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cege Discussion Paper

No. 425

July 2021

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GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

ISSN: 1439-2305

Business Flies: The Trade Promoting Effect of Air Connectivity*

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First version: July 11, 2021

Abstract

Despite the increasing dominance of digital technology in modern communications, face-to-face interactions are believed to play an irreplaceable role in facilitating complex cross-border business transactions. However, empirical research to identify the impact often faces the challenge of two-way causality when cross-country in-person meetings are measured by international air passenger flows. We propose a novel instrumental variable to estimate the causal effect of international air travel on bilateral trade. Our identification strategy exploits variations in connecting flight capacities in the global flight network to leverage exogenous variations in the air connectivity between two countries. With the inclusion of stringent fixed effects in our estimations and checked for robustness against many possible threats to the identification, our results show that international air connectivity facilitates trade between countries, but only for industries with a higher reliance on relationship-specific investments or incomplete contracts. We also find that stronger enforcement of contracts in the importing country amplifies the trade promoting effect of air connectivity, and that trade in new products, relative to existing products, responds more positively to improved air transport links. Together, these findings suggest that in-person communications reduce transaction costs in international trade by facilitating the exchange of complex knowledge that cannot be easily and completely codified and by breaking market entry barriers.

Keywords: air connectivity, face-to-face communications, connecting flights, trade

JEL classifications: F1, F2, R4

*We are grateful to the participants of seminars at the University of Göttingen and De Montfort University for their valuable comments. Zheng Wang acknowledges the British Academy (grant no. SRG1920\100546) for financial support on this research. The usual disclaimer applies. Please address all correspondence to: Zheng Wang. Postal address: Hugh Aston Building, De Montfort University, Leicester, LE1 9BH, United Kingdom. Email: zheng.wang@dmu.ac.uk.

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1 Introduction

In this modern-day world, instant communication technology becomes increasingly accessible and versatile while long-distance travel remains relatively expensive and time consuming, leading to the expectation of a rapidly diminishing importance of face-to-face meetings in business relations. However, the real-world data suggests that the demand for business travel appears to be surprisingly resilient to this sweeping technological revolution.[1] This contrast leads to the question: to what extent could in-person communications be replaced, or rather not replaced, by the virtual communication technology? In this paper, we ask this question in the context of international trade: how do face-to-face interactions, measured by air passenger connectivity between countries, facilitate exports?

While some recent evidence has come to light suggesting that face-to-face contact still has an irreplaceable role to play in a workplace setting,[2] the benefits of in-person communications are relevant for international trade for unique reasons. First, the share of knowledge and technology intensive goods in global trade has been rising as a result of general technological progress (National Science Board, 2018). Second, the prevalence of globally organised production, as evident in the growing dominance of intermediate products (UNCTAD, 2020) and value-added creation activities (Wang et al., 2017; Li et al., 2019) in global trade, means a buyer-seller relationship is most likely part of an intricate international production chain, connected with other trade transactions in an intertwined production network. Combined, these forces make international trade more sophisticated and more reliant on the transmission of complex information between transaction parties, driving the demand for face-to-face meetings as measured by international business travel (Cristea, 2011). The importance of air connectivity in maintaining international business networks is also reflected in a cross-country survey which shows that most companies surveyed consider air services vital or very important in meeting their domestic and foreign customers (Air Transport Action Group, 2005). Nevertheless, surprisingly, the notion that in-person interactions stimulate international trade has so far relied almost entirely on anecdotal or descriptive evidence, and the lack of a rigorous causal evaluation, which is crucial for policy decisions, leaves a significant gap for empirical quests.

Our paper fills this void of knowledge by using a novel identification strategy to quantify the

[1] According to the data from the World Travel and Tourism Council, the average year-on-year growth rate of business travel spending for the period 2000-2019 was 4.1%; see https://wttc.org/Research/Economic-Impact. During the same period, the world average annual GDP growth rate was 5.1%; see https://databank.worldbank.org/.

[2] It is shown that in-person interactions remain a powerful means of stimulating creativity (Xiao et al., 2021), improving productivity (Battiston et al., 2021), generating knowledge spillover (Frakes and Wasserman, 2021), and delivering technological know-how that cannot be easily codified (Storper and Venables, 2004).

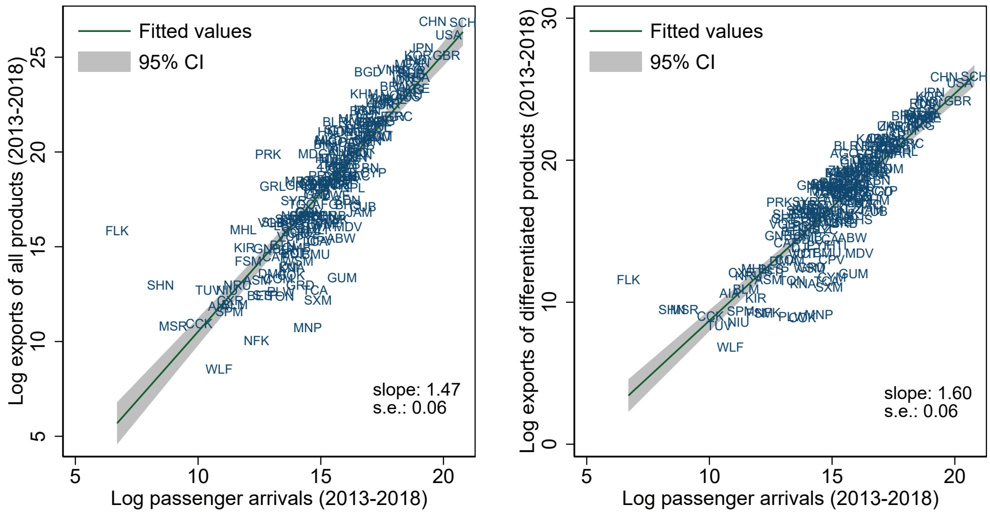

Figure 1. Passenger arrivals and exports by country: 2013-2018. Vertical axis is the log value of total exports in the left figure and the log value of exports of differentiated products in the right figure. Differentiated products are those that are neither traded on organised exchanges nor reference priced in trade publications. Sources of data: OAG for passenger flows, CEPII-BACI for export value, and Rauch (1999) for the classification of products.

causal impact of in-person communications on international trade on a global scale. Following the literature (Andersen and Dalgaard, 2011; Cristea, 2011; Hovhannisyan and Keller, 2015), we use international air passenger traffic to measure in-person communications across countries. Figure 1 shows compelling evidence that countries which attract more international passengers also export more to the world, especially so for differentiated products. However, correlation at this face value by no means implies causality because of the obvious endogeneity of passenger flows. To isolate the causal effect from spurious correlations, we employ an instrumental variable approach to leverage the exogenous variation in air connectivity between two countries. We do so by exploiting changes in the connecting capacity of transit airports in third countries. This identification strategy depends crucially on the geographical coverage and granularity of data: it requires detailed information on air passenger flows of all flight segments of the entire global flight network. This demanding task is made possible by a uniquely rich air traffic data set we use. The data is disaggregated at the itinerary-level and covers virtually the universe of all scheduled passenger flights in the entire world, allowing us to track passenger flows associated with all flight legs and connecting points (if any). Thus it serves as an ideal source of data for studying connecting options in a global network setting.

Specifically, this estimation strategy is based on the idea that for two countries A and B, when a third country C has a higher connecting capacity for passengers travelling from the rest of the world (excluding A) to B, it also facilitates passengers travelling from A to B, thus improving the air connectivity between these two locations. Since the connecting capacity of the third country C defined above excludes connections between A and B, it should be mainly driven by the connecting demand of the rest of the world for destination B, which is independent of the demand for travel between the pair A and B. Conditional on a set of control variables, including origin and destination country specific time trends to capture demand or supply shocks intrinsic to these countries, this external connecting capacity provides a source of plausibly exogenous variation for air connectivity at the country-pair level.

Our baseline results show that the trade impact of air passenger connectivity is heterogeneous: it depends on the contract intensity of the industry, a measure of the dependence of an industry on relation-intensive inputs (Nunn, 2007). Specifically, air connectivity between countries does not affect trade in products belonging to industries with relatively low contract intensity, while for industries with relatively high contract intensity the effect is estimated to be both statistically and economically significant. For an industry which is one standard-deviation above the average contract intensity, our estimated trade volume effect is approximately 5% for an 100% increase in air connectivity. On the global scale, this means that doubling the current air passenger connectivity between countries would create nearly 2 trillion USD exports of contract-intensive products, surpassing the size of the economy of Canada or Sub-Saharan Africa in 2018. When benchmarked against the effect of import tariffs, the above estimated trade promoting effect is equivalent to a 35%-41% cut in the world average *ad valorem* tariff rate.

Our finding that the trade promoting effect is prevalent only for contract-intensive products that rely heavily on relationship-specific investment suggests that improved air connectivity facilitates trade through reducing information asymmetries and subsequently reducing contract incompleteness. In our further analysis, we find that air connectivity is complementary to the strength of contract enforcement of importers, indicating that a decline in contract enforcement frictions with more face-to-face communications is another channel though which air connectivity affects trade. Air connectivity is also found to be more effective in promoting the trade of new products, relative to exiting products, to existing markets, highlighting the positive role of face-to-face business interactions in breaking market barriers that involves sunk costs.

This research contributes to the existing literature in several ways. First, with a novel identification strategy our paper adds new credible evidence on the impact of transport network or transport cost on economic outcomes. A large body of empirical work has looked at the development of transport network or technology on economic growth (North, 1958; Fogel, 1964; Blonigen and Cristea, 2015; Campante and Yanagizawa-Drott, 2017; Donaldson and

Hornbeck, 2016; Donaldson, 2018; Cristea, 2020), international trade (Baier and Bergstrand, 2001; Feyrer, 2009; Hummels, 2007; Bernhofen et al., 2016; Alderighi and Gaggero, 2017), and foreign investment (Campante and Yanagizawa-Drott, 2017; Fageda, 2017). While all of them point to a positive impact, a key challenge with the empirical work on air links is finding a suitable instrument that provides exogenous variation in connectivity at the country-pair level. This paper contributes a novel instrumental variable for the estimation of the causal effect. The global itinerary-level air traffic data that we use enables us to exploit all possible connecting routes between countries and use third countries' connecting capacity as a leverage to isolate exogenous variation in air connectivity. The validity of this instrument can be extended to many other settings, for example the evaluation of the impact of air connectivity on a plethora of social and economic outcomes. The credibility of our estimation is further enhanced by the use of stringent fixed effects that control for a wide set of confounding channels to mitigate possible bias from omitted variables.

