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ORIGINAL ARTICLE

Do changes in air transportation affect productivity? A cross-country panel approach

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This paper quantifies the economic impact of air transportation worldwide using two panel data methods to assess the effect of air cargo and air passenger volumes on GDP per employee (aggregate labour productivity). Fixed effects methods and instrumental variables allow us to tackle endogeneity concerns and simultaneity biases. We first use a generalized method of moments specification (GMM) on a World Bank panel dataset containing information for all countries worldwide, separated into 264 areas over the period 1990-2017. Results show that a 10% increase in air passengers is associated with a 0.6% increase in GDP per employee. Complementary instrumental variables estimates indicate a slight negative bias in this result, yielding an effect of 0.86%. Results are very similar for different parts of the world, with elasticity estimates ranging between 0.01 and 0.04, except in North Africa and Middle Eastern countries, where effects on labour productivity are found to be insignificant. Overall, air passenger traffic has a stronger and more positive effect on GDP per employee than air cargo. We conduct a complementary analysis at the European level using Eurostat data (NUTS2) and perform an analysis on over 300 European sub-regions. Results indicate that air transport has a positive, stronger and more significant effect on GDP per employee than air cargo, with a 10% increase in air passengers being associated with a labour productivity increase of 3.2%.

KEYWORDS

air transport, aviation, causal inference, instrumental variables, productivity

JEL CLASSIFICATION

L93; R4; R11

1 | INTRODUCTION

Air transport is regarded as an important factor for economic growth. The academic literature defines various different channels through which air transport can affect the economy, which can be categorized as direct effects, indirect effects and spillover effects, also known as wider economic impacts (for recent reviews, see Button & Yuan, 2013, Zhang & Graham, 2020). Direct effects come from supply-chain activities including impacts from airport operations or aircraft manufacture and maintenance. Indirect effects arise from links with fuel suppliers as well as induced effects such as expenditure by aviation industry employees. Spillover effects are sourced from the influence that aviation has on access to markets, resources, labour, knowledge and other benefits of enlargement in economic scale and scope.

Through competition amongst airlines and interactions with airports and passengers, the development of airline markets are expected to reduce costs and increase trade levels; these effects are discussed at length in several studies (see Fu, Lijesen, and Oum (2006); Fu and Zhang (2010); Brueckner (2003); Lijesen and Behrens (2017); Williams (2017). Air transport allows firms to firms to shorten delivery times and promotes innovation by encouraging networking and exchange of information and may also encourage greater spending in research and development. In addition, the rise of air transport substantially reduces frictional constraints on long-distance economic interactions. In the context of air transport, previous studies have shown that an airport's local impact includes attracting business investment and raising productivity at the aggregate level. Some studies referred to the agglomeration benefits that are reflected in the composition of firms clustering around an airport (Warffemius, 2007; Kasarda, 2000; Kasarda John, 2008).

In terms of empirical work, much of the existing literature on the relationship between air transport and the economy has important limitations. These are as follows. First, little attention has been paid to the causal nature of relationships between aviation and the economy. Second, existing studies typically do not differentiate effects by geographic area or investigate heterogeneity in response, since most research is case study based with an emphasis on the developed world. Third, econometric specifications have often not dealt adequately with problems of endogeneity, which comes from a variety of sources including omitted variables and reverse causality. This is problematic because the relationship between air transport and spatial economic outcomes is plagued with reverse causality because locations with high economic activity tend to attract more air transport, but conversely, air transport has also an effect on the economy through the aforementioned mechanisms (direct, indirect, and spillover effects). Air transport is highly endogenous to economic activity; therefore, in this study, we account for various aspects of endogeneity (including reverse causality) by using empirical methodologies that can clearly identify causal effects.

