Received: 26 May 2021 | Revised: 10 January 2022 | Accepted: 18 January 2022

DOI: 10.1111/twec.13245

ORIGINAL ARTICLE

The World Economy WILEY

The determinants of air cargo flows and the role of multinational agreements: An empirical comparison with trade and air passenger flows

Katrin Oesingmann[1,2]

[1]Department of Economics and Policy, TUM School of Management, Technical University of Munich, Munich, Germany

[2]Institute of Air Transport and Airport Research, German Aerospace Center (DLR), Cologne, Germany

Correspondence
Katrin Oesingmann, Department of Economics and Policy, TUM School of Management, Technical University of Munich, Munich, Germany.
Email: katrin.oesingmann@tum.de

Abstract

This paper analyses the effect of the standard gravity model variables and of various multinational agreements—namely the Euro, the European Union (EU), the Schengen Agreement and other regional trade agreements (RTAs)—on the volume of air cargo flows. To compare the impacts, the data set created for this analysis contains intra- and extra-European air cargo flows as well as data on air passenger and total trade flows. The results suggest that the impact of the analysed multinational agreements on air cargo flows diverges completely from their impact on total trade flows—however, the effects on air cargo flows are more similar to the effects on air passenger flows. Whereas the Euro and the Schengen Agreement affect air cargo volumes positively, EU membership and other RTAs do not significantly affect trade by air. Methodology-wise, different dynamic structural gravity models are formulated and estimated with Poisson pseudo-maximum likelihood (PPML). Including intranational flows and controlling for multilateral

[Correction added on 07 February, 2022, after first online publication: In Equation (4) is term after summation should read as INTERijt. Last sentence in Footnote of Table 3 should read as FE = fixed effects. An additional sentence is added to the Acknowlegment section as follows, "The author would like to thank Martin Moog, Fabian Baier and Yoto V. Yotov, as well as the editor and the anonymous reviewer(s) for valuable comments on the research idea and the paper."]

resistance, endogeneity and globalisation effects reverses the impact of some of the policy variables compared with an estimate based on a simple structural gravity model.

KEYWORDS

air cargo, air passengers, multinational agreements, poisson pseudo-maximum likelihood, structural gravity, trade

JEL CLASSIFICATION

L93; F10; F14; C18

1 | INTRODUCTION

Air cargo accounts for <1% of the total trade volume worldwide, but when measured in value, airfreight makes up about 35% of all trade (IATA, 2015). Aeroplanes transport high value goods in particular, such as consumer electronics, pharmaceuticals, vaccines and medical instruments. Transport of these products necessitates high quality and security standards, both in the air and during loading and unloading at the airports. Moreover, since transportation by air is much faster than ground transportation, aircrafts are the favoured mode of transport in the case of valuable and perishable freight. In the past decade, total air cargo volumes of the EU countries have been rising constantly at an average rate of 2.2% p.a. However, during that same period, total trade rose by an average of 4.6% p.a. In addition, the number of passengers transported by air has also increased at an average rate of over 4% each year.[1] Air cargo and air passenger transportation are linked, since these air services often operate on the same routes and use the same infrastructure, or even the same aeroplanes. Passenger planes transport half of all transported airfreight in their bellies.

Up to now, scholars have analysed the determinants of air cargo flows to a much lesser degree than they have analysed the determinants of total trade flows. In the area of trade economics, empirical studies typically investigate the determinants of bilateral trade flows by applying a gravity model approach. The gravity model is an economic model that successfully explores the amount of spatial interaction between countries, regions or cities. This model relates to Newton's law of universal gravitation and indicates that the attraction between two entities depends positively upon the size of them and negatively upon the distance between them. In recent decades, the gravity model became the 'workhorse' of international trade analysis (Anderson, 2011; Head & Mayer, 2014), but it also serves well in the analysis of air transportation flows, tourism flows, migration flows or foreign direct investment (FDI) flows between countries. The traditional gravity model predominately includes the variables GDP or GDP per capita, population, distance and additional variables that represent bilateral trade costs (colonial ties, common borders and same languages). Empirical evidence strongly supports that distance impacts bilateral trade negatively, whereas the other mentioned gravity model variables impact trade flows between two regions positively (Head & Mayer, 2014). As to be shown in the following literature review section, up to now, no clear conclusion is possible with respect to the impact of the classical gravity model variables such as distance, common borders, colonial ties or common languages on bilateral cargo

[1]The growth rate figures are calculated with data derived from Eurostat on passenger numbers, air cargo volumes (in tons) and trade volumes (in Euros, deflated) between 2010 and 2019. That includes data within and to and from the EU-27 countries plus the United Kingdom. See Eurostat (2021a, b).

flows. The impact of currency unions such as the Euro and economic integration unions such as the EU, the Schengen Agreement is even still unexplored. Previous studies have focused on single source countries or certain regional markets but have not analysed air cargo flows within and to/from the European market. Therefore, this paper intends to give four contributions, three empirical ones and one methodological one:

Firstly, apart from the analysis of the impact of the classical gravity model variables on air cargo flows, this paper analyses the impact of various multinational agreements on the volume of air cargo flows. These are the Euro, the EU, the Schengen Agreement and other RTAs. Secondly, the data set generated for this paper covers the years 1994 until 2016 for a sample of 16 EU countries including the UK, as both origin and destination, combined with 55 other European and worldwide destinations. Thirdly, this paper compares the effects of these variables on air cargo flows with their effect on trade flows and on passenger flows. Air cargo is—as explained in the beginning of this introductory section—closely related to air passenger services since it uses the same mode of transportation. Finally, concerning the methodological contribution, this paper applies the newest econometric advances from the area of trade econometrics to an analysis of air cargo flows. This contains the estimation of different structural gravity models with fixed effects in a panel-data set setting. Moreover, the regressions are performed with the Poisson pseudo-maximum-likelihood (PPML) estimator.

The remainder of the paper is structured as follows: Section 2 covers the literature review on the effects of the gravity model variables and of multinational agreements on air cargo but also on trade and on air passenger flows. Section 3 gives background information on the methodology used in this paper and presents the latest structural gravity model specifications and estimation methods from the area of trade economics. Building on this, the empirical strategy of this paper is introduced. This includes the econometric gravity models to be estimated and the formulation of various robustness checks. Section 4 gives a data description, and Section 5 presents the results of the gravity model estimations and the robustness checks. The paper closes with Section 6, which provides the conclusions of this research.

2 | LITERATURE REVIEW

The roots of the gravity model in aviation economics trace back to the 1950s, when the model helped the investigation and forecasting of the volume of passenger flows within the U.S. (Harvey, 1951). Since the 2000s, further studies have applied the gravity model to the analysis of passenger flows. Early contributions include Matsumoto (2004, 2007), Grosche et al. (2007) and Hazledine (2009). More recent contributions were made by Piermartini and Rousová (2013), Cristea et al. (2015) and Boonekamp et al. (2018). Moreover, tourism flows between countries have been analysed within a gravity model framework by Keum (2010), Morley et al. (2014) and Galli et al. (2016). Gravity model applications for air cargo were developed much later than for passenger flows and research in that area is still scarce. Turner (2002) applied the gravity model to the analysis of domestic and international air cargo flows to and from Vancouver. Matsumoto (2004, 2007) combined a gravity model-based analysis of passenger flows with the analysis of air cargo flows, but only for a very restricted number of city-pairs. Further research also focused on air cargo flows within a certain geographic area (Alexander & Merkert, 2017; Button et al., 2015; Geloso Grosso & Shepherd, 2011) or to and from a specific origin country (Alexander & Merkert, 2020; Gong et al., 2018; Hwang & Shiao, 2011; Yamaguchi, 2008).