Second, our finding that air passenger connectivity promotes trade only in contract-intensive industries is consistent with the importance of in-person communications in trade transactions. Face-to-face business meetings are widely believed to be able to help overcome informational barriers and facilitate knowledge transfer (Andersen and Dalgaard, 2011; Hovhannisyan and Keller, 2015), lubricating transaction frictions and enhancing the chance of securing a deal. This mechanism implies that the trade promoting effect of in-person communications should be more prominent in business deals that involve more relation-specific investments or complicated knowledge which would be difficult to specify without a physical visit or meeting. Cristea (2011) finds that indeed demand for business travel is higher in industries that are more relation intensive or produce more sophisticated products. Our research supplements her study in that we estimate the causal impact in the opposite direction: better air connectivity leads to more trade opportunities in industries which require more relation-specific investments hence in-person interactions.

Third, this study also enriches the literature on the role of social networks in international trade. The existing evidence suggests that, other things equal, more trade happens between countries that are more closely connected through ethnic and cultural linkages (Rauch, 1999, 2001; Rauch and Trindade, 2002), or through friendship networks formed on social media (Bailey et al., 2021). Our findings imply that economic relationships between countries can also be strengthened by international transport links and especially so for industries involving complicated contracts.

Finally, to the best of our knowledge, our constructed measure of air connectivity is the first of its kind at the country-pair level and on a global scale. In particular, this measure supplements and improves the country-level air connectivity score published by International Air Transport Association (2020), and can be readily matched with other country-pair-level data, providing a granular and useful resource for research on a wide range of topics across many disciplines.[3]

The rest of our paper proceeds as follows. In Section 2, we introduce the empirical strategy, with a detailed explanation on our instrumental variable approach. Section 3 describes the data and summary statistics. Section 4 presents the baseline results, robustness checks, and further analysis looking at the role of contractual environment and extensive and intensive margins of trade. Section 5 concludes the paper.

2 Empirical methods

Our estimations rely on an instrumental variable to identify the causality. In this section, we first motivate and discuss our second-stage estimation specification, and then explain in detail our first-stage strategy which exploits third country connecting capacities in our uniquely rich global flight network data to leverage the exogenous variation in air connectivity.

2.1 Estimation specification

Our baseline empirical specification adopts a gravity framework that follows a large extant literature on the effects of information barriers on international trade (e.g. Rauch, 1999; Rauch and Trindade, 2002; Freund and Weinhold, 2004; Fink et al., 2005; Tang, 2006; Choi, 2010; Juhsz and Steinwender, 2018; Bailey et al., 2021). A key hypothesis of these studies is that a reduction in information costs in trade, facilitated by reduced communication costs or better access to social or business network, leads to more trade between a pair of countries. This relationship is often tested using a gravity equation with a communication cost or network access measure included as an explanatory variable alongside standard trade cost measures (distance, tariffs, common language etc.). This reduced-form empirical approach can be easily rationalised when information costs affect only the variable costs of trade and thus constitute part of the iceberg trade costs in a standard, theoretically derived gravity model (Anderson and van Wincoop, 2004). In the case of information costs affecting the fixed costs of trade, although the theoretical underpinning of the above form of the gravity equation is less straightforward, aggregating firm responses to the country-pair level could still give rise to an empirical equation with a gravity structure (Freund and Weinhold, 2004; Krautheim, 2012).

[3] This measure will be shared with the research community and the public in the format of a panel data set deposited in the public domain.

Our research builds on this body of work by using air connectivity and its interaction term with the industry contract intensity to estimate the effect of in-person communications on trade. Based on the above reasoning, to the extent that improved air connectivity reduces trade frictions or fosters the formation or expansion of business networks through its effects on the variable and/or fixed costs, the trade response to air connectivity at the aggregate level can be formulated with a gravity model.[4]

Specifically, we regress exports of product k from country i to j on our air connectivity measure, that is, annual flight passengers from country j to i. This captures how the ease of travelling from a buyer's country to the seller's country increases the latter's exports. Equivalently, viewed from the buyer's perspective, we look at how the ease of travelling to the seller's country reduces the costs of imports from the seller. In one of our robustness checks, we ignore the direction of travel by using two-way passenger flows as our measure of air connectivity. It turns out that because passenger flows are, in reality, highly symmetric, our results are hardly affected. Considering that business travels mainly affect products that are more vulnerable to information frictions and incomplete contracts (Cristea, 2011), we interact a contract intensity index for each product k with the air connectivity measure, which constitutes our main variable of interest. Our baseline empirical specification thus takes the following form:

$$\begin{aligned} Exports_{ijkt} = {} & \beta Connectivity_{ijt} + \theta ContractIntensity_k \times Connectivity_{ijt} \\ & + \mathbf{X}_{ijkt}\mathbf{\Gamma} + \delta_{it} + \omega_{jt} + \eta_{ij} + \sigma_k + \epsilon_{ijkt}, \end{aligned} \tag{1}$$

where the outcome variable $Exports_{ijkt}$ is the natural logarithm of annual exports of product k from country i to country j in year t. $Connectivity_{ijt}$ is the air connectivity measure constructed as the number of air passengers from j to i in year t. This measure differs from the country-level connectivity measure of International Air Transport Association (2020) in that ours is defined at the country-pair level and thus more granular. We use two alternative air connectivity measures in our empirical analysis: the number of all passengers and the number of connecting passengers. The latter is crucial for our identification as our instrumental variable exploits improvement in external flight capacity in third countries for connecting flights. More details about our identification strategy are discussed in the next section and in Appendix. $ContractIntensity_k$ measures the intensity of contract requirement for each six-digit industry (US IO sector) k and is originally from Nunn (2007). Its interaction with the connectivity measure allows for differential effects of air connectivity on trade of contract-intensive versus less contract-intensive goods.

[4]To more explicitly address the influencing mechanisms of air connectivity through its effect on the fixed costs, we check the extensive and intensive margins separately in Section 4.3.2.

More precisely, the coefficient β measures the average effects of air connectivity on exports of products that are not contract-intensive (reference products), and θ measures the additional effects on contract-intensive products relative to the reference counterparts.

The vector $\mathbf{X}_{ijkt}$ denotes a set of control variables that may affect trade within country pairs, including the log value of the average tariffs imposed by country j on product k from country i,[5] and a dummy variable indicating whether country pair ij is in the same regional trade agreement in year t. Taking advantage of the multidimensional nature of our data set, we include a rich set of fixed effects in our estimation. δ_{it} and ω_{jt} denote the exporter (arrival country)-year and importer (sending country)-year fixed effects, respectively, capturing all time-varying factors at the respective country level that may simultaneously affect trade and air connectivity between countries. Specifically, δ_{it} captures all supply shocks to country i that affect its export supply, such as productivity increase, technology advancement, etc., which could also attract more travellers. Analogously, ω_{jt} accounts for all demand shocks to importers, for instance, income growth, that raise average import demand and also allow more people to travel. η_{ij} is the country-pair fixed effects, controlling for all time-invariant country-pair specific factors, such as the typical gravity variables including distance, adjacency, common language, common currency, colonial links, etc. σ_k is the product fixed effects, controlling for all time-invariant factors at the product level. ϵ_{ijkt} is the error term. We cluster standard errors at the country-pair level to allow for possible correlations of estimation residuals within country pairs.

2.2 Identification strategy

The identification of the effects of air connectivity on exports in Equation (1) derives from inter-temporal variations in air passengers from country j to i conditional on all baseline controls and fixed effects, allowing for heterogeneity between products with varying contract intensity. Any potential threats to the identifying assumption would come from unobserved time-variant factors at the country-pair level that are correlated to both travels and trade. One possible example is bilateral economic linkages, through foreign direct investment for instance, which raise demand of air travels, akin to Cristea (2011), especially between distant countries, and which may also promote bilateral trade (Fuchs et al., 2020). Another example is that migration control policies (e.g. visa requirements) and migration between countries may simultaneously affect international travelling and trade (Neumayer, 2011; Artal-Tur et al., 2012; Aleksynska and Peri, 2014) and thereby cause spurious correlations. Due to limited availability of data measuring bilateral migration on a yearly basis, we are not able to fully address possible

[5] Due to the large number of zero tariff rates, they are added the value of one before being converted to logarithms.

endogeneity problems arising from migration. In our later analysis, we use the number of visitors recorded at national borders for selected countries as an alternative measure of air connectivity, which excludes permanent migrants who have already hold a citizenship of the country, and our main findings remain robust. An additional source of endogeneity of our identification is the reverse causality from trade to air connectivity as documented in Cristea (2011).

To address the endogeneity of our air connectivity measure, we employ an instrumental variable approach by exploiting improvements in external connecting capacity that increase connectivity between an origin country and a destination country through connecting flights via third countries. Intuitively, our identifying assumption is that for a given pair of origin and destination countries, an improvement in a third country's air connectivity to the destination country is uncorrelated with the travel demand between these two countries, but makes it easier for a traveller from the origin country to book a ticket in order to travel to the same destination.

The idea is illustrated in Figure 2. In this illustrated example, to travel from airport a in country i to airport b in country j, one can either travel by non-stop flight services (if there are any), or by connecting flight services via an airport c in a third country. In reality, connecting services are more relevant for travelling between distant countries as the availability of non-stop flight services are often limited, as shown in Figure 3. Exogenous improvements in the flight capacity between airports c and b due to, for instance, the opening of new airports or new flight routes, or upgraded fleet or plane size, could benefit passengers travelling from a to b and thereby raise the overall connectivity between a and b. To measure this external connecting capacity, we take the maximum number of monthly air passengers within a year from all airports to b, excluding those from country j and i. This measure constitutes our instrument for the connectivity between a and b, and is indicated by the thick solid lines. In our actual computation, the above air connectivity and external connecting capacity measures are first constructed at the airport-to-airport level, and then aggregated to the country-pair level so that they can be matched to the trade data to facilitate our analysis.[6]

The reason for the exclusion of travels from country j as a departure country from the instrument is to address the concern that connectivity improvement between c and i could be triggered by demand for travel from country j to i, especially when c serves as a major transit point for those who travel between j and i. We use the maximum number of monthly passengers instead of actual yearly passenger flows to ensure that our capacity measure approximates

[6] The OAG data reports flights with up to two connecting points (or three legs of flights). In Appendix we provide more details on how we calculate external connecting capacities for the cases of flight journeys with one or two connecting points, as well as how the constructed measures are aggregated to the country-pair level.