This paper contributes to the literature on aviation and economic development by conducting a cross country analysis of effects in aggregate labour productivity. We also differentiate between the effect of cargo and passenger traffic, whereas the majority of papers focus on passengers. Crucially, we do it by using models that address endogeneity concern by using via panel data estimators designed to negate problems of reverse causality and omitted variables. Our analysis is based on a World Bank panel dataset of all countries worldwide separated into 264 areas over the period 1990-2017. We estimate the effect of air passengers and air cargo on the level of GDP per employee. We develop two complementary analyses: (i) on all countries, and (ii) on sub-samples for different world zones: Europe and central Asia, South and East Asia, Latino America and Caribbean, Sub-Saharan Africa, and Arab World with Middle East.

We address the endogenous nature of the relationship between air transport and the economy using two methodologies: (i) a fixed-effect estimator (FE) and (ii) an instrumental variable methodology (IV) that utilises past growth rates as instruments. The fixed effect component removes bias from unobserved time invariant confounding. Also, since both air passengers and air cargo are likely to be correlated with time variant unobservable components of GDP per employee, due to both omitted variables and reverse causality, we also use an IV Generalized Method of Moments regressions (GMM) estimator to nullify these remaining sources of bias.

Overall, we find that air transport has a positive effect on labour productivity. We find a larger and more significant effect on the GDP per employee from air passenger traffic than from cargo. We find that a 10% increase in air passengers is associated with an increase of 0.6% in GDP per employee. Using sub sampled data for different geographic zones, we find that estimates that ranges from 0.37% in Europe and Central Asia to 0.13% in South Asia and Eastern Asia. The only sub sample for which air passengers is insignificant is the Arab World and Middle East. Results from IV estimations indicate that the fixed effects estimates may have a downwards biased. The IV analysis indicates that a 10% increase in air passengers is associated with an increase of 0.86% of GDP per employee. When using sub samples for different geographic zones, we find estimates ranging from 0.88% in Europe and Central Asia to 1.6% in South Asia and Eastern Asia. We perform robustness check and relevance tests for the instruments in the appendix. Additionally, we use panel data from Eurostat for all 300 European sub-regions in NUTS2 areas and perform a similar exercise. We find similar results to those obtained using the World Bank Data. Thus, our findings indicate that air transportation has a significant effect on the economy, particularly passenger traffic, and that effects are fairly homogeneous across developing and developed regions.

The paper is organised as follows. Section 2 reviews the relevant literature, Section 3 describes the trends in world aviation and world economy from 1990 onwards. Section 4 describes the data and Section 5 introduces the econometric methods. Section 6 presents the results. Section 7concludes.

2 | LITERATURE REVIEW

A large stand of literature is dedicated to the study of the economic impacts of air transportation (see Zhang & Graham, 2020, for a literature review). Employment is chosen as the outcome variable in the large majority of these studies since it constitutes a consistent and standard measure of the growth of the aviation industry.

Among the first studies analysing the economic impact of air transport, Irwin and Kasarda (1991) investigated the effect of extending the airline network of metropolitan areas on economic outputs. They found that a 10% increase in urban aviation centrality and accessibility was associated with a 4.29% increase in employment.

Button, Lall, Stough, and Trice (1999), Button and Taylor (2000) used data collected after the 1978 deregulation of the US domestic air transport market to estimate the relationship between air transport and high technology employment. The former paper found a significant and positive effect on technological employment, while the latter found that 1.5 jobs are created for every 1000 air passengers in industries dependent on the quality of local transportation services. These results, however, are derived from associational inference and thus tell us little about the causal economic effect of air transportation Button et al. (1999). Brueckner (2003) studied the effect of hub airports in metropolitan areas. He found that a 10% increase in passengers causes a 1% increase in employment in service-related industries in US. This result relies on a form of ignorability assumption, with the impacts of airports being regarded as exogenous conditional on a set of observed covariates.

Using a similar approach, Percoco (2010) studied the impact of airports on Italian provinces. He found that a 10% increase in passengers corresponds with a 0.45% increase in service employment. Other studies have used instrumental variable (IV hereafter) approaches to achieve causal identification. Green (2007) used geographic and lagged variables as instruments and found that air passenger flow can predict total employment at the metropolitan level, while air cargo activity cannot. However, the exogeneity of instruments is in this case is perhaps hard to demonstrate. Other studies have also used historical IVs to deal with the endogeneity problem, a popular approach within the transport literature. Sheard (2014) used the 1944 National Airport Plan to instrument for the current distribution of airports. He found that the effect of airport size is positive on the employment of tradeable services, but the effect on total local employment is practically zero.

