypothesis, the coefficient of *Residual* × *Treat* × *Post* seems positive for operating income per passenger (β = 1.394, p-value = 0.002, 95% C.I. = [0.533, 2.255]) and for operating ROS (β = 0.102, p-value = 0.009, 95% C.I. = [0.025, 0.179]). Accordingly, AIR-21 seems to have a stronger positive effect on the financial performance of residual- versus compensatory-based airports. Looking at the subsample DD models, the coefficient of *Treat* × *Post* seems positive in cross-subsidizing (i.e., residual-based) airports for both operating income per passenger (β = 1.239, p-value = 0.001, 95% C.I. = [0.500, 1.976]) and operating ROS (β = 0.091, p-value = 0.003, 95% C.I. = [0.0314, 0.151]). The magnitude of the effect is economically significant: AIR-21 coverage seems to lead to a 1.24 USD increase in operating income per passenger (44 per cent increase relative to the overall sample mean) and a 0.091 point increase in operating ROS (25 per cent increase relative to the overall sample mean) for cross-subsidizing (residual-pricing) airports, compared to the control group.

However, AIR-21 has a different effect on the financial performance of non-subsidizing (i.e., compensatory-based) airports. In the subsample DD, the coefficient of *Treat* × *Post* seems negative for both operating income per passenger (β = −0.197, p-value = 0.439, 95% C.I. = [−0.697, 0.304]) and operating ROS (β = −0.013, p-value = 0.609, 95% C.I. = [−0.064, 0.037]). Applying a t-test to compare the coefficients of *Treat* × *Post* in the residual and compensatory subsamples leads to p-values of 0.000 and 0.004 for operating income per passenger and operating ROS, respectively, which means the coefficients are statistically different across subsamples. These results are consistent with Hypothesis 2: financial performance is more likely to improve in airports with residual pricing (i.e., cross-subsidizing airports).

There are only 23 residual airports and 16 compensatory airports across ten years. Given this relatively small sample size, particularly in our subsample DDs, we conduct the statistical power analysis for our regressions. Applying the 'power oneslope' command in Stata, the estimated power is based on the hypothesis that the *Residual* × *Treat* × *Post* coefficient (in DDD models) and *Treat* × *Post* coefficient (in subsample DD models) equals the one that is obtained from our regression against the null hypothesis that the coefficient (i.e., the effect) is zero. As reported at the end of Table V, although the estimated power for the regression with one of our measures of performance (Operating ROS) as the dependent variable is low in the subsample DD models, we have strong statistical power for other regressions.

It is noteworthy that we leverage the AIR-21 intervention, which is exogenous to our model, to mitigate endogeneity issues associated with the platform gatekeeping strategy and the intensity of within-platform competition. Disregarding these endogeneity concerns, one could simply measure within-platform competition by *Airside HHI*. Conducting a similar OLS regression and substituting *Treat* × *Post* with *Airside HHI* leads to qualitatively similar results (as reported in Table A13 of Appendix B).

An Additional Measure for Testing the First Hypothesis and Other Robustness Analyses

We further investigate the difference in the composition of airlines (i.e., complementors) in residual-based (cross-subsidizing) versus compensatory-based (non-subsidizing) airports using an alternative dependent variable: We use the percentage of the number of legacy airlines (i.e., non-low-cost) to all airlines operating in each airport as an alternative dependent variable to test the first hypothesis. The results corroborate our previous findings, showing that after AIR-21 and lower airline entry barriers, the composition of the airside shifts toward legacy airlines (i.e., high-quality complementors) only in residual-based (cross-subsidizing) airports. We report these results in Table A9 of Appendix B.

One may argue that Airports with specific unobservable characteristics may be more likely to be highly concentrated and thus covered by AIR-21. Hence, the impact of AIR-21 might be confounded by those characteristics. We apply a regression discontinuity design to rule out this possibility. Specifically, we look at differences between airports close to the AIR-21 coverage cut-off – more than half of their boarding passengers account for by the top two airlines. Therefore, the estimates produced by this design should not be related to different levels of airside concentration before AIR-21. We also discuss and provide evidence for why the potentially confounding effect of the September 11 attack (in 2001) is not driving our results. Furthermore, we show why the potential difference in risk attitudes between low-cost and legacy airlines does not seem to explain our results either. The details of these analyses, as well as additional robustness tests, have been provided in Appendix B, all of which corroborate our findings.