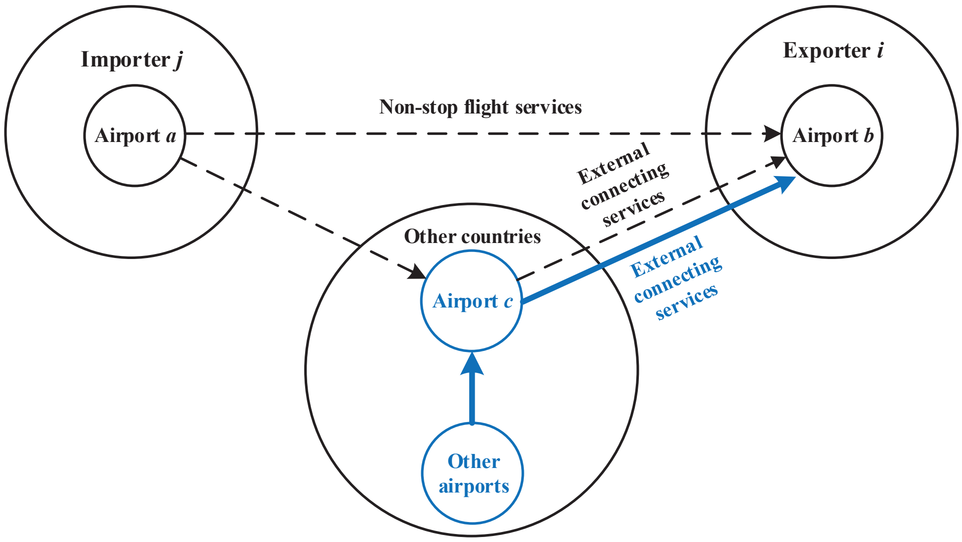

Figure 2. Illustration of the instrumentation strategy. Dashed lines represent flight services that carry passengers for at least part of their journey from airport a in origin country (importing country) j to airport b in destination country (exporting country) i. The dashed line connecting a to b represents non-stop flight services from a to b. The dashed line connecting a to c represents all (non-stop and connecting) flight services from origin airport a to third-country airport c that is located outside countries j and i. The dashed line connecting c to b represents all (non-stop and connecting) flight services from third-country airport c to destination airport b. The solid line connecting c to b also represents all (non-stop and connecting) flight services from third-country airport c to destination airport b, but their passengers originally depart from countries other than j and i. The solid line connecting "other airports" to airport c represents all (non-stop and connecting) flight services from airports outside countries j and i to airport c and their passengers originally depart from countries other than j and i.

the physical capacity (seat numbers) and is not driven by changes in actual travel demand. We also check our results using the annual number of air passengers, and the results remain quantitatively similar.

Notice that our instrumental variable can explain the air links between j and i through connecting flight capacities, but is not related to non-stop flights.[7] When we use the total number of passengers as our air connectivity measure, the instrumental variable can only explain the part of variation that originates from connecting flights. In other words, our identification relies on the variation of air connectivity between j and i that can be explained by exogenous variations in external connecting capacity. In an alternative and our preferred specification where we use the number of connecting passengers as our air connectivity measure, we explore the relationship between external connecting capacity and connecting passengers

[7]Connecting flights and non-stop flights may be substitutes such that improved connectivity through connecting flights may reduce the number of passengers taking non-stop flights.

directly while treating non-stop passengers as a control variable.

Another concern with the instrumental variable is that improved air connectivity between c and i may be driven by increased travel demand due to shocks in country i which in turn affect its exports. This could be the case if country i for example experiences a positive productivity shock that attracts more overseas business partners to country i, while at the same time stimulates country i's overall exports, including exports to country j. As such, improved air connectivity between c and i could be positively correlated with i's exports to country j through a channel other than air connectivity between j and i, and the exclusion restriction assumption would be violated. This concern is addressed by the exporter-year fixed effects (δ_{it}), which absorb all time-varying exporter-side shocks related to country i that could be correlated with both the air connectivity and trade between country j and i. Analogously, ω_{jt} controls for all time-varying importer-specific shocks (i.e. shocks of country j) that could drive the correlation between passenger flows and trade.

A second endogenous variable in our main estimation is the interaction term between air connectivity and the contract intensity index. Since the endogenous part solely comes from air connectivity, we use external connecting capacity interacted with the contract intensity index as its instrumental variable. Following Wooldridge (2010), both instrumental variables and a full set of control variables are included in the first-stage estimations of each endogenous variable. Specifically, our first-stage estimations take the following form:

$$\begin{aligned} Connectivity_{ijkt} = \rho ExternalCapacity_{ijt} + \lambda ContractIntensity_k \times ExternalCapacity_{ijt} \\ + \mathbf{X}_{ijkt}\mathbf{\Gamma} + \delta_{it} + \omega_{jt} + \eta_{ij} + \sigma_k + \nu_{ijkt}, \end{aligned} \tag{2}$$

$$\begin{aligned} ContractIntensity_k \times Connectivity_{ijt} = \phi ExternalCapacity_{ijt} \\ + \kappa ContractIntensity_k \times ExternalCapacity_{ijt} \\ + \mathbf{X}_{ijkt}\mathbf{\Psi} + \delta_{it} + \omega_{jt} + \eta_{ij} + \sigma_k + \mu_{ijkt}. \end{aligned} \tag{3}$$

To check the relevance of our instrumental variable with concrete examples, we first present the time trend of connecting passengers, non-stop passengers, as well as external connecting capacity for four selected long-distance country pairs in Figure 3: UK to Australia, Kenya to India, Greece to South Korea, and Mexico to New Zealand. Connecting flights dominate direct flights in all four examples and the number of connecting passengers experienced a considerable growth. More importantly, external connecting capacity shows a very similar pattern, suggesting that external connecting capacity greatly facilitates air connectivity between countries that are relatively far apart. Given the non-existence or small share of non-stop passengers for these country pairs, we expect external connecting capacity as an instrument to be a good predictor of total number of passengers as well.

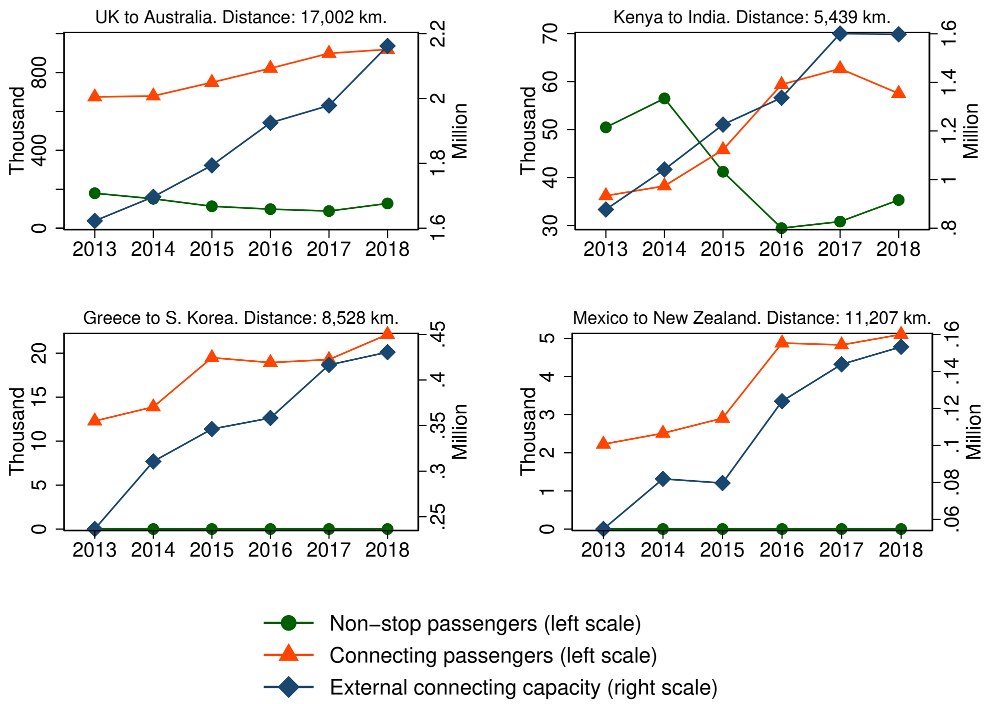

Figure 3. Air connectivity and external connecting capacity for selected country pairs. Source of data: OAG for air connectivity and CEPII Gravity for population-weighted distance between countries.

Figure 4 depicts the general relationships between air connectivity measures and external connecting capacity based on the sample of all country pairs. It is clear that external connecting capacity is positively correlated with both the number of all air passengers and the number of connecting passengers, providing graphical evidence on the relevance of our instrument.

3 Data

In this section we explain the sources of key data sets used in this research and how they are linked together to build the data for analysis. We also describe and discuss the key features of the data.

3.1 Itinerary-level air traffic data

Our air passenger traffic data comes from the Traffic Analyzer database of OAG, a leading commercial provider of aviation data and analysis. The original database we have covers 97% of worldwide scheduled flights, both domestic and international, and is updated monthly from

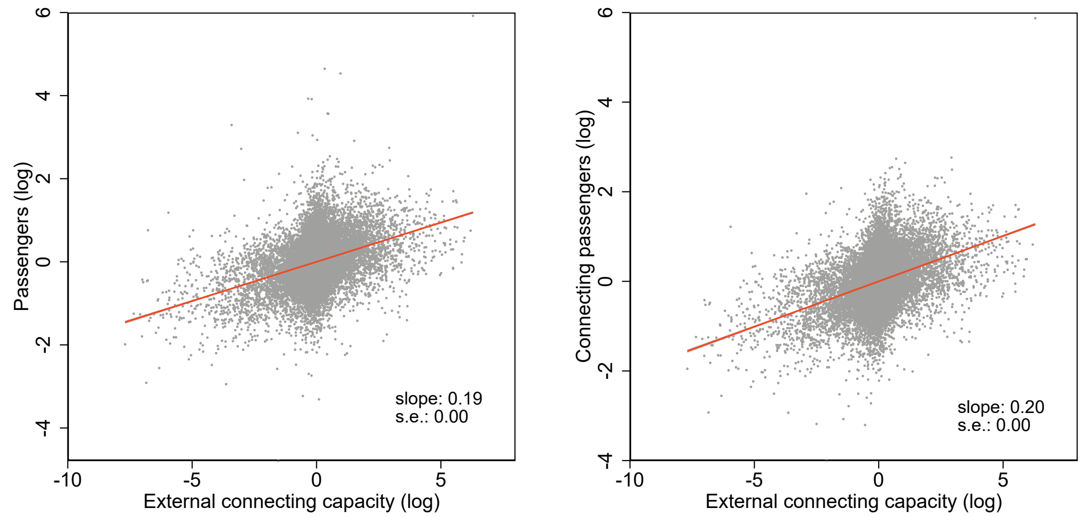

Figure 4. Relevance of the instrumental variable. Each grey dot is an exporter-importer-year observation. The straight lines are linear fits. The data is removed of exporter-year, importer-year, and exporter-importer fixed effects, i.e. each variable y_{ijt} here is taken as the estimation residual $\hat{\varepsilon}_{ijt}$ from the regression $y_{ijt} = \delta_{it} + \omega_{jt} + \eta_{ij} + \varepsilon_{ijt}$, where δ_{it}, ω_{jt}, and η_{ij} are the above fixed effects respectively. Sources of data: OAG.