According to previous empirical studies, GDP mainly affects air cargo and air passenger flows positively (Boonekamp et al., 2018; Cristea et al., 2015; Gong et al., 2018; Hwang & Shiao, 2011;

Turner, 2002). The impact of the other gravity model variables is hence not clear. Distance impacts cargo flows negatively, such as in trade economics (Button et al., 2015; Geloso Grosso & Shepherd, 2011; Gong et al., 2018; Hwang & Shiao, 2011), but some studies also indicate a positive impact of distance on air cargo flows (Matsumoto, 2004, 2007; Turner, 2002). Studies on air travel flows found a non-linear relationship between distance and the volume of passenger flows (Cristea et al., 2015). Moreover, previous studies give conflicting results concerning the impact of sharing a common border or a common language on airfreight (Alexander & Merkert, 2020; Geloso Grosso & Shepherd, 2011; Gong et al., 2018). Apart from the classical gravity model variables, additional air service-related variables such as price and frequency are often included in aviation economic gravity models (Boonekamp et al., 2018; Button et al., 2015; Geloso Grosso & Shepherd, 2011). Whereas rising prices impact demand negatively, increased frequency impacts aviation demand positively.

The effect of regional trade agreements (RTAs) on trade flows is of great interest in trade economics. Decreasing or removing tariffs on international trade reduces trade costs and should influence bilateral trade flows positively. Several studies empirically confirmed the trade-enhancing effects of the EU, the Schengen Agreement or of other RTAs. The effects are mostly positive and significant, although with different magnitudes of the estimated effects (Baier & Bergstrand, 2007; Bergstrand et al., 2015; Cipollina & Salvatici, 2010; Felbermayr et al., 2018; Felbermayr & Steininger, 2019; Head & Mayer, 2014). The famous debate on the effect of currency unions on trade has, however, been very controversial. The debate was initiated by Rose (2000), who concluded from his empirical research that trade is more than three times greater if countries share the same currency. According to further studies conducted by the same author, a common currency doubled bilateral trade and the Euro increased trade by up to 50% (Glick & Rose, 2002, 2016). The results were put into perspective by newer studies, which could only find small and non-significant effects of the Euro on trade flows (Baldwin & Taglioni, 2007; Larch et al., 2019; Santos Silva & Tenreyro, 2010). The differing results are mainly due to different gravity model specifications and estimation techniques.

Papers that have studied the effect of bi- or multinational agreements on air cargo flows have mainly examined the impact of air liberalisation agreements such as Open Skies Agreements (OSA) and Air Service Agreements (ASA).[2] Hwang and Shiao (2011) analysed international air cargo flows to and from Taiwan and included a dummy variable for a bilateral Open Skies Agreements (OSA) between Taiwan and the United States. Their results show that the OSA increased the amount of transported goods by air between the two countries by about 10%. Geloso Grosso and Shepherd (2011) utilise the Aviation Liberalization Index (ALI) on a data set that includes air cargo flows between the countries of the Asia-Pacific Economic Cooperation (APEC). The ALI is a constructed and expert-based index provided by the WTO that translates the openness of bi- or multilateral aviation markets into a continuous variable (WTO, 2011a, 2011b). Overall, Geloso Grosso and Shepherd (2011) found positive but small effects of the ALI on air cargo flows. Hence, for manufactured goods transported by air, the effect of the ALI is positive and significant with a coefficient that translates into an effect of 1.4%. Gong et al. (2018) analysed international air cargo flows to and from China and included a dummy that indicates the complete liberalisation of air services from China to the United States. The effect on exports from

[2]Open Skies Agreements (OSA) and Air Service Agreements (ASA) are bi- or multinational agreements with the intention to reduce or completely remove barriers that apply to air travel or air transport services between the respective countries. The process of air liberalization started in the 1990s, and in 1992, the first international OSA signed was between the United States and the Netherlands. See Alexander and Merkert (2020), Piermartini and Rousová (2013).

China to the United States is positive, relatively high (above 80%) and significant. Cristea et al. (2015) and Piermartini and Rousová (2013) analysed the effect of the Air Liberalization Index (ALI) on air passenger flows. Both studies found significant positive effects, although in a relatively small degree (between 1% and 3%). Alexander and Merkert (2020) analysed the US international air freight market. They included a foreign trade agreement (FTA) dummy into their air cargo gravity model and found a strong positive and significant effect of FTAs on air cargo flows. Lastly, with regard to the effect of currency unions on air transport flows, two recent papers analyse the effect of the Euro on tourism flows (Saayman et al., 2016; Santana-Gallego et al., 2016). Both studies find relative strong and significant effects of the Euro on the amount of tourism flows between two countries. Saayman et al. (2016) additionally analyse the effect of economic integration agreements and conclude from their results that the effect of the EU is weaker than the effect of a common currency.

3 | METHODOLOGY AND EMPIRICAL MODEL

This paper follows the structural gravity model approach, which can be traced back to Anderson and van Wincoop (2003). After much criticism that the traditional gravity model lacked theoretical foundations, Anderson and van Wincoopp (AvW) presented an approach of a micro-founded gravity model. The merit of the paper was to show the importance of including (unobservable) multilateral resistance terms (MRTs) in the gravity equation—the 'theoretically appropriate average trade barrier' (Anderson, 2011; Anderson & van Wincoop, 2003). The common method to control for MRTs is to include inward and outward (exporter/importer or origin/destination) fixed effects in the gravity model (Baldwin & Taglioni, 2007; Feenstra, 2004). Baier and Bergstrand (2007) enhanced the AvW-structural gravity model due to their concerns of possible endogeneity in the analysis of the effects of trade policies on trade flows. They showed that in a panel-data model, the inclusion of time-varying origin and destination fixed effects and additional time-invariant country-pair fixed effects controls for possible matters of endogeneity.[3] In addition, the country-pair fixed effects control for any unobservable bilateral resistances to trade. In recent years, there have been further developments concerning theoretical and empirical gravity model specifications. New structural gravity models also include intranational trade flows (Beverelli et al., 2018; Heid et al., 2021) and time-varying international border dummies (Bergstrand et al., 2015; Larch et al., 2019; Yotov et al., 2016). The rationale for including domestic flows is to capture trade diversions from intranational to international trade flows that may arise due to RTAs. Moreover, consistent with the theory, consumers choose between domestic goods and international goods. The international border dummies should control for globalisation effects such as technology and innovations, and represent the average declining international trade costs relative to intranational trade costs (Bergstrand et al., 2015). Finally, it is now standard practice within trade economics to run gravity models with the Poisson pseudo-maximum-likelihood (PPML) estimator. Santos Silva and Tenreyro (2006) and subsequent studies showed the superiority of the PPML estimator over OLS if the data used are heteroscedastic and contain many zero flows (Bergstrand et al., 2015; Correia et al., 2020; Fally, 2015; Larch, Wanner, et al., 2019; Santos Silva & Tenreyro, 2010, 2011; Yotov et al., 2016).

[3]Country-pair fixed effects control for potential endogeneity by absorbing most of the linkages between the endogenous policy variables and the remainder error term. See Yotov et al. (2016).

Only a limited number of papers in the gravity model literature on the analysis of air cargo flows adopted these new theoretical and empirical advances from trade economics. Most recent papers still use linear estimators such as OLS (Alexander & Merkert, 2020; Button et al., 2015; Gong et al., 2018; Hwang & Shiao, 2011). In addition, fixed effects are only included in form of a linear Fixed Effects Estimator (FE-Model) and the traditional, a-theoretical gravity model predominates. Geloso Grosso and Shepherd (2011) stand in contrast, since they estimate the effects of the Air Liberalization Index (ALI) with a structural gravity model and PPML, although in a cross-section model and therefore with time-invariant origin and destination fixed effects. Cristea et al. (2015) apply the Poisson estimator to a structural air passenger gravity model.