DISCUSSION

Theoretical Implications

Rapid growth strategies that grant access to many platform participants exacerbate a fundamental tension between positive cross-side and negative same-side network externalities, which drives the product variety versus quality strategic trade-off (Chen et al., 2022; Dushnitsky et al., 2022; Hagiu, 2014). On the one hand, the quality-enhancing strategies recommended in prior studies, predominantly non-pricing strategies (e.g., Claussen et al., 2013; Liang et al., 2019; Rietveld et al., 2021; Skiti et al., 2022), often come at the cost of sacrificing variety. On the other hand, despite the importance of pricing strategies to address the complementors' high-quality contributions (Li and Penard, 2014), the quality implications of pricing strategies have been largely overlooked. Huang et al. (2022), applying economic modelling, illustrate that offering *fixed* subsidies only to high-quality complementors can enhance quality while maintaining variety in monopolistic platforms, but it becomes inefficient if the proportion of low-quality to high-quality complementors is unbalanced. Fu and Lyu (2022) and Lyu et al. (2024) extend this finding and show that competition across platforms and within platforms – among complementors – may add additional limitations to the effectiveness of such subsidies. Wang (2021) also demonstrates that reduced fixed royalty fees for rewarding high-quality complementors may not be sufficient to incentivize high-quality complementors to join the platform in case of fierce within-platform competition. We advance this line of research and demonstrate the benefit-linked cross-subsidization strategy – where subsidies *vary* based on complementors' revenue generation – can maintain the quality of the complementors' contribution (Kretschmer et al., 2022) even when complementors' entry barriers are reduced and competition among complementors is increased.

Platforms often employ a blend of pricing and non-pricing strategies to regulate their market and optimize performance (Boudreau and Hagiu, 2009; Dushnitsky et al., 2022; Gawer, 2021; Jing et al., 2023; Li and Penard, 2014). However, empirical research on the impact of combining multiple strategic choices on platform performance remains scarce. As notable exceptions, Cennamo and Santalo (2013) demonstrate the detrimental impact on platform performance of combining two strategies: expanding product variety while imposing exclusivity agreements with complementors. Dushnitsky et al. (2022) identify distinct mixes of pricing and non-pricing strategies. They show that pricing strategies, such as imposing membership fees or high transaction fees, are often used as constricting forces to balance more open non-pricing strategies. Our findings reveal a potential complementarity between pricing strategies and less restrictive gatekeeping strategies: benefit-linked cross-subsidization can steer entry dynamics toward high-quality complementors and uphold a favourable heterogenicity of complementors (Weyl, 2010) without the necessity to restrict access. It is worth noting that in our context, the relaxation of entry barriers was enforced by exogenous regulatory intervention, which enables us to mitigate empirical endogeneity issues. Nonetheless, our hypotheses and theoretical framework remain applicable if a higher influx of complementor entry occurs due to a deliberate strategy employed by the platform.

Benefit-linked cross-subsidization strategies are not confined to our empirical context. In several other markets, we can find platform pricing examples that resemble the cross-subsidization strategy that we have studied in this paper. An example is the AdSense scheme in Google and YouTube, where content creators are rewarded based on the value they generate for advertisers through pay-per-click or pay-per-impression methods. Sun and Zhu (2013) show how such an ad-revenue-sharing strategy elevated the quality of contributions from content providers in a major Chinese blogging platform. In the videogame industry, platforms often charge lower royalty fees to superstar game publishers that disproportionately drive console sales by users (Binken and Stremersch, 2009). For instance, Sega charged a standard royalty fee of $10 per game unit for all games compatible with the Genesis console. However, for top high-quality games such as Madden, Sega charged the publisher (Electronic Arts) only $2 per game unit, which was five times less than the standard fee. In 2016, Apple implemented lax app review policies and introduced search Ads, thus lowering entry barriers for app developers and intensifying competition through an advertising auction system for user attention. These governance changes were paired with modified pricing strategies, allowing subscription-based apps with high engagement and subscriber retention beyond one year to benefit from reduced royalties (15 per cent instead of the standard 30 per cent) after the first year. Finally, Amazon typically levies sellers a fixed percentage of their sales based on the product category. However, in specific categories, this percentage decreases in a stepwise fashion as sales increase, suggesting that, in those categories, Amazon applies better pricing to those sellers that generate higher value for the platform.