January 2013 to December 2018. In addition to the near-universal coverage, the itinerary-level granularity is another distinctive feature of this database. The traffic flows are reported by itinerary, i.e. a unique combination of the departure, arrival, and connecting airport(s), as well as the airlines of all flight legs. Other key information provided includes the number of passengers carried, the name of the airline for each flight leg, the total great-circle distance travelled,[8] and the city and country names and codes of all airports associated with an itinerary. Compared to other commonly used air traffic databases, such as the data from International Civil Aviation Organization (ICAO), the highly disaggregated air travel information in this OAG data allows us to trace the full air journeys of travellers. Therefore, we can differentiate flows of passengers who travel by different routes and flights for any given departure and destination airport pair. Specific to the context of this research, the detailed global flight route network data enables us to link the passengers flows between two airports to the connecting capacity of third countries which serve as transit points.

While OAG data covers both domestic and international flights, in this paper we only look at international journeys. For itineraries which have domestic legs, we only extract the international part so that the first leg and the last leg are both international flights. Our first measure of air connectivity uses the number of all air passengers. We then split all passengers into

[8] In case of connecting flights, the reported great-circle distance is the sum of great-circle distances of each flight leg.

connecting passengers and non-stop passengers, and use the number of connecting passengers as the main air connectivity measure while keeping the number of non-stop passengers as a control variable. Connecting passengers are defined as the number of passengers who transit at least once in a third country. Non-stop passengers are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country.

Table A1 in Appendix contains some aggregated statistics of the OAG data for international air traffic. For the period 2013-2018, on average over one billion passengers were carried between more than 26 thousand country pairs every year. Of these international trips, about 85% were carried by non-stop flights, and 15% by connecting flights during the course of which passengers transited at least once before landing in the destination airport.[9]

Table 1 reports more detailed summary statistics of the international air traffic data, summarised at the country-pair-year level. While an average country-pair in a year sees over 43 thousand air passengers travelling from one country to the other, again, about 15% of them are served by connecting flights via a third country. However, the large standard deviations indicate a huge disparity across countries in terms of the size of passenger flows. A caveat in interpreting these patterns is that they are based on raw data so can be heavily driven by country size and distance.

Table 1. Summary statistics of the international air traffic data (2013-2018)

	N	Mean	SD	Min	Max
Number of passengers	160,115	43,444	590,777	1	61,786,240
Number of non-stop passengers	160,115	36,963	575,238	0	61,617,648
Number of connecting passengers	160,115	6,481	46,740	0	3,376,696
External connecting capacity	160,115	762,784	2,682,718	0	85,929,024
Number of external connecting services for a country pair	160,115	44	240	0	11,795

Notes. Data is reported for country-pair-year observations. Source of data: authors' calculation based on OAG.

3.2 Trade and other data

The global trade data used in this paper is from CEPII-BACI trade database (Gaulier and Zignago, 2010), in which the original data is available for all country pairs and six-digit products classified by the Harmonized System (HS). Contract intensities for industries are from Nunn

[9]Our estimation strategy exploits third country connecting capacities, but travels between countries with short distances are mainly served by non-stop flights or ground transport unless a traveller chooses to transit via a third country. We make several attempts to ensure our estimates are not driven by the influence of distance. First, since we control for country-pair fixed effects in all estimations, our baseline estimates are already net of the influence of country-pair-specific factors - including distance - that could be correlated with both air connectivity and trade. Second, in robustness checks, we rerun our estimations by: (1) excluding country pairs with shared land borders, (2) excluding country pairs for which less than half of air passengers travel by connecting flights, and (3) using a specification to allow country pairs with different distances to have different estimates. Results from these alternative samples and specifications are only marginally different from our baseline estimates.

(2007), in which industries are classified as the US Input-Output (IO) Table (1997) sectors. Our tariff data is extracted from the UNCTAD Trade Analysis Information System (TRAINS) database (World Bank, 2020b), specified for each exporter-importer pair and six-digit HS product. Our data on shared borders and distance between countries is obtained from CEPII Gravity database (Head and Mayer, 2014).[10] We use the index of enforcing contracts from the World Bank Doing Business database to measure a country's business regulatory quality (World Bank, 2020a). Other supplementary data used in this paper will be described along with the respective analysis.

3.3 Merged data

We map the import tariff data to the trade data using three-digit country ISO codes and six-digit HS product codes. These product codes are then converted to the US IO (1997) sectors using the concordance provided by the U.S. Bureau of Economic Analysis,[11] and further merged with Nunn's (2007) contract intensities which are also specified at the same IO sector level. Schengen area is treated as a "*country*" due to open border and free travel policies within the bloc, except for Iceland and Greece who do not share land borders with other Schengen members.

Described in Table 2, the merged data covers nearly 16 thousand country pairs, over 300 six-digit industries (US IO sectors), giving us nearly one million exporter-importer-industry triads and 2.7 million exporter-importer-industry-year observations. The two variables that vary at the most granular (observation) level are export and import tariff rates. All passengers-related variables, including the external connecting capacity measure which will be used to leverage exogenous variation in air connectivity, give reasonably large variations for our estimations. A closer look at the specific country/region pairs in Table A2 in Appendix reveals that the most connected countries/regions in terms of overall passenger flows also have some of the largest trade values with each other, but the link is slightly weaker for connectivity measured in the number of connecting passengers.

[10] The distance variable we extract from CEPII Gravity is the population weighted distance between countries, which is different from the great-circle distance in the OAG data.

[11] The concordance can be found at: https://www.bea.gov/industry/historical-benchmark-input-output-tables

Table 2. Summary statistics of the analytical sample

	N	Mean	SD	Min	Max
Number of exporter-importer pairs	15,776				
Number of industries (six-digit)	332				
Number of exporter-importer-industry triads	946,586				
Log export value (exporter-importer-industry-year level)	2,674,087	6.09	3.62	0.00	22.61
Log passengers (exporter-importer-year level)	51,547	6.48	3.51	0.00	16.80
Log non-stop passengers (exporter-importer-year level)	51,547	2.14	4.33	0.00	16.61
Log connecting passengers (exporter-importer-year level)	51,547	6.08	3.09	0.00	15.03
Log external connecting capacity (exporter-importer-year level)	51,547	9.58	3.65	0.00	16.18
Tariff rate (%) (exporter-importer-industry-year level)	2,674,087	4.88	15.04	0.00	3,000.00
Dummy for regional trade agreement (exporter-importer-year level)	51,547	0.17	0.38	0.00	1.00
Industry contract intensity (unstandardized, industry level)	328	0.51	0.22	0.02	0.98
Index of enforcing contracts (unstandardized, exporter-year level)	872	54.10	12.97	20.82	89.16
Index of enforcing contracts (unstandardized, importer-year level)	796	62.39	12.74	20.82	89.16

Notes. Data is reported for country-pair-year observations. Source of data: merged from OAG, CEPII-BACI, and others; see text in Section 3 for exact details.

4 Empirical results

This section presents and analyses the empirical results. We start with a discussion on the baseline results in Section 4.1, followed by robustness checks in Section 4.2 to address various specific concerns about our estimates. We report extended analyses in Section 4.3 to understand the role of contractual environment in exporting and importing countries, and how air connectivity affects trade along the extensive and intensive margins.

4.1 Baseline results

To assess the effects of improved business linkages through air connectivity on trade, we first estimate Equation (1) using the OLS method, and the results are reported in Table 3. Columns (1)-(2) report the estimation results at the country-pair level and columns (3)-(6) present the results at the country-pair-industry level. In all specifications, we use the natural logarithm of exports as the dependent variable. We include an indicator for being in a regional trade agreement (RTA dummy) and product-level tariffs as well as a rich set of fixed effects, including exporter-year fixed effects, importer-year fixed effects, and exporter-importer fixed effects in all specifications, and industry fixed effects additionally in the country-pair-industry level regressions to absorb possible effects of observed and unobserved confounders at these levels.

In column (1) we use the total number of arrival passengers as the measure of air connectivity, and in column (2) we split the total number of passengers into the number of connecting passengers and the number of non-stop passengers. The results show that countries receiving more passengers from a country tend to export more to that country, and such a pattern is more obvious for non-stop passengers. Our results based on country-pair-industry-level estimations show a similar pattern, as seen in columns (3) and (4). Compared to the analysis of country pairs, country-pair-industry level analysis allows for an investigation on the possible heterogeneity

Table 3. Air connectivity and exports: OLS estimates

	Country-pair level		Country-pair-industry level			
Dependent variable: Log of exports	(1)	(2)	(3)	(4)	(5)	(6)
All passengers	0.032**		0.019**		0.014*	
	(0.015)		(0.008)		(0.008)	
Connecting passengers		0.016		0.003		-0.003
		(0.015)		(0.008)		(0.008)
Contract intensity × All passengers					0.024***	
					(0.003)	
Contract intensity × Connecting passengers						0.047***
						(0.003)
Non-stop passengers		0.011**		0.002		0.002
		(0.005)		(0.002)		(0.002)
Tariff	-0.257***	-0.257***	-0.139***	-0.139***	-0.134***	-0.133***
	(0.018)	(0.018)	(0.007)	(0.007)	(0.007)	(0.007)
RTA dummy	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	Yes	Yes	Yes	Yes
Observations	48,228	48,228	2,672,536	2,672,536	2,635,810	2,635,810
Adjusted R^2	0.949	0.949	0.554	0.554	0.555	0.555

Notes. OLS estimates are reported. Time period: 2013-2018. Unit of observation is exporter-importer-year in columns (1)-(2), and exporter-importer-industry-year in columns (3)-(6). “All passengers" are the number of all air passengers, “Connecting passengers" are the number of passengers who transit at least once in a third country, “Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, “Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, “Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-year unit (columns (1)-(2)) or exporter-importer-industry-year unit (columns (3)-(6)), and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

across industries and in particular the role of contract intensity, which is the main interest of this paper. In columns (5) and (6), we respectively multiply the two air connectivity measures with the measure of industry contract intensity, originally from Nunn (2007), to form interaction terms. For the ease of interpretation of its value and marginal effect, the contract intensity measure is standardised so that it has a mean of zero and a standard deviation of one, indicating an industry's degree of reliance on relationship-specific investments relative to an average industry in the sample. The estimated coefficients of the interaction terms in both specifications are positive and highly significant, meaning that air connectivity is associated with higher exports for contract-intensive industries. By contrast, such an association is not observed for less contract-intensive industries. In line with our expectations, the coefficients on tariff rates are negative and highly significant in all specifications, indicating that lower import tariff rates encourage trade.