In this paper, the different forms of the structural gravity model presented in the beginning of this section will be applied: Firstly, a basic structural gravity model is formulated that contains time-varying origin and destination fixed effects to control for the multinational resistance terms (MRTs). Equation (1) gives the respective gravity regression equation in PPML-form.

$$X_{ijt} = \exp\left[\beta' Gravity_{ij} + \beta' AGRMNT_{ijt} + \lambda_{it} + \mu_{jt}\right] + \varepsilon_{ijt} \quad \text{with } i \neq j \tag{1}$$

The dependent variable X_{ijt} represents the volume of international air cargo flows (*aircargo*), trade flows (*trade*) and air passengers flows (*airpax*) between two countries i and j at time t. $GRAVITY_{ij}$ denotes a vector that includes the time-invariant gravity model variables distance (*dist*), colonial ties (*COL*), common language (*COML*) and common border (*CONT*). Since it is common practice with air passenger gravity models (Cristea et al., 2015; Piermartini & Rousová, 2013), the temperature differences between two countries (*temp_diff*) will also be included into the model. The temperature differences capture touristic relationships, and higher temperature differences are expected to affect passenger flows positively. The policy variables are summarised by the vector $AGRMNT_{ijt}$. The vector includes the variables Euro (*EURO*), European Union (*EU*), Schengen Agreement (*SCHENG*) and other RTAs (*OTHER_RTA*). λ_{it} and μ_{jt} are the time-varying origin and destination fixed effects, and ε_{ijt} denotes the error term.

Secondly, to account for domestic trade and aviation flows, the dependent variable X_{ijt} in Equation (2) represents the volume of international *and* intranational air cargo, trade and air passenger flows. The international border dummy *INTER* differentiates intranational from international flows. This dummy variable takes the value of 1 if country i is not equal to country j and therefore an international border separates the two countries.

$$X_{ijt} = \exp\left[\beta' GRAVITY_{ij} + \beta' AGRMNT_{ijt} + \beta' INTER_{ij} + \lambda_{it} + \mu_{jt}\right] + \varepsilon_{ijt} \tag{2}$$

Thirdly, to control for matters of endogeneity and following the structural gravity model approach by Baier and Bergstrand (2007), the first model (Equation (1)) is enhanced by additional country-pair fixed effects. Equation (3) gives the respective regression equation with time-varying origin and destination fixed effects and with the time-invariant country-pair fixed effects ν_{ij}.

$$X_{ijt} = \exp\left[\beta' AGRMNT_{ijt} + \lambda_{it} + \mu_{jt} + \nu_{ij}\right] + \varepsilon_{ijt} \quad \text{with } i \neq j \tag{3}$$

Finally, to account for globalisation effects, the fourth model will follow the new structural gravity model approach by Bergstrand et al. (2015). The model includes intranational flows and time-varying international border dummies. The international border dummies in Equation (4) are defined as follows: $INTER_{ijt} = D_t * INTER_{ij}$, where D_t is a year dummy.

$$X_{ijt} = \exp\left[\beta' AGRMNT_{ijt} + \beta' \sum_t INTER_{ijt} + \lambda_{it} + \mu_{jt} + \nu_{ij}\right] + \varepsilon_{ijt} \tag{4}$$

Some basic robustness checks will be performed on the impact of the policy variables on air cargo, trade, and passenger flows. The number of variables in the vector $AGRMNT_{ijt}$ will be reduced since the policy variables *EU*, *EURO* and *SCHENG* might interact with each other and influence the estimates. In addition, the geographical scope and time-range of the analysis will be changed. The regressions are therefore run on a subdataset that only contains the intra-European country-pairs. To differentiate the time-range of the data set, only observations from the years 1994 until 2011 will be analysed. The Air Liberalization Index (ALI)—for which data are only available until 2011—can thus be inserted into the model.

4 | DATA

Data on international and intranational air cargo flows and air passenger flows on a country-pair basis are retrieved from Eurostat (Eurostat, 2020). The unit of measure of air cargo flows is tons;[4] the unit of measure of passenger flows is the number of passengers carried. Data on international and intranational trade flows come from the WTO's Structural Gravity Manufacturing Sector Dataset and include trade flows of manufactured goods in nominal US dollars (Monteiro, 2020). For usage in this data set, the trade flows are deflated to real values with the GDP deflator from the World Bank's WDI Database (World Bank, 2021). The data set generated for this paper covers the years 1994 until 2016[5] and contains about 1000 country-pairs in total. The country-pairs include the 16 major EU countries as origin and destination countries, combined with each other and with another 14 European and 41 worldwide destinations. The countries taken into account as the major EU countries are Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Luxembourg, the Netherlands, Poland, Portugal, Spain, Sweden and the United Kingdom. Each country-pair is defined on a one-way basis and therefore represents the amount of unilateral air cargo, trade or passenger flows. There is always an observation for a counter country-pair. The control variables distance, colonial ties, common border and common language stem from the CEPII Gravity Database (CEPII, 2011). Differences in yearly average temperatures are calculated from the World Bank's Climate Change Knowledge Portal (World Bank, 2011). Data on the policy variables stem from various sources. The information on EU, Schengen and Euro membership comes from the respective official sources.[6] The variable *OTHER_RTA* includes RTAs that apply to extra-EU aviation or trade flows. The information on

[4]The numbers on air cargo flows from Eurostat include freight and mail transported by air.

[5]The WTO's Structural Gravity Manufacturing Sector Dataset currently contains data only until 2016.

[6]Table A1 in the Appendix lists the European countries included in the data set and indicates the beginning of a EU, Schengen and Euro membership.

TABLE 1 Summary statistics

Variable	Count	Mean	Min	Max	Unit/*Type*	Group
aircargo	28,984	6,498.83	0	404,143	tons	Dependent variables (X_{ijt})
trade	41,207	4.96e+09	0	8.75e+11	USD, deflated	
airpax	32,713	411,807.89	0	2.21e+07	passengers	
dist	46,736	4,501.87	59.62	13,501.46	km	Gravity variables ($GRAVITY_{ij}$)
COML	46,736	0.04	0	1	*dummy*	
COL	46,736	0.05	0	1	*dummy*	
CONT	46,736	0.04	0	1	*dummy*	
temp_diff	46,736	9.11	0	26.15	Celsius	
EURO	46,736	0.06	0	1	*dummy*	Policy variables ($AGRMNT_{ijt}$)
EU	46,736	0.21	0	1	*dummy*	
SCHENG	46,736	0.71	0	1	*dummy*	
OTHER_RTA	46,736	0.15	0	1	*dummy*	
ali	36,576	13.08	0	51	*continuous*	
INTER	46,736	0.98	0	1	*dummy*	Border dummies ($INTER_{ij}$ / $INTER_{ijt}$)
INTER_t	46,736	0.04	0	1	*dummies*	

Notes: Continuous variables are written in lower case letters; dummy variables are written in capital letters. i = Country i, j = Country j, t = Year.

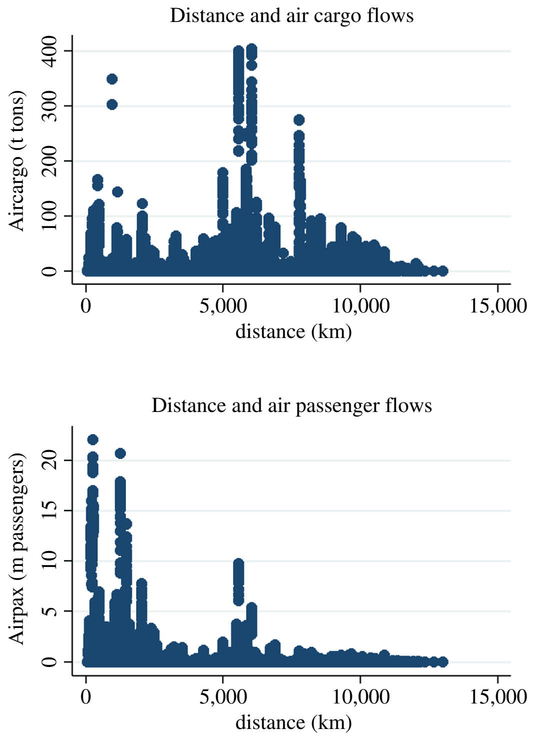

FIGURE 1 The impact of distance on air cargo, trade and air passenger flows. *Notes*: Including intranational and international air cargo, trade and air passenger flows. b = billion, m = million, t = thousand, USD = US Dollars (deflated) [Colour figure can be viewed at wileyonlinelibrary.com]