More broadly, although most studies on platform pricing strategy assume, at least implicitly, a fixed membership fee and/or a fixed rate of royalties/subsidies (Sanchez-Cartas and Leon, 2021), various 'shades' of cross-subsidization pricing exist in practice (Dushnitsky et al., 2022), including the examples mentioned above. Optimal cross-subsidization schemes may change dynamically over time and according to market conditions (Cabral, 2019; Seamans and Zhu, 2014). However, empirical examinations of platform pricing remain relatively underexplored (Sanchez-Cartas and Leon, 2021), with the nuances and dynamics of pricing structures particularly overlooked (Rietveld and Schilling, 2021). Our study introduces a specific cross-subsidization strategy and empirically assesses its implications for quality and performance.

Managerial Implications

Our paper also issues an open call to platform managers regarding the merits of the proposed benefit-linked cross-subsidization pricing strategy. Platforms aiming to capitalize on larger cross-side network externalities without undermining incentives for quality – driven by negative same-side network externalities – should seriously consider adopting this pricing approach. For instance, the Digital Markets Act, which was recently introduced in the European Union, requires Apple to allow third-party app stores to distribute apps on its iOS devices. This regulation could lead to an influx of a larger pool of app developers. However, this increased entry and heightened competition among developers can dilute the incentives for high-quality app development. Apple can mitigate this effect by incentivizing quality through the endorsement and promotion of high-quality complementors (Dewan et al., 2023; Rietveld et al., 2019, 2021). Additionally, according to the arguments we posit in this paper, Apple can further reduce royalties for specific high-quality apps based on user rating and engagement. By rewarding developers based on their value generation and quality contributions (Fu and Lyu, 2022; Shi et al., 2021), Apple can nudge developers' entry and offerings toward high-quality contributions.

Limitations and Avenues for Further Research

Our study exhibits several limitations, highlighting the need for further research. First, our primary measure of complementors' quality does not gauge the quality as perceived by users but rather its direct impact on complementors' sales. We posit that this serves as a suitable proxy for complementors' quality as defined in the works of Cennamo and Santalo (2019) and Hagiu (2009). Nevertheless, this raises the question of the extent to which our results would remain consistent using user satisfaction measures of quality, which are more common in empirical studies within the platform market literature. Second, we have not explored the rationale behind why certain airports opt for a cross-subsidizing approach rather than a non-subsidizing one. As previously discussed, our findings were unlikely to be influenced by this aspect, as these decisions are typically long-term and remained constant during the period under examination. However, future research utilizing comprehensive historical data on vertical lease agreements between airports and airlines could shed light on which airports have adopted one pricing strategy over another and the implications of these motivations for other platform strategies.

Furthermore, many airports in our sample operate as local monopolies within their respective city markets. This raises the question of the extent to which our findings can be extrapolated to other settings where inter-platform competition is more vigorous. Heightened inter-platform competition could intensify the competition for high-quality complementors or, conversely, amplify the benefits of price competition irrespective of quality. We leave examining the performance impact of benefit-linked subsidization strategies as an intriguing avenue for future research. In addition, we have developed the possibility that the benefit-linked cross-subsidization strategy aids platforms in retaining and attracting the right type of complementors and incentivizing them for quality investments. However, we have not directly examined its impact on complementors' behaviour. We conjecture that, with such a pricing strategy, complementors may be more motivated to engage in behaviour that benefits the participants on the other side, thereby enhancing platform performance. For instance, in our context, it might be plausible that airlines operating in cross-subsidizing airports may find it beneficial to induce passengers' expenses at the airport terminals (for instance, by withholding onboard sales). In a different context, for instance, if Apple or Google were to adopt a benefit-linked pricing strategy on their app stores, this approach could not only encourage the selection of high-quality app developers but also incentivize them to update their apps more frequently or invest more in marketing campaigns to expand their user base further.