Although we include a rich set of fixed effects and other control variables, the results in Table 3 can still be biased if there are unobserved factors that are simultaneously correlated with the number of travellers and trade. To address this problem, we employ an instrumental variable approach and estimate Equation (1) using external connecting capacity as the instrumental variable for the number of connecting passengers. Notice that we use it as the instrumental variable for the total number of passengers in the specifications where we do not distinguish between connecting and non-stop passengers; in the specifications that include connecting passengers and non-stop passengers as separate measures, the instrument is only for the former. Accordingly, the instrumental variable for the interaction term is contract intensity interacted with external connecting capacity.

Table 4 reports the first-stage estimation results. In analogue to Table 3, we report results at both the country-pair level and the country-pair-industry level. The results show that external connecting capacity is highly correlated with both the total number of all passengers and the number of connecting passengers with an anticipated sign. This is evident in specifications based on country-pair-level and country-pair-industry-level regressions, and is consistent with Figure 4. In estimations of the interaction term, we observe a strong, positive correlation between external connecting capacity interacted with contract intensity and the endogenous air connectivity measures interacted with contract intensity. Overall, the results in Table 4 reveal that external connecting capacity (and its interaction with contract intensity) is a strong predictor of our air connectivity measures (and their interaction with contract intensity).

Before turning to the second-stage results, we report the reduced-form regression of exports on the instruments in Table A3 in Appendix. The results show that the instrumental variable

Table 4. External connecting capacity and air connectivity: First-stage estimates

	Country-pair level		Country-pair-industry level			
Dependent variable: As in column headings	All passengers (1)	Connecting passengers (2)	All passengers (3)	Contract intensity × All passengers (4)	Connecting passengers (5)	Contract intensity × Connecting passengers (6)
External connecting capacity	0.189***	0.202***	0.139***	-0.137***	0.212***	-0.115***
	(0.005)	(0.005)	(0.013)	(0.013)	(0.009)	(0.011)
Contract intensity × External connecting capacity			0.000	0.997***	-0.000	0.902***
			(0.000)	(0.017)	(0.000)	(0.013)
Non-stop passengers		-0.034***			-0.028***	-0.002***
		(0.003)			(0.003)	(0.001)
Tariff	0.002	-0.000	0.001	0.028***	0.001	-0.007
	(0.004)	(0.004)	(0.001)	(0.006)	(0.001)	(0.004)
RTA dummy	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	48,193	48,193	2,635,810	2,635,810	2,635,810	2,635,810
F	420.29	430.17	33.78	1009.26	134.09	1,039.95

Notes. First-stage results of 2SLS estimations are reported. Time period: 2013-2018. Unit of observation is exporter-importer-year in columns (1)-(2), and exporter-importer-industry-year in columns (3)-(6). "All passengers" are the number of all air passengers, "Connecting passengers" are the number of passengers who transit at least once in a third country, "Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, "External connecting capacity" is the capacity of connecting flight services which depart from a third country, "Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, "Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-year unit (columns (1)-(2)) or exporter-importer-industry-year unit (columns (3)-(6)), and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

is positively correlated with exports at the country-pair level, albeit statistically insignificant. Results that incorporate the industry dimension in columns (3) and (4) show a substantial heterogeneity between industries with differential contract intensities: external connecting capacity is negatively correlated with exports of less contract-intensive products while it has a large and positive correlation with exports of contract-intensive products.

Table 5 examines the above relationships formally by estimating Equation (1) using the 2SLS approach. The first-stage F-statistics at the bottom of the table suggest that we can safely rule out possible weak instrumental variable problems. At the country-pair level, we continue to find positive coefficients on the number of all passengers and connecting passengers but lose statistical significance in both specifications. As we observe in Tables 3 and A3, products with various contract intensities may be affected differently, we thereby turn to country-pair-industry-level estimations in columns (3) and (4) addressing heterogeneity across industries. Improved air connectivity significantly promotes exports of contract-intensive products, as indicated by the positive and highly significant coefficients on the interaction term between contract intensity and the total number of all passengers or the number of connecting passengers. Compared to the OLS estimation results, the coefficient estimates of the 2SLS regressions are modestly larger, implying that the OLS estimates are underestimated.

The estimated coefficients in columns (3) and (4) suggest that for an industry with a contract intensity that is one standard deviation above the average, a 100 percent increase in air connectivity raises exports by $(0.056 - 0.009) \times 100 = 4.7$ or $(0.062 - 0.008) \times 100 = 5.4$ percent, other things equal. As a reference point, the average growth in air connectivity for country pairs during the six-year period 2013-2018 is approximately 140% when measured in the number of all passengers or 130% when measured in the number of connecting passengers. Therefore at the sample mean for the whole sample period, the contribution of the improvement in air connectivity to trade is about 7 ($(0.056 - 0.009) \times 140 = 6.6$, or, $(0.062 - 0.008) \times 130 = 7$) percent increase in export value with either of the air connectivity measures.

Anchored to the world economic data in 2018, doubling air connectivity would increase global trade in contract-intensive industries by $37.95 \times 0.047 = 1.78$ to $37.95 \times 0.054 = 2.05$ trillion USD, larger than the gross output of Canada or all Sub-Saharan African countries combined.[12] Using the estimated coefficients of tariffs in columns (3) and (4), we can also work out the *ad valorem* tariff equivalent of the estimated effect of doubling air connectivity:

[12]World total trade in 2018 is 37.95 trillion USD (World Bank, 2021b). The total GDP of all Sub-Saharan African countries is 1.72 trillion USD in 2018, and GDP of Canada is 1.71 trillion USD according to the World Bank (World Bank, 2021a). In 2018 Sub-Saharan Africa includes 48 countries. The list of those countries can be found at https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=ZG.

Table 5. Air connectivity and exports: Baseline 2SLS estimates

	Country-pair level		Country-pair-industry level	
Dependent variable: Log of exports	(1)	(2)	(3)	(4)
All passengers	0.040		-0.009	
	(0.043)		(0.035)	
Contract intensity × All passengers			0.056***	
			(0.005)	
Connecting passengers		0.038		-0.008
		(0.041)		(0.022)
Contract intensity × Connecting passengers				0.062***
				(0.005)
Non-stop passengers		0.011**		0.002
		(0.005)		(0.002)
Tariff	-0.027***	-0.027***	-0.134***	-0.132***
	(0.009)	(0.009)	(0.007)	(0.007)
RTA dummy	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	48,193	48,193	2,635,810	2,635,810
Kleibergen-Paap F	1,258.89	1,577.48	60.91	275.33

Notes. Second-stage results of 2SLS estimations are reported. Time period: 2013-2018. Unit of observation is exporter-importer-year in columns (1)-(2), and exporter-importer-industry-year in columns (3)-(4). "All passengers" are the number of all air passengers, "Connecting passengers" are the number of passengers who transit at least once in a third country, "Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, "Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, "Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-year unit (columns (1)-(2)) or exporter-importer-industry-year unit (columns (3)-(4)), and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. "All passengers" and "Connecting passengers" are instrumented by "External connecting capacity" which is the capacity of connecting flight services departing from a third country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

$((0.056 - 0.009)/0.134) \times 100 = 35$ or $((0.062 - 0.008)/0.132) \times 100 = 41$ percent reduction in tariff rates. This means that our estimated trade promoting effect of doubling air connectivity is equivalent to a 35%-41% reduction in tariff rates. Considering that the world average tariff rate stands at 4.9 percent in 2018, a 100 percent increase in air connectivity would bring about the same trade growth as a reduction of 1.7 to 2 percentage points in the global average import duties.

To summarise, the results in Table 5 show that improved air connectivity through business travels has a trade promoting effect for contract-intensive industries, and such an effect is economically sizable.

4.2 Robustness checks

4.2.1 Share of connecting passengers, borders, distance, and country size

Our baseline results in Table 5 are based on the full sample of all country pairs with positive imports and/or exports and primarily focus on the role of air connectivity through connecting passengers. Connecting flight services, however, matter more for country pairs that have relatively few non-stop flights. A transit stop in a third country is less likely, for instance, between two neighbouring countries. In this section, we examine the robustness of our results by considering the importance of connecting flights between country pairs.

Table 6 reports the results of the first set of robustness checks, where columns (1) to (4) and columns (5) to (8) use the number of all passengers and the number of connecting passengers to measure air connectivity, respectively. Our first exercise is to exclude country pairs with the share of connecting passengers below 50 percent. The results are reported in columns (1) and (5). We find similar results to those in Table 5 that air connectivity raises exports for contract-intensive industries, and the size of the effects is virtually the same for the two alternative measures of air connectivity. Notice that this approach excludes country pairs for which connecting flights still play a crucial role, though not as important as non-stop flights. In columns (2) and (6), we conduct a more conservative check by excluding country pairs with shared land borders, for which travelling by air through a third country can hardly be the first choice. The estimates remain very close to baseline results.

In columns (3) and (7), we employ an alternative approach to account for the influence of distance on our estimates, assuming that connecting flights are more prevalent for travels between geographically distant locations. In fact, exporter-importer fixed effects have already absorbed the effects of distance on trade. To account for possible heterogeneous effects of air connectivity on distant versus closer country pairs, we interact bilateral distance with our air

Table 6. Robustness checks: Borders, distance, and country size

	Instrumented: all passengers				Instrumented: connecting passengers			
Dependent variable: Log of exports	Excl. country pairs with share of connecting passengers <50% (1)	Excl. country pairs with shared land borders (2)	Effect of distance (3)	Excl. US, China, Schengen Area (4)	Excl. country pairs with share of connecting passengers <50% (5)	Excl. country pairs with shared land borders (6)	Effect of distance (7)	Excl. US, China, Schengen Area (8)
All passengers	-0.036	-0.017	-0.064	-0.013				
	(0.028)	(0.034)	(0.089)	(0.037)				
Contract intensity × All passengers	0.049***	0.056***	0.057***	0.044***				
	(0.006)	(0.005)	(0.005)	(0.004)				
Distance × All passengers			0.062					
			(0.066)					
Connecting passengers					-0.033	-0.013	-0.005	-0.009
					(0.026)	(0.023)	(0.022)	(0.023)
Contract intensity × Connecting passengers					0.050***	0.062***	0.063***	0.049***
					(0.006)	(0.005)	(0.005)	(0.005)
Distance × Connecting passengers							0.015	
							(0.011)	
Non-stop passengers					0.002	0.002	0.002	0.003*
					(0.002)	(0.002)	(0.002)	(0.002)
Tariff	-0.131***	-0.128***	-0.134***	-0.153***	-0.131***	-0.126***	-0.132***	-0.152***
	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)
RTA dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,517,806	2,451,966	2,622,202	2,147,425	1,517,806	2,451,966	2,622,202	2,147,425
Kleibergen-Paap F	192.41	60.95	0.92	63.85	252.24	270.46	110.83	270.35

Notes. Second-stage results of 2SLS estimations are reported. Time period: 2013-2018. Unit of observation is exporter-importer-industry-year. “All passengers" are the number of all air passengers, “Connecting passengers" are the number of passengers who transit at least once in a third country, “Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, “Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, “Distance" is the population-weighted geographical distance between countries, “Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-industry-year unit, and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. “All passengers" and “Connecting passengers" are instrumented by “External connecting capacity" which is the capacity of connecting flight services departing from a third country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

connectivity measures. The coefficients on the interaction terms, however, are statistically insignificant, suggesting that air connectivity influences country pairs with different geographical distances alike. More importantly, conditional on the role of distance, we continue to find highly significant effects of air connectivity on exports of contract-intensive products.