RTAs captures all multilateral and bilateral regional trade agreements as notified to the WTO (Larch, 2020). The information on the Air Liberalization Index (ALI) is taken from the WTO's Air Services Agreements Projector (WTO, 2011a). The ALI is a continuous indicator, taking the values from zero to 50 if an air liberalisation agreement applies between two country-pairs. The higher the value of the index, the deeper is the respective agreement and the less friction applies to international aviation. To differentiate from country-pairs in the data set that do not have an air agreement in place, the variable *ali* is increased by one compared to the original ALI. The index now runs from one to 51 in this analysis. Consequently, a value of zero indicates that there is no ALI in effect between two countries. Data on the ALI are available up to 2011. To preserve zero values of the continuous variables *temp_diff* (in the case of domestic flows) and *ali*, the square root of the original value is taken instead of the natural log. Table 1 displays the summary statistics of the mentioned variables, grouped in the categories dependent variables, gravity variables and policy variables.[7]

For a first and descriptive analysis, Figure 1 displays the relationship between the dependent variables and the variable distances in three different graphs. The dimension distance affects the amount of air cargo, trade and passenger flows differently. While the amount of flows peak at medium and greater distances in the case of air cargo, in the case of trade flows, the amount

[7]Table A2 in the Appendix gives the summary statistics when only international flows are included ($i \neq j$).

of flows peak at very short distances. In the case of air passenger flows, the relationship with distance has two peaks, one at shorter distances and one smaller peak at medium distances. According to the data set, intranational trade flows account for 61% of the total trade volume, whereas 22% of all air passengers are from domestic flows and only 6% of all air cargo tons are transported on intranational routes. In the case of air cargo flows, the country-pair with the single highest volume (in tons) is USA–Germany in 2011. For trade flows, the respective country-pair is Germany–Germany in 2007, and the country-pair with the highest number of air passengers is Spain–Spain in 2007.

5 | RESULTS AND DISCUSSION

Tables 2 to 4 show the results of the regressions on air cargo flows, trade and air passenger flows. All regressions are processed with the PPML estimator since the data used in this study are heteroscedastic. Moreover, the dependent variables are not log linearised and zero flows can be taken into account.[8] The first two columns of Table 2 contain the results for the gravity model variables with regard to air cargo flows. Both regressions (1) and (2) include time-varying origins and destination fixed effects. The second regression also incorporates intranational flows. The variables distance, common language and colonial ties have a positive and highly significant impact on air cargo flows. The effect of a common border is non-significant. Temperature differences between two countries significantly affect trade by air negatively. Shifting from regression (1) to regression (2) does not change the direction of the impact of the significant standard gravity variables, though the magnitude of the coefficients is reduced. In the case of the variable temperature differences, the negative impact is strengthened in magnitude when entering intranational flows. The coefficient of the variable international border (*INTER*) is negative (−1.067) and significant at the 5% level. This negative border effect indicates that the amount of cargo flows per observation is reduced if an international border exists between countries i and j. With regard to the effect of the policy variables, the four different structural gravity models give contradictory results. The impact of the Euro and of a Schengen membership, for example, changes from negative and highly significant in column (1) to positive and highly or well significant in column (4). The effects of the variables EU and OTHER_RTA also invert, though all estimates are non-significant. The estimates imply that when controlling for endogeneity in regression (3) and (4), the impact of the Euro, the EU and other RTAs inverts. The impact of the Schengen Agreement changes from negative to positive when including intranational flows. The structural gravity model that includes intranational flows and controls for endogeneity and globalisation effects is the most comprehensive and up to date. Column (4) therefore shows the preferred model in this study, and the results with regard to the policy variables are the following: Adaptation of the Euro impacts air cargo flows positively (0.446) and the results are highly significant. Also, Schengen membership affects air cargo flows positively and significantly (0.339). Somewhat surprisingly, membership in the EU and other RTAs does not influence air cargo flows. Both results are non-significant, but whereas the coefficient of the EU variable is small but positive (0.034), the coefficient of other RTAs is negative (−0.250). For brevity, only the results of every fifth international border dummy are reported, as well as the result of 2015s dummy. The last international border dummy (*INTER_2016*) is dropped from the regression, since it is collinear with the fixed effects. The results of the other border dummies are to be interpreted

[8]The regressions are computed with the Stata command *ppmlhdfe* by Correia et al. (2020).

TABLE 2 Regression results—Air cargo flows

	(1) aircargo	(2) aircargo	(3) aircargo	(4) aircargo
ln(*dist*)	0.652***	0.602***		
	(0.130)	(0.161)		
COML	0.455***	0.412***		
	(0.096)	(0.104)		
COL	0.801***	0.586***		
	(0.075)	(0.104)		
CONT	−0.009	0.101		
	(0.177)	(0.192)		
sq(temp_diff)	−0.170***	−0.258***		
	(0.061)	(0.075)		
EURO	−0.498***	−0.310*	0.382***	0.446***
	(0.151)	(0.169)	(0.088)	(0.090)
EU	−0.262	−0.405	0.127	0.034
	(0.282)	(0.283)	(0.195)	(0.182)
SCHENG	−0.483***	0.813***	−0.129*	0.339**
	(0.158)	(0.217)	(0.077)	(0.132)
OTHER_RTA	0.492	0.474	−0.166	−0.250
	(0.360)	(0.355)	(0.363)	(0.358)
INTER		−1.067**		
		(0.487)		
INTER_1994				−0.399
				(0.381)
INTER_1999				−0.266
				(0.186)
INTER_2004				−0.780***
				(0.178)
INTER_2009				−0.639***
				(0.164)
INTER_2014				−0.350**
				(0.147)
INTER_2015				−0.285**
				(0.144)
Origin-year and destination-year FE	x	x	x	x
Country-pair FE			x	x
Intranational flows		x		x
N	28,377	28,939	27,535	28,097
Pseudo-R^2	0.878	0.849	0.969	0.969

Notes: All models are estimated with PPML. The estimates of the constant and the fixed effects are not reported. Only the estimates of the international border dummies of every fifth year and of the year 2015 are reported. Standard errors, clustered by country-pair, are given in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. FE =fixed effects.

TABLE 3 Regression results—Trade flows

	(1)	(2)	(3)	(4)
	trade	trade	trade	trade
ln(dist)	−0.238***	−0.510***		
	(0.078)	(0.066)		
COML	0.597***	0.586***		
	(0.092)	(0.124)		
COL	0.238***	0.047		
	(0.082)	(0.129)		
CONT	0.490***	0.385***		
	(0.085)	(0.086)		
sq(temp_diff)	−0.144***	−0.270***		
	(0.039)	(0.043)		
EURO	−0.114	0.234***	0.010	0.010
	(0.088)	(0.077)	(0.037)	(0.032)
EU	−0.301***	0.248***	0.073	0.330***
	(0.115)	(0.086)	(0.060)	(0.041)
SCHENG	0.447***	0.488***	−0.004	0.008
	(0.091)	(0.049)	(0.032)	(0.023)
OTHER_RTA	0.801***	1.325***	0.300**	0.578***
	(0.153)	(0.142)	(0.122)	(0.130)
INTER		−2.448***		
		(0.161)		
INTER_1994				−0.833***
				(0.069)
INTER_1999				−0.738***
				(0.044)
INTER_2004				−0.568***
				(0.044)
INTER_2009				−0.364***
				(0.027)
INTER_2014				−0.126***
				(0.018)
INTER_2015				−0.057***
				(0.015)
Origin-year and destination-year FE	x	x	x	x
Country-pair FE			x	x
Intranational flows		x		x
N	40,521	41,207	40,521	41,207
Pseudo-R^2	0.947	0.977	0.995	0.998

Notes: All models are estimated with PPML. The estimates of the constant and the fixed effects are not reported. Only the estimates of the international border dummies of every fifth year and of the year 2015 are reported. Standard errors, clustered by country-pair, are given in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. FE = fixed effects relative to that omitted dummy (Bergstrand et al., 2015; Larch, Monteiro, et al., 2019; Yotov et al., 2016). All coefficients of the border dummies are negative, and from 2004 on, the value of the border dummy's coefficients is constantly decreasing and significant. The results show that the negative border effect—which was also proofed by the negative impact of the dummy variable *INTER*—has been shrinking since 2004. The results indicate that the costs of international air cargo goods relative to the costs of domestic air cargo goods have been declining since 2004. Though the coefficient of the last border dummy of the year 2015 is still −0.285, a border effect still applies in 2015.