CONCLUSION

Our study has demonstrated that a benefit-linked cross-subsidization strategy, where subsidies are adjusted based on complementors' revenue generation, can sustain complementors' quality contribution even in environments with reduced complementors' entry barriers and increased competition among them. Therefore, this pricing strategy could mitigate the trade-off between variety and quality in multisided platforms, enabling platforms to maintain both the breadth and depth of complementors and their offerings. We hope our paper inspires future research to explore the impact of combining distinct pricing strategies and non-pricing strategies on platform performance.

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NOTES

[1] By platform complementors, we *generally* refer to suppliers of complementary products or services, providing their offerings to the platform users. For instance, in videogame consoles, complementors are videogame publishers and in crowdsourcing platforms such as Upwork, complementors are freelancers who offer their services on the platform.

[2] The trade-off is particularly salient in contexts in which entry barriers for complementors are lowered because of exogenous factors, such as regulatory requirements (as in our context) or strategic decisions by the platform owner.

[3] For the sake of parsimony and without loss of generality, we refer to the participants on the other side as 'users'. For more nuances, particularly on platforms with more than two sides (as in our research context), see Appendix A, 'Additional Notes on Airports as Multisided Platforms' section.

[4] One may argue that the airport industry is an example of a multiproduct business rather than a multi-sided platform. We discuss this in detail in Appendix A.

[5] We can thus safely assume that once we observe a pricing approach for an airport for any year between 1996 and 2005, either from ACI-NA surveys or from airports' competition plans, the same pricing regime will be used for a few years before or after. Alternatively, as a more conservative approach, we conduct our analyses using only the data in ACI-NA 1998 and considering the expiration date of the agreements, which leads to qualitatively the same results – not reported here but available upon request.

[6] Operating income is the profit or loss from airports' aeronautical and non-aeronautical operations (i.e., operating revenue minus operating costs), and it may have positive or negative values. Thirteen observations pertaining to seven airports (in both control and treatment groups) have negative operating income. If we carry out the natural logarithm transformation and treat those observations as missing data, our findings suffer from probable sample selection bias. Therefore, we do not use the natural logarithm transformation for this ratio.

[7] This analysis would have been more conclusive if we had been able to consider ROA or ROE as an additional measure of performance. However, the huge amount of unreported data in the FAA records on airports' assets before 2000 made it impossible for us to compute these variables.

[8] We exclude hybrid-pricing airports (23 airports). Importantly, hybrid-based airports subsidize airline landing fees with only a certain part(s) of non-airside revenues (e.g., from parking alone or from a specific category of commercial concessionaires, such as food and beverages) (Faulhaber et al., 2010). Since our reasoning is based on passengers' retail spending profile, including the hybrid-pricing airports creates *noise* in our analysis: Some may cross-subsidize only through parking and/or car-rental revenue, for which we do not have information. Having said that, the main results (not reported here but available upon request) follow a similar pattern if the hybrid airports are also included.

[9] More explanation and robustness tests pertinent to the airport pricing schemes have been provided in 'The Possibility of Anti-competitive Actions by Incumbent Airlines' and 'The Possibility of Airlines' Risk Attitude as an Alternative Mechanism' sections and Table A10 of Appendix B.

[10] Although the correlation between dependent variables for testing the first and second hypotheses – operating income and Ln (commercial revenue per passenger) – is only 47 per cent, we explore this potential issue further in Tables A14 and A15 of Appendix B.

[11] $100 \times (e^{-\beta=0.540} - 1)$.

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