McGraw (2014) used three instruments (collection point locations on the Air Mail system of 1938, a network of emergency airfields in the early years of aviation, and a 1922 plan of airways for US defence) to estimate the effect of airports on population and employment. He found a positive effect ranging between 14.6% and 29% on population growth, and between 14.6% and 29% on employment growth. Blonigen and Cristea (2015) used changes in air traffic resulting from the 1978 Airline Deregulation as an instrument and found that a 50% increase in an average city's air traffic growth rate generates an increase of 7.4% in real GDP.

More broadly, the literature on the economic impacts of air transportation contains mostly studies of developed countries. Fewer studies focus on developing countries, partly due to the recent availability of data as well as the later development of the aviation sector in these countries. Gibbons and Wu (2017) found that in China, air connections have a positive effect on GDP, especially on the manufacturing sector rather than services. They used military airports from the Second World War as instrument for current airports. Carbo and Graham (2019) use the deregulation of Chinese aviation in 2003 as a quasi-natural experiment to find the effect of air transport in Chinese regional economy: they find that a 10% increase in aviation yields a 2.6% increase in GDP per employee. Bourguignon and Darpeix (2016) estimated the GDP elasticity of air traffic in developing countries. They used panel co-integration techniques and error correction model to find those elasticities. Interestingly, they conclude that there are no significant differences between developing regions. Yet, they fail to provide precise estimates, nor do they properly address endogeneity concerns.

Table 1 below summarizes key results found in the literature which vary by sector, study units and periods of interest. Passenger elasticities range between 0.03 and 0.08 while airport size elasticities in the literature remain smaller (0.03). Elasticities with respect to airport access are larger, but this is potentially in line with the fact that airports in China are more recent than US ones, and both the aviation sector and industries appear to be in a growing period.

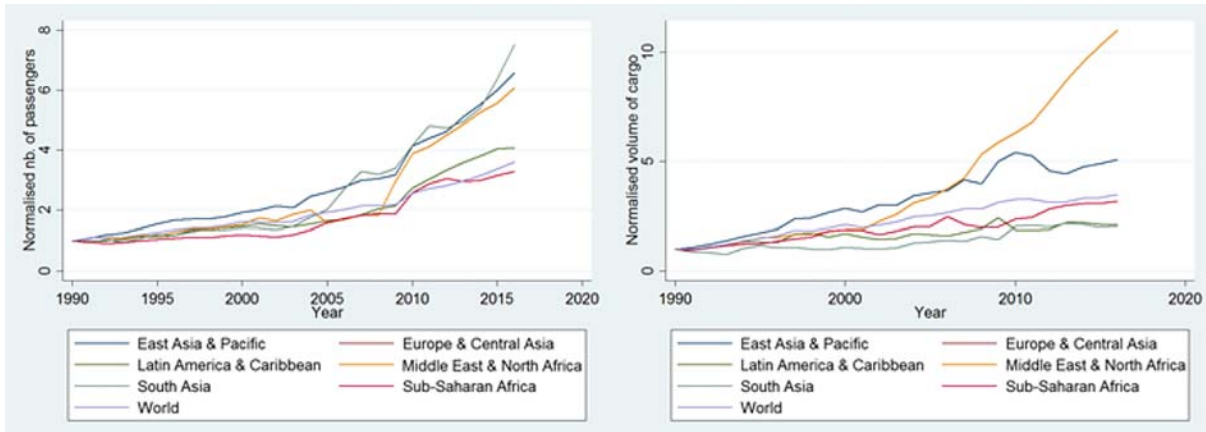
It is important to note that most existing studies in the field have found the identification of causal effects challenging due to endogeneity issues, namely reverse causality concerns and omitted variable biases. Consequently, it appears that estimates of the effect of air transport differ depending on the empirical approach chosen to tackle this heterogeneity.