The results of the regressions on the dependent variable trade flows are shown in Table 3. Distance has a negative and significant impact on trade flows. Sharing a common language or a common border affects trade positively. The impact of colonial ties changes from positive and highly significant to almost zero and non-significant when including intranational flows. The negative impact of higher temperature differences on trade flows is significant and is strengthened in the second regression, as is the case for air cargo flows. As mentioned in the data section, intranational trade accounts for 61% of the total trade volume. The strong impact of the variable *INTER* (−2.448) endorses the higher value of domestic trade flows compared with international trade flows. With regard to the policy variables, the impact of the Euro becomes positive and significant when including intranational flows, but turns to zero when controlling for endogeneity. The effect of a Schengen membership changes from positive to almost zero when including country-pair fixed effects. The impact of the EU changes from negative to positive when including intranational trade flows. Looking at the last column and at the preferred model, the following conclusion can be drawn: The Euro does not affect trade flows—the coefficient is small in magnitude (0.010) and non-significant. This result is in line with the latest research on this subject, in which the effect of the Euro was also small (0.030) and non-significant (Larch, Wanner, et al., 2019). The effects of the EU and of other RTAs on trade flows also correspond with the results of previous studies (Head & Mayer, 2014). Both agreements impact trade flows positively (0.330 and 0.578) and significantly. Moreover, the stronger impact of economic agreements on trade flows when regressing a model that includes intranational flows and international border dummies was also found in previous research (Bergstrand et al., 2015). A Schengen membership does not impact trade flows. The negative amount of the international border dummies' coefficients consequently shrinks over time. The effect is in line with previous research (Bergstrand et al., 2015; Larch, Monteiro, et al., 2019; Yotov et al., 2016) and represents the decreasing border effect. The costs of international trade flows relative to the costs of domestic trade flows consequently have decreased over time to a border effect of only −0.057 in 2015.

Table 4 gives the results of the regressions on air passenger flows. Distance impacts passenger flows positively, though the impacts reduce to almost zero when including intranational flows. The variables common language and colonial ties impact passenger flows positively and are as highly significant as they are for trade and air cargo flows. The effect of a common language is higher on air passenger numbers than on air cargo or trade flows. A common border affects air passenger flows negatively, and the negative effect is also significant when including intranational flows. In contrast to the results on air cargo and trade flows, but as expected, temperature differences impact passenger flows positively and to a significant degree when only regressing on international air passenger flows. The dummy variable INTER is negative (−1.602) and highly significant, such as in the regressions on air cargo and trade flows. A negative border effect also applies in the case of air passenger flows, and an international border between county i and j reduces the volume of air passenger flows per observation. The effect of the Euro is positive (0.106) and significant at the 5% level when looking at the results in column (4). Although when

TABLE 4 Regression results—Air passenger flows

	(1)	(2)	(3)	(4)
	airpax	airpax	airpax	airpax
ln(dist)	0.142*	0.024		
	(0.085)	(0.087)		
COML	0.682***	0.770***		
	(0.114)	(0.120)		
COL	0.626***	0.630***		
	(0.141)	(0.150)		
CONT	−0.164	−0.322***		
	(0.113)	(0.099)		
sq(temp_diff)	0.160*	−0.024		
	(0.089)	(0.094)		
EURO	−0.197*	−0.265*	0.063	0.106**
	(0.116)	(0.155)	(0.041)	(0.045)
EU	0.781***	0.307*	0.397***	0.317***
	(0.171)	(0.163)	(0.077)	(0.066)
SCHENG	0.347***	0.572***	0.182***	0.144***
	(0.091)	(0.115)	(0.035)	(0.042)
OTHER_RTA	0.065	−0.521**	0.135	0.063
	(0.221)	(0.220)	(0.154)	(0.146)
INTER		−1.602***		
		(0.263)		
INTER_1994				−0.309**
				(0.128)
INTER_1999				−0.307***
				(0.060)
INTER_2004				−0.365***
				(0.044)
INTER_2009				−0.301***
				(0.033)
INTER_2014				−0.063***
				(0.010)
INTER_2015				−0.044***
				(0.010)
Origin-year and destination-year FE	x	x	x	x
Country-pair FE			x	x
Intranational flows		x		x
N	32,127	32,713	32,025	32,611
Pseudo-R^2	0.892	0.899	0.990	0.992

Notes: All models are estimated with PPML. The estimates of the constant and the fixed effects are not reported. Only the estimates of the international border dummies of every fifth year and of the year 2015 are reported. Standard errors, clustered by country-pair, are given in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. FE =fixed effects.

TABLE 5 Robustness checks—Air cargo flows

	(0)	(1)	(2)	(3)	(4)	(5)
	aircargo	aircargo	aircargo	aircargo	aircargo	aircargo
	Total dataset	Total data set	Total data set	Total data set	Intra-Europe	1994–2011
EURO	0.446***	0.417***			0.365***	0.425***
	(0.090)	(0.091)			(0.085)	(0.087)
EU	0.034		0.090		−0.076	−0.033
	(0.182)		(0.181)		(0.214)	(0.170)
SCHENG	0.339**			0.270*	0.665***	0.221*
	(0.132)			(0.140)	(0.182)	(0.118)
OTHER_RTA	−0.250	−0.250	−0.197	−0.261		−0.054
	(0.358)	(0.345)	(0.357)	(0.346)		(0.362)
sq(ali)						0.021*
						(0.011)
N	28,097	28,097	28,097	28,097	10,920	19,662
Pseudo-R^2	0.969	0.969	0.968	0.968	0.968	0.974

Notes: All models are estimated with PPML and include intranational flows as well as origin-year, destination-year and country-pair fixed effects. The estimates of the constant, the international border dummies and the fixed effects are not reported. Standard errors, clustered by country-pair, are given in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

not controlling for endogeneity the impact is negative (Regressions 1 and 2), EU or Schengen membership influences bilateral air passenger numbers positively (0.317 and 0.144) and both impacts are highly significant. The impact of both variables is consequently positive throughout all regressions. Other RTAs—as expected—do not affect passenger air travel. The coefficients of the international border dummies are negative and significant. They basically stayed stable until 2009 and were reduced to −0.044 in 2015. However, although the globalisation effect is weaker, the coefficients of the international border dummies are lower in the regressions on air passenger flows with a maximum of −0.365 than they are in the regressions on air cargo (maximum of −0.780) or trade flows (maximum −0.833). The price discrepancy between domestic and international air travel destinations can be assumed to be lower since the medium distance of international air passenger flows is shorter than the medium distance of international air cargo or trade flows.

Table 5 displays the robustness checks on air cargo flows. For a better comparison, Regression 0 gives again the estimates of the preferred Regression 4 from Table 2. The results of the robustness checks confirm the positive impact of the Euro and of the Schengen Agreement on air cargo flows. The EU still does not impact air cargo flows, even when leaving the Euro and Schengen membership out of the regressions (Regression 2). The robustness checks also approve the negative but non-significant impact of other RTAs on air cargo flows. The results for the ALI (0.021) are in line with previous studies. Geloso Grosso and Shepherd (2011)—although with a different geographic scope—estimated small effects of the ALI (0.014) for air trade with manufactured goods. With regard to trade flows, the Euro does not affect bilateral trade flows, even if the variables EU and SCHENG are dropped from the regressions (Table A3, Regression 1). Hence, the impact of a Schengen membership becomes positive and significant when leaving the EU and

TABLE 6 Summary—The effect of multinational agreements

	aircargo	*trade*	*airpax*
EURO	0.446***		0.106**
EU		0.330***	0.317***
SCHENG	0.339**		0.144***
OTHER_RTA		0.578***	

Notes: The results are based on the Regression 4 of Tables 2, 3 and 4. Only significant coefficients are considered. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 7 Impact analysis