Our last exercise is to exclude the U.S., China and Schengen countries to check whether our results are driven by large economies. Notice that those large economies are both large traders and the most connected regions, as shown in Table A2. In the meantime, connecting passengers between those large economies and many other countries weigh substantively in the number of total passengers, and thereby may play a significant role in affecting trade. The results in columns (4) and (8) show that our main findings still hold without the three large economies whereas the magnitude of the effects has a small drop relative to the baseline results in Table 5, as expected.

4.2.2 *Alternative measures of air connectivity*

Table 7 reports results using alternative measures of air connectivity. In columns (1) and (2), we first consider two-way measures of air connectivity, i.e. passengers flows in both directions between two countries. It follows that export growth due to improved air connectivity can not only be induced by more potential purchasers travelling to the exporting country, but also caused by increased convenience in international marketing activities of exporters. To better capture the summed effects of both possibilities, we use the total number of outbound and inbound travellers between two countries as the measure of air connectivity in column (1), and distinguish between connecting passengers and non-stop passengers in column (2). Our instrumental variables are adjusted in a similar manner. The results show a rather similar pattern to what we observe in Table 5, although the size of the effects turns out to be smaller.

An additional issue with our air connectivity measure is that our passenger flow data does not allow us to identify the purpose of travel. In particular, we do not know how many passengers travel for business. In fact, people can travel for various non-business purposes (e.g. leisure and study) and combine multiple purposes in one trip. As we expect the trade effects of improved air connectivity to be mainly through business travels, we make several efforts to at least partially address this concern by combining our data with international visitors and tourists statistics from World Tourism Organization (2020).[13] First, we exclude

[13]The data contained in the *Yearbook of Tourism Statistics, Data 2014–2018*, released by World Tourism Organization (2020), covers 111 arrival countries and regions for tourists and 63 arrival countries and regions for visitors. The coverage of source countries is more comprehensive, including over 230 countries and regions. According to the *Yearbook*, the counts on tourists and visitors are based on the number of arrivals instead of people, so that "when a person visits the same country several times a year, each visit is counted as one arrival" (World Tourism Organization, 2020). This definition is consistent with the one used in our passenger flow data.

Table 7. Robustness checks: Alternative air connectivity and external connecting capacity measures

	Two-way air connectivity		Excluding tourists		
Dependent variable: Log of exports	All passengers (1)	Connecting passengers (2)	Excl. tourists (3)	Only visitors (4)	Visitors excl. tourists (5)
All passengers	-0.045		-0.587	-0.036	-0.136
	(0.035)		(0.434)	(2.977)	(0.652)
Contract intensity × All passengers	0.039***		0.151***	0.106***	0.043***
	(0.004)		(0.003)	(0.003)	(0.006)
Connecting passengers		-0.031			
		(0.022)			
Contract intensity × Connecting passengers		0.044***			
		(0.005)			
Non-stop passengers		0.001			
		(0.002)			
Tariff	-0.134***	-0.133***	-0.150***	-0.143***	-0.162***
	(0.007)	(0.007)	(0.005)	(0.006)	(0.008)
RTA dummy	Yes	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	2,635,810	2,635,810	403,612	410,883	157,265
Kleibergen-Paap F	63.72	315.78	120.40	11.80	59.77

Notes. Second-stage results of 2SLS estimations are reported. Time period: 2013-2018. Unit of observation is exporter-importer-industry-year. "All passengers" are the number of all air passengers, "Connecting passengers" are the number of passengers who transit at least once in a third country, "Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, "Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, "Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-industry-year unit, and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. "All passengers" and "Connecting passengers" are instrumented by "External connecting capacity" which is the capacity of connecting flight services departing from a third country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

(non-resident) tourists from the total number of flight passengers in column (3).[14] Although some countries report the total number of arrivals including all means of transportation, a large majority exclusively reports tourists arriving by air. Unfortunately, the data on tourists does not distinguish between non-stop and connecting passengers. We therefore can only subtract tourists from the total number of flight passengers. Due to the reduced number of countries and years available, we end up with a much smaller sample size.[15] The estimation results in column (3), however, show that excluding tourists from the passenger flows still yields a strong effect, suggesting that our finding is unlikely to be driven by tourism travels, and the larger size of the coefficient could be the result of a much more restricted country-pair sample.

In column (4), we use the total arrivals of (non-resident) visitors at national borders to focus only on travellers of short-term visit purposes and thus exclude migrants from our air connectivity measure. The estimate becomes smaller than in column (3) but remains positive and statistically significant. In column (5), we further refine our measure by excluding tourists - who by definition are all short-term visitors - from these visitors in column (4) so as to get even closer to the number of international business travellers. The estimated effect is now only modestly smaller than the baseline estimates. Together, with the help of this additional source of data, these checks suggest that our key conclusions still hold when our air connectivity measure is improved to more precisely capture travels of short-term business purposes.

4.2.3 The influence of air cargo shipping

Our main interpretation of the trade promoting effects of improved air connectivity is the reduction in information asymmetries due to more in-person meetings, and our primary identification stems from improvement in external flight capacity in third countries. One threat to this interpretation is that a passenger aircraft often carries freight to utilise its shipping capacity, especially during off-peak seasons. In particular, increased air passenger connectivity due to upgraded fleet size, higher frequencies of flight services, or opening of new routes can be associated with more cargo being shipped along the same route as passenger connecting services. For example, recent anecdotal evidence shows that many airlines use their aircraft for cargo shipping during the Covid-19 pandemic to compensate the loss due to sharp declines in passengers.[16] It then follows that our estimated trade effect of air connectivity could be upward

[14] The *Yearbook of Tourism Statistics* reports the number of arrivals at national borders by both country of residence and/or by nationality. We use country of residence only because the nationality of a traveller can be different from his/her habitual residence.

[15] Of 15,776 country pairs in our data, 2,787 can be matched with the visitors data of (World Tourism Organization, 2020), and 3,840 can be matched to the tourists statistics, accounting for 12.8% and 21.5% global passengers respectively for the period 2014-2018. The list of these country pairs are available from the authors upon request.

[16] See, for example, https://www.nytimes.com/2020/05/25/business/coronavirus-airlines-cargo-passengers.htmlhttps://www.nytimes.com/2020/05/25/business/coronavirus-airlines-cargo-passengers.html

biased as it could be capturing an effect realised through easier cargo shipping in addition to an effect stimulated by better passenger connections.

To address this concern, we need to rule out the influence of cargo air shipping on trade. While data for cargo shipping is not available at this disaggregated level of analysis, we turn to the Chinese customs data from the General Administration of Customs of China, which differentiates the value of trade goods by transportation method (air, sea, road etc.) and by partner country, to compute an index measuring the intensity, or the likelihood, of cargo air shipping for each product, conditional on country-pair-specific factors such as distance and geographical conditions. Specifically, we use the 2012 Chinese customs data to estimate the cargo air shipping intensity based on the following regression:

$$AirShare_{kc} = \boldsymbol{\alpha}^k \mathbf{D}_k + \omega_c + \mu_{kc}, \tag{4}$$

where $AirShare_{kc}$ is the observed percentage of value of trade between China and country c that was shipped by air, $\mathbf{D}_k$ contains the dummies for all six-digit industries, $\boldsymbol{\alpha}^k$ are the associated coefficients of $\mathbf{D}_k$, ω_c is the country fixed effects capturing all time-invariant factors such as distance and geography that could affect the share of air shipping in trade between China and country c, and μ_{kc} is the estimation residual. Our estimated air shipping intensities are extracted from the estimated values of $\boldsymbol{\alpha}^k$, which could be interpreted as the expected likelihood of air shipping. Here the underlying assumption is that after filtering out the influence of distance and geography as well as noise on the choice of transportation method, the air shipping intensities should be similar for all countries as the intensities constructed the above way should mainly reflect the physical and intrinsic features (e.g. unit value and product life) of the product.

Table 8 reports the estimation results separately for four industry categories with increasing reliance on air shipping. Columns (1) to (4) correspond to the results using the total passenger number to measure air connectivity and columns (5) to (8) switch to connecting passengers. Interestingly but as expected, the estimated effect is generally larger for industries in the top percentiles (above 50%) of air shipping intensity than for industries in the lower percentiles, indicating a possibility of upward bias from the confounding influence of cargo shipping. However, for industries with the highest dependence (75%-100%) on air shipping where the influence of this confounding channel is expected to be the largest, the size of the key estimate remains close to our baseline estimates; and for industries with the lowest dependence (0%-25%) on air shipping where the influence of this confounding channel is expected to be minimal, the size of the key estimate is also not distant from the baseline results. Therefore our conclusion

Table 8. Robustness checks: Influence of air cargo shipping

	Instrumented: all passengers Sample: industries with air shipping intensity in region of percentiles:				Instrumented: connecting passengers Sample: industries with air shipping intensity in region of percentiles:			
	0%-25%	25%-50%	50%-75%	75%-100%	0%-25%	25%-50%	50%-75%	75%-100%
Dependent variable: Log of exports	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All passengers	0.139**	-0.046	0.030	-0.118*				
	(0.071)	(0.049)	(0.050)	(0.068)				
Contract intensity $\times$ All passengers	0.047***	0.020***	0.064***	0.053***				
	(0.006)	(0.004)	(0.006)	(0.006)				
Connecting passengers					0.088**	-0.031	0.013	-0.067*
					(0.044)	(0.032)	(0.033)	(0.040)
Contract intensity $\times$ Connecting passengers					0.052***	0.022***	0.072***	0.058***
					(0.006)	(0.004)	(0.007)	(0.006)
Non-stop passengers					0.005*	-0.000	0.004*	0.001
					(0.003)	(0.002)	(0.002)	(0.003)
Tariff	-0.161***	-0.135***	-0.117***	-0.152***	-0.158***	-0.134***	-0.115***	-0.152***
	(0.009)	(0.008)	(0.010)	(0.010)	(0.009)	(0.008)	(0.010)	(0.010)
RTA dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	507,615	795,414	831,693	495,355	507,615	795,414	831,693	495,355
Kleibergen-Paap F	48.96	55.96	52.19	52.13	217.15	258.13	253.38	214.04

Notes. Second-stage results of 2SLS estimations are reported using samples of industries with different air shipping intensities. Industry-level air shipping intensities are estimated from Equation (4). Time period: 2013-2018. Unit of observation is exporter-importer-industry-year. "All passengers" are the number of all air passengers, "Connecting passengers" are the number of passengers who transit at least once in a third country, "Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, "Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, "Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-industry-year unit, and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. "All passengers" and "Connecting passengers" are instrumented by "External connecting capacity" which is the capacity of connecting flight services departing from a third country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

here is that although we cannot rule out the influence of cargo shipping entirely, it is unlikely to be able to explain our main findings.