	(1)	(2)	(3)
	aircargo	**trade**	**airpax**
ln(aircargo)		−0.000	0.043***
		(0.005)	(0.007)
ln(trade)	−0.021		0.075***
	(0.020)		(0.017)
ln(airpax)	0.346***	0.054***	
	(0.038)	(0.018)	
N	23,877	20,551	20,848
Pseudo-R^2	0.978	0.998	0.995

Notes: All models are estimated with PPML and include intranational flows as well as origin-year, destination-year and country-pair fixed effects. The estimates of the constant effects, the fixed effects and of the international border dummies are not reported. Standard errors, clustered by country-pair, are given in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

the Euro out of the regressions (Regression 3). The positive and highly significant results for EU membership and other RTAs on trade flows are confirmed by the robustness checks. Finally, the results of the additional regressions for air passenger flows (Table A4) are in line with those of the main regression in Table 4. The impact of the Euro, the EU and of a Schengen membership is positive and significant throughout all different robustness checks. The effect of other RTAs is still non-significant, which is well justified in the case of air passenger flows. The effect of the ALI on air passenger flows is also non-significant (Regression 5). Previous studies on that subject showed a small positive impact of the ALI on air passenger numbers however (about 1% to 3% impact; Cristea et al., 2015; Piermartini & Rousová, 2013).[9]

To summarise the results of the regressions, Table 6 gives only the results on the impact of multinational agreements according to Regression 4 of the Tables 2, 3 and 4. These regressions include intranational flows, origin-year and destination-year fixed effects and country-pair fixed effects.

Since the results on air cargo flows with regard to the impact of the policy variables are surprising, to what extend air cargo flows, trade flows and air passenger flows affect each other

[9]When running the robustness check on a data set that only covers the observations until 2008 (to not include the impact of the financial crisis), the impact of the ALI on air passenger numbers turns slightly positive but is still non-significant.

has been analysed by conducting three additional regressions. These regressions include only the amount of air cargo, trade and air passenger flows as variables as well as origin-year and destination-year fixed effects, country-pair fixed effects and international border dummies. The results are given in Table 7. Bilateral air cargo flows are positively influenced by air passenger numbers (0.346, significant at the 1% level) but are not impacted by bilateral trade numbers (−0.021, non-significant). Trade is mildly impacted by air passenger flows (0.054, significant at the 1% level) but not by air cargo flows (−0.000). And finally, air passenger numbers are mildly impacted by both air cargo flows (0.043, significant at the 1% level) and trade flows (0.075, significant at the 1% level). The strongest impact is the effect of passenger numbers on the volume of air cargo flows. This comes as no surprise, since 50% of the amount of air cargo is transported in the bellies of passenger planes.

6 | CONCLUSION

Based on the analysis in this paper, the following conclusions with regard to the impact of multinational agreements are drawn: first, the Euro affects air cargo flows and air passenger flows positively. The EU membership impacts trade and air passenger flows positively but has no significant effect on air cargo flows. A Schengen membership promotes air passenger numbers and the amount of air cargo flows between two countries. Other RTAs impact total trade, but not trade by air. Trade flows are not impacted by the Euro or by a Schengen membership (see Table 6). Overall, the results on the impact of the policy variables on air cargo flows are somewhat surprising. Firstly, air cargo does not seem to have statistically gained from multinational, regional trade agreements such as the EU and other RTAs so far. According to economic theory, trade agreements foster trade between two countries by reducing or removing tariffs and other non-monetary barriers to trade. As air cargo flows are per meaning trade flows, the EU and other RTA should have fostered air cargo flows as well. Secondly, in this research, the effect of a common currency is positive on passenger flows but also on air cargo flows. The enhancing effect of the Euro on passenger flows likely is triggered by the positive effect of the Euro on tourism flows. As shown by previous research, the common currency raises bilateral tourism flows between two countries. The effect of the Euro on trade flows has been negated by this paper as well by previous research. Therefore, the positive effect of the Euro on air cargo flows appears unexpected. Thirdly, a Schengen membership facilitates the free movement of people as no visa is required to enter another member country. This policy measure therefore should foster air passenger flows but should have no effect on air cargo flows. Lastly, the international border dummies revealed a declining negative border effect for air cargo, trade and air passenger numbers. However, in the case of air cargo flows, the cost discrepancies between intranational and international air cargo flows have not been reduced to the extent they have been in the case of trade or air passenger flows; globalisation effects therefore have promoted air cargo flows to a much lesser degree than total trade flows.

In summary, as shown by this paper, air cargo flows are positively impacted by the two variables that mainly enhance passenger flows—the Euro and Schengen membership. Since half of total air cargo volumes are transported in the bellies of passenger planes, air passenger services determine on which routes 50% of total air cargo is transported. Air cargo may depend too much on air passenger services in order to fully exploit the effects of RTAs as trade is able to do in general. By this, air cargo transportation services likely do not operate on the optimal set of routes. This might be one of the possible explanations for the lower growth rates compared to total trade flows that are mentioned in the Introduction. Moreover, when air cargo depends this much on air passenger planes, air cargo is extremely affected by shock events that affect air passenger services. Not only in the light of the current pandemic, but also in order to gain from RTAs that should reduce trade costs, it seems necessary to foster air cargo network management that is more independent from air passenger transportation services.

With regard to the methodology used in this paper, four different structural gravity models were applied. This study showed the importance of correctly specifying a structural gravity model in the area of aviation economics. Currently, the most comprehensive and up-to-date structural gravity model includes intranational flows, time-varying international border dummies, and origin-year, destination-year, and country-pair fixed effects. The model thus controls for multilateral resistances, endogeneity and globalisation effects. In this study's regressions, the inclusion of intranational flows and controlling for endogeneity changed the impact of the policy variables, especially in the case of air cargo and trade flows. Controlling for endogeneity inverted the impact of the Euro on air cargo flows to be positive, and the inclusion of intranational flows turned the effect of a Schengen membership positive. Previous gravity model estimations in the area of aviation economics were predominantly based on linear estimators such as OLS. Since air cargo and air passenger data may share the characteristic of heteroscedasticity with data sets on trade flows, a Poisson-based estimator should be applied instead of a linear estimator.

ACKNOWLEDGMENT

Open access funding enabled and organized by ProjektDEAL. The author would like to thank Martin Moog, Fabian Baier and Yoto V. Yotov, as well as the editor and the anonymous reviewer(s) for valuable comments on the research idea and the paper.

ORCID

Katrin Oesingmann https://orcid.org/0000-0002-2206-7527

REFERENCES

Alexander, D. W., & Merkert, R. (2017). Challenges to domestic air freight in Australia: Evaluating air traffic markets with gravity modelling. *Journal of Air Transport Management*, *61*, 41–52. https://doi.org/10.1016/j.jairtraman.2016.11.008

Alexander, D. W., & Merkert, R. (2020). Applications of gravity models to evaluate and forecast US international air freight markets post-GFC. *Transport Policy*, *104*, 52–62. https://doi.org/10.1016/j.tranpol.2020.04.004

Anderson, J. E. (2011). The gravity model. *Annual Review of Economics*, *3*, 133–160. https://doi.org/10.1146/annurev-economics-111809-125114

Anderson, J. E., & van Wincoop, E. (2003). Gravity with Gravitas: A solution to the border puzzle. *American Economic Review*, *93*, 170–192. https://doi.org/10.1257/000282803321455214

Baier, S. L., & Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics*, *71*, 72–95. https://doi.org/10.1016/j.jinteco.2006.02.005

Baldwin, R., & Taglioni, D. (2007). Trade effects of the Euro: A comparison of estimators. *Journal of Economic Integration*, *22*, 780–818. https://doi.org/10.11130/jei.2007.22.4.780

Bergstrand, J. H., Larch, M., & Yotov, Y. V. (2015). Economic integration agreements, border effects, and distance elasticities in the gravity equation. *European Economic Review*, *78*, 307–327. https://doi.org/10.1016/j.euroecorev.2015.06.003

Beverelli, C., Keck, A., Larch, M., & Yotov, Y. (2018). *Institutions, trade and development: A quantitative analysis*. Drexel University School of Economics. Working Paper Series.

Boonekamp, T., Zuidberg, J., & Burghouwt, G. (2018). Determinants of air travel demand: The role of low-cost carriers, ethnic links and aviation-dependent employment. *Transportation Research Part A: Policy and Practice*, *112*, 18–28. https://doi.org/10.1016/j.tra.2018.01.004

Button, K., Brugnoli, A., Martini, G., & Scotti, D. (2015). Connecting African urban areas: airline networks and intra-Sub-Saharan trade. *Journal of Transport Geography*, *42*, 84–89. https://doi.org/10.1016/j.jtrangeo.2014.11.007

CEPII. (2011). *CEPII Database - GeoDist*. Retrieved July 3, 2020, from http://www.cepii.fr/cepii/en/bdd_modele/bdd.asp

Cipollina, M., & Salvatici, L. (2010). Reciprocal trade agreements in gravity models: A meta-analysis. *Review of International Economics*, *18*, 63–80. https://doi.org/10.1111/j.1467-9396.2009.00877.x

Correia, S., Guimarães, P., & Zylkin, T. (2020). Fast Poisson estimation with high-dimensional fixed effects. *The Stata Journal*, *20*, 95–115. https://doi.org/10.1177/1536867X20909691

Cristea, A. D., Hillberry, R., & Mattoo, A. (2015). Open Skies over the Middle East. *World Econ*, *38*, 1650–1681. https://doi.org/10.1111/twec.12314

Eurostat. (2020). *Air passenger traffic, freight and mail air transport (avia_goincc, avia_goexcc, avia_paincc, avia_paexcc)*. Retrieved November 11, 2020, from https://ec.europa.eu/eurostat/data/database

Eurostat. (2021). *Air passenger transport [AVIA_PAOC], Freight and mail air transport [AVIA_GOOC]*. Eurostat. Retrieved February 9, 2021, from https://ec.europa.eu/eurostat/data/database

Eurostat. (2021b). *Intra and Extra-EU trade by Member State and by product group [EXT_LT_INTRATRD]*. Eurostat. Retrieved February 9, 2021 from https://ec.europa.eu/eurostat/data/database

Fally, T. (2015). Structural gravity and fixed effects. *Journal of International Economics*, *97*, 76–85. https://doi.org/10.1016/j.jinteco.2015.05.005

Feenstra, R. C. (2004). *Advanced international trade: Theory and evidence* (p. 484). Princeton University Press.

Felbermayr, G., Gröschl, J., & Steinwachs, T. (2018). The trade effects of border controls: Evidence from the European Schengen Agreement. *JCMS. Journal of Common Market Studies*, *56*, 335–351. https://doi.org/10.1111/jcms.12603

Felbermayr, G., & Steininger, M. (2019). Revisiting the Euro's trade cost and welfare effects. *Jahrbücher Für Nationalökonomie Und Statistik*, *239*, 917–956. https://doi.org/10.1515/jbnst-2019-0015

Galli, P., Fraga, C., & de Sequeira Santos, M. P. (2016). Gravitational force exerted by Brazilian tourist destinations on foreign air travelers. *Journal of Air Transport Management*, *55*, 76–83. https://doi.org/10.1016/j.jairtraman.2016.04.011

Geloso Grosso, M., & Shepherd, B. (2011). Air cargo transport in APEC: Regulation and effects on merchandise trade. *Journal of Asian Economics*, *22*, 203–212. https://doi.org/10.1016/j.asieco.2011.02.004

Glick, R., & Rose, A. K. (2002). Does a currency union affect trade? The time-series evidence. *European Economic Review*, *46*, 1125–1151. https://doi.org/10.1016/S0014-2921(01)00202-1

Glick, R., & Rose, A. K. (2016). Currency unions and trade: A post-EMU reassessment. *European Economic Review*, *87*, 78–91. https://doi.org/10.1016/j.euroecorev.2016.03.010

Gong, Q., Wang, K., Fan, X., Fu, X., & Xiao, Y. (2018). International trade drivers and freight network analysis - The case of the Chinese air cargo sector. *Journal of Transport Geography*, *71*, 253–262. https://doi.org/10.1016/j.jtrangeo.2017.02.009

Grosche, T., Rothlauf, F., & Heinzl, A. (2007). Gravity models for airline passenger volume estimation. *Journal of Air Transport Management*, *13*, 175–183. https://doi.org/10.1016/j.jairtraman.2007.02.001

Harvey, D. (1951). Airline passenger traffic patterns within the United States. *Journal of Air Law and Commerce*, *18*, 157–165.

Hazledine, T. (2009). Border effects for domestic and international Canadian passenger air travel. *Journal of Air Transport Management*, *15*, 7–13. https://doi.org/10.1016/j.jairtraman.2008.09.007

Head, K., & Mayer, T. (2014). Gravity Equations: Workhorse, Toolkit, and Cookbook. In: G. Gopinath, E. Helpman, & K. S. Rogoff (Eds.), *Handbook of international economics* (pp. 131–195). Elsevier North-Holland.

Heid, B., Larch, M., & Yotov, Y. V. (2021). Estimating the effects of non-discriminatory trade policies within structural gravity models. *Canadian Journal of Economics/Revue Canadienne D'économique*, *54*, 376–409. https://doi.org/10.1111/caje.12493

Hwang, C.-C., & Shiao, G.-C. (2011). Analyzing air cargo flows of international routes: An empirical study of Taiwan Taoyuan International Airport. *Journal of Transport Geography*, *19*, 738–744. https://doi.org/10.1016/j.jtrangeo.2010.09.001

IATA. (2015). *Value of air cargo: Air transport and global value chains*. IATA.

Keum, K. (2010). Tourism flows and trade theory: a panel data analysis with the gravity model. *The Annals of Regional Science*, *44*, 541–557. https://doi.org/10.1007/s00168-008-0275-2

Larch, M. (2020). Mario Larch's Regional Trade Agreements Database from Egger and Larch (2008). Retrieved November 29, 2020 from https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html

Larch, M., Monteiro, J.-A., Piermartini, R., & Yotov, Y. (2019). On the Effects of GATT/WTO Membership on Trade: They Are Positive and Large after All. CESifo Working Paper 7721, 31 pp. (Accessed January 14, 2021).

Larch, M., Wanner, J., Yotov, Y. V., & Zylkin, T. (2019). Currency unions and trade: A PPML re-assessment with high-dimensional fixed effects. *Oxford Bulletin of Economics and Statistics*, *81*, 487–510. https://doi.org/10.1111/obes.12283

Matsumoto, H. (2004). International urban systems and air passenger and cargo flows: some calculations. *Journal of Air Transport Management*, *10*, 239–247. https://doi.org/10.1016/j.jairtraman.2004.02.003

Matsumoto, H. (2007). International air network structures and air traffic density of world cities. *Transportation Research Part E: Logistics and Transportation Review*, *43*, 269–282. https://doi.org/10.1016/j.tre.2006.10.007

Monteiro, J.-A. (2020). *Structural Gravity Manufacturing Sector Dataset: 1980–2016*. World Trade Organization. Retrieved December 1, 2020 from https://www.wto.org/english/res_e/reser_e/structural_gravity_e.htm

Morley, C., Rosselló, J., & Santana-Gallego, M. (2014). Gravity models for tourism demand: theory and use. *Annals of Tourism Research*, *48*, 1–10. https://doi.org/10.1016/j.annals.2014.05.008

Piermartini, R., & Rousová, L. (2013). The sky is not flat: How discriminatory is the access to international air services? *American Economic Journal: Economic Policy*, *5*, 287–319. https://doi.org/10.2307/43189348

Rose, A. K. (2000). One money, one market: The effect of common currencies on trade. *Economic Policy*, *15*, 7–45. https://doi.org/10.1111/1468-0327.00056

Saayman, A., Figini, P., & Cassella, S. (2016). The influence of formal trade agreements and informal economic co-operation on international tourism flows. *Tourism Economics*, *22*, 1274–1300. https://doi.org/10.1177/1354816616672600

Santana-Gallego, M., Ledesma-Rodríguez, F., & Pérez-Rodríguez, J. (2016). The euro effect: Tourism creation, tourism diversion and tourism potential within the European Union. *European Union Politics*, *17*, 46–68. https://doi.org/10.1177/1465116515600533

Santos Silva, J., & Tenreyro, S. (2006). The Log of Gravity. *Review of Economics and Statistics*, *88*, 641–658. https://doi.org/10.1162/rest.88.4.641

Santos Silva, J., & Tenreyro, S. (2010). Currency unions in prospect and retrospect. *Annual Review of Economics*, *2*, 51–74. https://doi.org/10.1146/annurev.economics.102308.124508

Santos Silva, J., & Tenreyro, S. (2011). Further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator. *Economics Letters*, *112*, 220–222. https://doi.org/10.1016/j.econlet.2011.05.008

Turner, S. A. (2002). *An application of a gravity model to air cargo at Vancouver International Airport*. The University of British Columbia.