4.3 Further analysis

4.3.1 The role of contract enforcement

Our results so far suggest that countries better connected by passenger flights trade more with each other in industries characterised by more sophisticated contractual relationships. Now we ask the question: could this finding be explained by better legal environments which offer better support and protection to complex business transactions? A specific concern is that contract incompleteness can be attributed to weak enforcement of contracts as a result of low-quality institutions such as weak rule of law, high levels of corruption, or low levels of trust, which further influence trade (e.g. Anderson and Marcouiller, 2002; Berkowitz et al., 2006; Nunn, 2007; Levchenko, 2007; Álvarez et al., 2018; Bailey et al., 2021). It follows that contract enforcement can be another channel through which increased air connectivity affects trade if face-to-face communications reduce contract enforcement frictions. This could be the case as in-person meetings could shorten socioeconomic distance between potential traders, build up trust, improve relation-based governance, and eventually facilitate contract enforcement (Dixit, 2003; Li, 2003). Empirical evidence shows that, following a reduction of travel costs, face-to-face communications stimulate collaborations among distant scientists (Catalini et al., 2020), suggesting a positive impact on trust, and reduce contract enforcement frictions between buyers and sellers (Startz, 2021).

Nevertheless, how business travels interact with the local environment of contract enforcement is unclear *ex ante*. On the one hand, improved relations between trading partners can be substitutes of local rules of law such that more frequent in-person communications could enhance contract enforcement in countries with inadequate formal institutions (Yu et al., 2015). On the other hand, stronger local institutions could also reinforce the efficiency of business meetings as they can reduce the risk of possible non-compliance of agreements (Berkowitz et al., 2006). In this section, we empirically examine this second possible channel by exploring the role of contract enforcement in fashioning the effects of air connectivity on trade.

We measure the quality of contract enforcement using the enforcing contracts score from the World Bank Doing Business database (World Bank, 2020a). It measures the overall efficiency and quality of contract enforcement by evaluating practices of revolving commercial disputes in the local court system. The original score ranges from 0 to 100 with a higher score indicating better performances. Because the change in the measurement method in 2015 makes the score not directly comparable before and after that year, we standardise the score by each year so

Table 9. Additional checks: Role of contract enforcement

Dependent variable: Log of exports	(1)	(2)
All passengers	-0.020	
	(0.036)	
Contract intensity $\times$ All passengers	0.056***	
	(0.005)	
Exporter enforcing contracts $\times$ All passengers	0.005	
	(0.004)	
Importer enforcing contracts $\times$ All passengers	0.010**	
	(0.005)	
Connecting passengers		-0.016
		(0.024)
Contract intensity $\times$ Connecting passengers		0.063***
		(0.006)
Exporter enforcing contracts $\times$ Connecting passengers		0.006
		(0.004)
Importer enforcing contracts $\times$ Connecting passengers		0.010**
		(0.005)
Non-stop passengers		0.002
		(0.002)
Tariff	-0.136***	-0.134***
	(0.007)	(0.007)
RTA dummy	Yes	Yes
Exporter-year fixed effects	Yes	Yes
Importer-year fixed effects	Yes	Yes
Exporter-importer fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	2,478,696	2,478,696
Kleibergen-Paap F	31.94	130.10

Notes. Second-stage results of 2SLS estimations are reported. Time period: 2013-2018. Unit of observation is exporter-importer-industry-year. "All passengers" are the number of all air passengers, "Connecting passengers" are the number of passengers who transit at least once in a third country, "Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, "Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, "Exporter enforcing contracts" or "Importer enforcing contracts" are standardised measures of the strength of contract enforcement in the exporting or importing country respectively, "Tariff" is the log of one plus the weighted average tariff rates for an exporter-importer-industry-year unit, and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. "All passengers" and "Connecting passengers" are instrumented by "External connecting capacity" which is the capacity of connecting flight services departing from a third country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

that it falls between 0 and 1 with a larger value indicating an easier enforcement of contract relative to other countries in the same year. Considering that the enforcement of contract in both importing and exporting countries matters for trade (Berkowitz et al., 2006), we interact the indicators for both countries separately with air connectivity. Notice that the average effects of contract enforcement are absorbed by importer-year and exporter-year fixed effects. The interaction terms capture the possible differential effects of air connectivity on countries with heterogeneous environment of contract enforcement.

The results are reported in Table 9, where column (1) uses total number of air passengers and column (2) uses the number of connecting passengers as measures of air connectivity. The positive sign of the interaction term of air connectivity and importer's quality of contract enforcement suggests that there exists a complementarity between the two: air connectivity could further promote trade when the importing country has stronger enforcement of contracts. The exporting country's quality of contract enforcement is also estimated to have a positive influence but the effect is not statistically significant. Although we are unable to identify the exact causes, a possible explanation could be related to the prevalence of trade finance in trade transactions: a more creditworthy buyer (importer) can be associated with a stronger market power which allows the buyer (importer) to extract more favourable contract terms from the supplier (exporter) (Klapper et al., 2011), securing contracts of higher values.

Controlling for the effects of contract enforcement, the results for contract intensity remain essentially unchanged. Comparing the estimated sizes, relative to contract enforcement, in-person meetings facilitated by better air connectivity appear to play a dominant role in promoting trade.

4.3.2 Effects along the intensive and extensive margins of trade

Trade theories with firm heterogeneity underline the role of fixed export costs in affecting firms' decision to export such that only productive enough firms are able to export (Melitz, 2003; Chaney, 2008). An important source of fixed costs of exports is related to market research before exporting which involves finding potential buyers and learning about foreign regulatory environments. Improved air connectivity between countries can substantively reduce the fixed costs of market research by lowering informational barriers and matching frictions between buyers and sellers, which subsequently promote exports along the extensive margin by exporting more new products. Here we explore possible heterogeneous effects along the intensive and extensive margins of trade.

To this end, we update our merged data so that all products are now defined at the six-digit HS level. For a given country pair, new and old products are defined by whether they have been exported by the exporter to the importer before. Considering that more sophisticated products generally require exchanges of more complex information in their transaction process, we further decompose both old and new products into homogeneous products and differentiated products using the classification of Rauch (1999) or our own criterion which is based on the price dispersion of products.[17] For each country-pair in a year, we then aggregate trade data

[17] In the original classification of Rauch (1999), products are separated into three categories: those traded on an organised exchange, those with reference prices, and differentiated products. Here we follow the same list of differentiated products, whereas homogeneous products are the other two categories (those traded on an organised exchange or with reference prices). The original classification is at the four-digit SITC level. To map it to our

to four product categories: old homogeneous, old differentiated, new homogeneous, and new differentiated. To see how our estimated effect varies across these product categories, we now run regressions where each observation is a unique combination of exporter, importer, product group, and year, and the key parameters to check are the coefficients of the interaction terms between product category dummies (with old homogeneous as the omitted group) and our air connectivity measures.

Table 10 reports the results, where the differentiation of homogeneous and differentiated products in columns (1) and (3) follows Rauch's (1999) classification, and the differentiation in columns (2) and (4) is based on the deviation from the median of the price dispersion from our own calculation using trade data. Echoing our earlier results on contract intensity, the effect of air connectivity on exports is estimated to be modestly larger for differentiated products than for homogeneous products, and this difference holds for both existing and new products. Moreover, relative to existing products, the effects on new products are much larger, underlining the more salient effects along the extensive margin of trade. This last finding is consistent with the existence of fixed costs in trading new products which were not previously sold to the existing markets, highlighting the positive role of in-person business connections in breaking market entry barriers.

data, we convert the classification to the six-digit HS level using the correspondence table provided by the UN Trade Statistics at https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp. The price dispersion for each six-digit product is measured by the coefficient of variation of product prices, i.e. the ratio of the standard deviation of price to the mean of price for each product. Here the product-specific time trends are removed from prices before the computation to ensure that our price dispersion measure is not driven by product-specific macro factors, i.e. prices are taken as the residuals $\hat{\nu}_{ijky}$ from the regression $Price_{ijkt} = \delta_{kt} + \nu_{ijkt}$, where δ_{kt} is the product-year dummies capturing product-specific time effects.

Table 10. Additional checks: Effects on extensive and intensive margins of trade

	Instrumented: all passengers		Instrumented: connecting passengers	
	Product differentiation based on:		Product differentiation based on:	
	Rauch's measure	Price dispersion	Rauch's measure	Price dispersion
Dependent variable: Log of exports	(1)	(2)	(3)	(4)
All passengers	-0.094	-0.024		
	(0.074)	(0.075)		
All passengers× Old differentiated	0.123***	0.004**		
	(0.004)	(0.001)		
All passengers× New homogeneous	0.243***	0.234***		
	(0.002)	(0.002)		
All passengers× New differentiated	0.321***	0.248***		
	(0.004)	(0.002)		
Connecting passengers			-0.138**	-0.039
			(0.068)	(0.069)
Connecting passengers× Old differentiated			0.175***	0.004**
			(0.006)	(0.002)
Connecting passengers× New homogeneous			0.277***	0.250***
			(0.004)	(0.003)
Connecting passengers× New differentiated			0.376***	0.270***
			(0.006)	(0.003)
Tariff	0.031	-0.221***	0.015	-0.222***
	(0.019)	(0.014)	(0.019)	(0.014)
RTA dummy	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	120,806	129,124	120,806	129,124
Kleibergen-Paap F	125.09	126.86	163.03	161.35

Notes. Second-stage results of 2SLS estimations are reported. Time period: 2013-2018. Unit of observation is exporter-importer-category-year, where category is one of four product categories defined as old homogeneous products (omitted group), old differentiated products, new homogeneous products, and new differentiated products. The differentiation of homogeneous and differentiated products in columns (1) and (3) follows Rauch's (1999) classification, and the differentiation in columns (2) and (4) is based on the deviation from the median of the price dispersion from our own calculation using trade data. The price dispersion for each six-digit product is measured by the coefficient of variation of product prices, i.e. the ratio of the standard deviation of price to the mean of price for each product, and the product-specific time trends are removed from the prices before the computation to ensure that our price dispersion measure is not driven by product-specific macro factors. "All passengers" are the number of all air passengers, "Connecting passengers" are the number of passengers who transit at least once in a third country, "Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, "Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, "Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-category-year unit, and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. "All passengers" and "Connecting passengers" are instrumented by "External connecting capacity" which is the capacity of connecting flight services departing from a third country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

5 Conclusions

Despite the explosive growth in the use of digital communication technology, a widely held belief is that face-to-face interactions still have a robustly important and irreplaceable role to play in facilitating business transactions. In this paper, we estimate the importance of in-person communications between buyers and sellers in international trade from the lens of international air passenger flows. To isolate the causality, we propose a novel instrumental variable by exploiting variations in connecting flight capacities in the global air traffic network. For a given country pair (origin and destination countries of travel), our identification comes from variations in the external capacity of international flights which depart from a third country and provide connecting services for travels between the two countries. With further controls for a range of confounding factors, this instrument leverages the exogenous variations in the air connectivity between two countries.