World Bank. (2011). *World Bank's Climate Change Knowledge Portal: Historical Data*. Retrieved February 25, 2020 from https://datacatalog.worldbank.org/dataset/climate-change-knowledge-portal-historical-data

World Bank. (2021). *World Development Indicators*. Retrieved October 20, 2021 from https://databank.worldbank.org/source/world-development-indicators

WTO. (2011). *Air Services Agreements Projector (ASAP) - Dataviewer*. Retrieved November 2, 2020 from https://www.wto.org/asap/index.html

WTO. (2011). *Air Services Agreements Projector (ASAP) 2011 - Methodology*. Retrieved March 11, 2021 from https://www.wto.org/asap/resource/data/html/methodology_e.htm

Yamaguchi, K. (2008). International trade and air cargo: Analysis of US export and air transport policy. *Transportation Research Part E: Logistics and Transportation Review*, *44*, 653–663. https://doi.org/10.1016/j.tre.2007.05.006

Yotov, Y., Piermartini, R., Monteiro, J.-A., & Larch, M. (2016). *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model*. World Trade Organization.

How to cite this article: Oesingmann, K. (2022). The determinants of air cargo flows and the role of multinational agreements: An empirical comparison with trade and air passenger flows. *The World Economy*, 45, 2370–2393. https://doi.org/10.1111/twec.13245

APPENDIX A

TABLE A1 European countries included in the data set and beginning of EU, Schengen and Euro membership[1]

	EU	Schengen[2]	Euro
Austria	1995	1998	2002
Belgium	1958	1995	2002
Bulgaria	2007		
Croatia	2013		
Cyprus	2004		2008
Czech Republic	2004	2008	
Denmark	1973	2001	
Estonia	2004	2008	2011
Finland	1995	2001	2002
France	1958	1995	2002
Germany	1958	1995	2002
Greece	1981	2000	2002
Hungary	2004	2008	
Ireland	1973		2002
Italy	1958	1997	2002
Latvia	2004	2008	2014
Lithuania	2004	2008	2015
Luxembourg	1958	1995	2002
Malta	2004	2008	2008
Netherlands	1958	1995	2002
Norway		2001	
Poland	2004	2008	
Portugal	1986	1995	2002
Romania	2007		
Slovakia	2004	2008	2009
Slovenia	2004	2008	2007
Spain	1986	1995	2002
Sweden	1995	2001	
Switzerland		2009	
United Kingdom	1973–2020		

Notes: (1) The total number of countries included in the data set are the following: (i) 16 major EU countries as origin countries: Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Luxembourg, the Netherlands, Poland, Portugal, Spain, Sweden and the United Kingdom; (ii) 14 additional European countries as destination countries: Bulgaria, Croatia, Cyprus, Estonia, Ireland, Latvia, Lithuania, Luxembourg, Malta, Norway, Romania, Slovakia, Slovenia, Switzerland; (iii) another 41 countries worldwide as destination countries: Algeria, Angola, Argentina, Bahrain, Brazil, Canada, Chile, China, Colombia, Ecuador, Egypt, Ethiopia, India, Indonesia, Iran, Israel, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Lebanon, Malaysia, Mexico, Morocco, Nigeria, Oman, Qatar, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Taiwan, Thailand, Tunisia, Turkey, Ukraine, United Arab Emirates, United States, Vietnam. (2) In the case of the information on Schengen membership, the year is shown when Schengen became effective and not when the Schengen agreement was ratified. When the respective date was for example 01.12.2001, the year 2002 is taken as the effective year.

TABLE A2 Summary statistics—International country-pairs

Variable	Count	Mean	Min	Max	Unit/*Type*	Group
aircargo	28,422	6,228.11	0	404,143	tons	Dependent variables (X_{ijt}, with $i \neq j$)
trade	40,521	1.94e+09	0	1.30e+11	USD, deflated	
airpax	32,127	328,145.00	0	2.07e+07	passengers	
dist	46,000	4,571.25	59.62	13,501.46	km	Gravity variables ($GRAVITY_{ij}$, with $i \neq j$)
COML	46,000	0.04	0	1	*dummy*	
COL	46,000	0.05	0	1	*dummy*	
CONT	46,000	0.04	0	1	*dummy*	
temp_diff	46,000	9.26	0.05	26.15	Celsius	
EURO	46,000	0.06	0	1	*dummy*	Policy variables ($AGRMNT_{ijt}$, with $i \neq j$)
EU	46,000	0.21	0	1	*dummy*	
SCHENG	46,000	0.72	0	1	*dummy*	
OTHER_RTA	46,000	0.16	0	1	*dummy*	
ali	36,000	13.29	0	51	*continuous*	

Notes: Continuous variables are written in lower case letters and dummy variables are written in capital letters. i = Country i, j = Country j, t = Year.

TABLE A3 Robustness checks—Trade flows

	(0)	(1)	(2)	(3)	(4)	(5)
	trade	**trade**	**trade**	**trade**	**trade**	**trade**
	Total data set	**Total data set**	**Total data set**	**Total data set**	**Intra-Europe**	**1994–2011**
EURO	0.010	−0.064			0.020	−0.019
	(0.032)	(0.040)			(0.030)	(0.027)
EU	0.330***		0.329***		0.347***	0.274***
	(0.041)		(0.047)		(0.039)	(0.037)
SCHENG	0.008			0.061**	0.002	−0.006
	(0.023)			(0.029)	(0.026)	(0.018)
OTHER_RTA	0.578***	0.539***	0.582***	0.506***		0.426***
	(0.130)	(0.137)	(0.130)	(0.136)		(0.129)
N	41,207	41,207	41,207	41,207	13,644	32,225
Pseudo-R^2	0.998	0.998	0.998	0.998	0.999	0.999

Notes: All models are estimated with PPML and include intranational flows as well as origin-year, destination-year and country-pair fixed effects. The estimates of the constant, the international border dummies and the fixed effects are not reported. Standard errors, clustered by country-pair, are given in parentheses. $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

TABLE A4 Robustness checks—Air passenger flows

	(0)	(1)	(2)	(3)	(4)	(5)
	airpax	airpax	airpax	airpax	airpax	airpax
	Total data set	**Total data set**	**Total data set**	**Total data set**	**Intra-Europe**	**1994–2011**
EURO	0.106**	0.107**			0.138***	0.071*
	(0.045)	(0.045)			(0.043)	(0.043)
EU	0.317***		0.342***		0.331***	0.291***
	(0.066)		(0.067)		(0.083)	(0.090)
SCHENG	0.144***			0.148***	0.177***	0.127***
	(0.042)			(0.041)	(0.053)	(0.041)
OTHER_RTA	0.063	−0.138	0.093	−0.150		0.112
	(0.146)	(0.142)	(0.146)	(0.142)		(0.121)
sq(ali)						−0.003
						(0.010)
N	32,611	32,611	32,611	32,611	13,989	24,042
Pseudo-R^2	0.992	0.992	0.992	0.992	0.994	0.993

Notes: All models are estimated with PPML and include intranational flows as well as origin-year, destination-year and country-pair fixed effects. The estimates of the constant, the international border dummies and the fixed effects are not reported. Standard errors, clustered by country-pair, are given in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.