Defended against many possible threats to our estimates, our result confirms the positive role of international air travels in facilitating trade transactions between countries, but a statistically significant effect is only found for industries with a higher reliance on relationship-specific investments, or industries more likely to be characterised by the use of incomplete contracts. Furthermore, we find that trade in new products, relative to existing products, respond more positively to improved air connectivity. These findings suggest that in-person communications are more useful in areas which involve more risks and exchanges of more complex knowledge that cannot be easily and completely codified.

The significance and implications of our research can also be well placed in the context of the Covid-19 pandemic. As international travels for face-to-face contact are forbidden or largely restricted, international trade has also experienced a significant drop in this unprecedented public health crisis.[18] However, until more recent trade and travel data becomes available, it remains intriguing to see how much of the trade during the pandemic is continued from existing or extended contracts between firms who were already in a business relationship before the pandemic, and how much of it is created from newly formed trade partnerships with or without face-to-face contacts. Against this unique backdrop, a full and careful investigation into the trade response to the travel restrictions will shed further light on the role of in-person communications in modern-day business activities.

[18] According to the World Trade Organization, the global trade in merchandise decreased by 7.5% in 2020 relative to 2019; see `https://data.wto.org/`.

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Appendix

A Construction of the instrument in a flight network structure

A.1 Flight journey with two external connecting points

We start from the case of a flight journey with two external connecting points between an origin country and destination airport. This is illustrated in equation (A1), where j is the origin country, i is the destination country, b is the first arrival airport (entry point) in i, airports c and d are the two external transit points located outside countries j and i, and services s and u are flight services that connect c to d and d to b, respectively. The external connecting route is defined as the entire route that starts from airport c all the way to airport b, including two connecting points (c and d) and two individual connecting flight services (s and u) en route to b.

$$\text{Origin country } j \longrightarrow \overbrace{\underbrace{\text{Airport } c \xrightarrow{\text{Service } s} \text{Airport } d}_{\text{Outside countries } i \text{ and } j} \xrightarrow{\text{Service } u} \underbrace{\text{Airport } b}_{\text{Country } i}}^{\text{External connecting route}} \tag{A1}$$

We measure the capacity of the above external connecting route as the maximum monthly number of passengers carried through the route by the above flight services, including passengers from all origin countries. Although this measure is based on an external connecting route, it could still be partly driven by the travel demand between country j and airport d in that operating airlines could respond to the connecting demand of passengers from country j by increasing their capacity through more frequent schedules and/or the use of aircraft with larger capacity. To address this concern so as to further isolate the exogenous part of this capacity, we refine the measure by excluding passengers from the origin country in question from the total route capacity. This is illustrated in equation (A2), where we construct the capacity measure based on the same route but only include passengers from countries other than j and i.

$$\underbrace{\text{Origin country } m}_{m \neq i,j} \longrightarrow \overbrace{\underbrace{\text{Airport } c \xrightarrow{\text{Service } s} \text{Airport } d}_{\text{Outside countries } i \text{ and } j} \xrightarrow{\text{Service } u} \underbrace{\text{Airport } b}_{\text{Country } i}}^{\text{External connecting route}} \tag{A2}$$

This way, our measure now captures external connecting capacity that is driven by third countries' travel demand. Intuitively, when the external travel demand is higher, it also improves connectivity for passengers traveling from country j to airport b as a result of enlarged overall flight route capacity.

A.2 Flight journey with one external connecting point

Now we consider the case of a journey with only one external connecting point en route from country j to airport b. As illustrated in equation (A3), airport d is now the only connecting point, and service v is the flight that links airports d and b.

$$\text{Origin country } j \longrightarrow \overbrace{\underbrace{\text{Airport } d}_{\substack{\text{Outside countries} \\ i \text{ and } j}} \xrightarrow{\text{Service } v} \underbrace{\text{Airport } b}_{\text{Country } i}}^{\textbf{External connecting route}} \tag{A3}$$

The construction of the exogenous external connecting route capacity is illustrated in equation (A4), where it follows the same steps as in the above case of a journey with two external connecting points.

$$\underbrace{\text{Origin country } m}_{m \neq i,j} \longrightarrow \overbrace{\underbrace{\text{Airport } d}_{\substack{\text{Outside countries} \\ i \text{ and } j}} \xrightarrow{\text{Service } v} \underbrace{\text{Airport } b}_{\text{Country } i}}^{\textbf{External connecting route}} \tag{A4}$$

A.3 Passengers who start their journey from an external connecting routes

If connecting flight services pick up local passengers from any of the connecting airports, these passengers should be included in the external connecting capacity. Specifically, passengers who travel from airport c as their starting point with services s and u in the route of (A2) are already captured in (A4), where airport c is located in one of the third countries m. For the same reason, we calculate the number of passengers who fly from d as their starting point to b with non-stop service v, and add it back to (A4) as part of the external connecting capacity there.

A.4 Aggregation to the country-pair level

To align our air connectivity measure with the trade data, we further aggregate the above capacity measure from destination airports (b) to destination countries (i) so that it is available at the country-country-year level.

B Additional tables

Table A1. Description of OAG international air traffic data - number of country pairs and passengers

	Country pairs	All passengers	Non-stop passengers	Connecting passengers
2013	26,276	986,631,620	838,663,903	147,967,717
2014	26,336	1,043,134,160	885,301,996	157,832,164
2015	26,678	1,106,346,345	936,644,490	169,701,855
2016	26,786	1,189,779,881	1,010,109,571	179,670,310
2017	26,996	1,279,156,257	1,091,092,079	188,064,178
2018	27,043	1,350,996,795	1,156,567,488	194,429,307
Total	160,115	6,956,045,058	5,918,379,527	1,037,665,531

Table A2. Most connected country pairs

Ranked by all passengers (two-way)					Ranked by connecting passengers (two-way)				
Rank	Country pairs	All passengers (mn people)	Share of connecting passengers (mn people)	Trade value (tn USD)	Rank	Country pairs	Connecting passengers (mn people)	Share of connecting passengers (mn people)	Trade value (tn USD)
1	GBR - SCH	642.87	0.01	3,156.08	1	SCH - USA	33.22	0.16	3,407.08
2	SCH - USA	202.61	0.16	3,407.08	2	IND - USA	22.48	0.78	361.96
3	MEX - USA	153.59	0.01	3,090.91	3	SCH - THA	14.41	0.47	227.72
4	CAN - USA	151.84	0.01	3,129.91	4	AUS - SCH	13.16	1.00	259.44
5	SCH - TUR	121.93	0.01	798.29	5	IND - SCH	12.35	0.50	510.52
6	CHN - KOR	91.63	0.00	1,404.78	6	IND - SAU	10.70	0.35	195.64
7	GRC - SCH	89.53	0.02	213.53	7	AUS - GBR	9.63	0.85	49.94
8	NOR - SCH	86.11	0.01	745.81	8	CHN - SCH	8.68	0.19	3,190.80
9	GBR - USA	85.45	0.09	614.89	9	PHL - USA	8.42	0.64	115.04
10	RUS - SCH	79.30	0.03	1,649.70	10	IDN - SCH	7.92	0.81	178.35
11	JPN - KOR	79.14	0.00	470.06	11	GBR - USA	7.59	0.09	614.89
12	CHN - JPN	74.86	0.05	1,607.47	12	USA - VNM	7.34	0.98	261.47
13	CHN - THA	73.49	0.05	396.51	13	CHN - USA	7.27	0.17	3,291.05
14	IRL - SCH	70.45	0.05	567.85	14	JPN - SCH	7.14	0.24	802.01
15	MAR - SCH	63.86	0.01	233.22	15	PAK - SAU	6.90	0.28	21.39
16	CHN - HKG	62.83	0.00	1,756.45	16	AUS - IND	6.79	0.90	100.84
17	ARE - IND	59.47	0.04	253.67	17	GBR - IND	6.66	0.39	92.29
18	GBR - IRL	55.09	0.00	260.85	18	THA - USA	6.13	0.96	224.65
19	JPN - USA	47.43	0.06	1,153.52	19	PHL - SCH	5.41	0.91	109.37
20	CHN - SCH	46.51	0.19	3,190.80	20	ISR - USA	5.05	0.38	142.88

Table A3. External connecting capacity and exports: Reduced-form estimates

	Country-pair level		Country-pair-industry level	
Dependent variable: Log of exports	(1)	(2)	(3)	(4)
External connecting capacity	0.007	0.007	-0.009*	-0.009*
	(0.008)	(0.008)	(0.005)	(0.005)
Contract intensity $\times$ External connecting capacity			0.056***	0.056***
			(0.005)	(0.005)
Non-stop passengers		0.009**		0.002
		(0.005)		(0.002)
Tariff	-0.292***	-0.292***	-0.133***	-0.133***
	(0.017)	(0.017)	(0.007)	(0.007)
RTA dummy	Yes	Yes	Yes	Yes
Exporter-year fixed effects	Yes	Yes	Yes	Yes
Importer-year fixed effects	Yes	Yes	Yes	Yes
Exporter-importer fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	48,193	48,193	2,635,810	2,635,810

Notes. Reduced-form estimates are reported. Time period: 2013-2018. Unit of observation is exporter-importer-year in columns (1)-(2), and exporter-importer-industry-year in columns (3)-(6). “External connecting capacity" is the capacity of connecting flight services which depart from a third country, “Contract intensity" is an industry-level standardised measure of reliance on relation-specific investments, “Non-stop passengers" are the number of passengers who travel by a non-stop flight service between the last departure point in the origin country and the first entry point in the destination country, “Tariff" is the log of one plus the weighted average tariff rate for an exporter-importer-year unit (columns (1)-(2)) or exporter-importer-industry-year unit (columns (3)-(4)), and RTA dummy is an indicator for both countries being in a same regional trade agreement. All passenger numbers are in logs and defined as from the importing to the exporting country. See text for sources of data. Standard errors reported in parentheses and clustered at the importer-exporter level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.