3 | AVIATION TRENDS

Figure 1 shows that aviation transportation has increased hugely over the last 30 years. This is true on average as well as for world regions divided into five areas: Europe and Central Asia, Latino America and Caribbean, Sub-Saharan Africa, Arab World and Middle East, and South/East Asia with Oceania. Air transportation is depicted for each region with its value normalized to one in 1990. The volume of air passengers is 8 time higher in Asia and Oceania, the Middle East and North Africa in 2016 compared to 1990 levels. On average, the volume of air passengers is approximately 4 time higher compared to 1990. Air cargo also experienced a large increase being between 2.5 and 5 times higher in 2016 compared to 1990. A more notable increase in air cargo is observable in the Middle East and North Africa: we record a ten-fold increase over the time period.

TABLE 1 Summary of results in the literature on the impact of aviation on the economic activity

Period	Country	Article	Air transport measure	Economic measure	Pooled sectors	Goods related	Pooled sectors
1979-1997	US	Button et al. (1999)	Passenger	High tech. empl.	-	+12,000 high tech. jobs	-
1950-1980	US	Irwin & Kasarda (1991)	Air network centrality	Employment	0.429	0.513 (manuf.)	0.505 (prod. serv.)
1996	US	Button & Taylor (2000)	Passenger	Employment	-	+1.5 jobs/1000 air passg.	-
1996	US	Brueckner (2003)	Passenger	Employment	0.08	0 (goods-related)	0.1 (serv. related)
1990	US	Green (2003)	Passenger Cargo	Employment	0.028 0	-	-
2002	Italy	Percoco (2010)	Passenger	Employment	0.045	-	-
2007	US	Sheard (2014)	Airport size	Employment	0	0 (manufacturing)	0.22 (tradable serv.) 0 (non-trad. serv.)
1991-2013	US	Sheard (2015)	Airport size	1. Employment 2. Output (GDP)	0.03 0.03	-	-
1900-2010	US	McGraw (2014)	Airport presence	1. Population 2. Employment	0.14 to 0.29 0.17-0.26	0.26-0.42 (trad. indus.) 0 (non-trad. indus.)	-
1978-1998	US	Bloningen & Cristea (2015)	Passenger	1. Population 2. Output (GDP)	0.031 0.14	-	-
2001-2010	China	Gibbons & Wu (2018)	Airport access	Output (GDP)	0.2591	0.4164 (manuf.)	0



(a) Passengers, reference year 1990 (b) Cargo, reference year 2000

FIGURE 1 Evolution of the volume of air passengers and air transport of freight, reference year 1990
Source: World Bank data.

4 | DATA AND METHODS

4.1 | Data

We use two annual databases sourced from the World Bank and Eurostat. The first dataset is the Civil Aviation Statistics of the World produced by the World Bank International Civil Aviation Organization. It contains annual records of both domestic and international aircraft passengers and of the cargo of air carriers registered in a total of 151 countries over the period from 1990 to 2016. We conduct a second complementary analysis using the Nomenclature of Territorial Units for Statistics (NUTS), which is Eurostat's common classification of European territorial units for statistics. This nomenclature is defined by three different levels. In this study, we use information on regions as defined by the second level (NUTS 2 hereafter). This dataset contains annual information on 239 regions over the period 2000-2016.

In terms of a dependent variable measuring economic development, both datasets allow us to compute the labour productivity measured as GDP per employee. We use the GDP per employee as the economic outcome of interest as it is commonly used in the literature, (*e.g.*, Bourguignon & Darpeix, 2016, Gibbons & Wu, 2017, among others) and mainly by institutions as well. [1]This indicator represents the GDP per hour worked, and it measures how efficiently employee hours worked are combined with other production factors involved in the production process.

The main independent, or 'treatment' variables used in this analysis are: (i) the annual number of passengers and (ii) the annual freight volume of air transport. We consider many potential determinants of growth in order to isolate the net effect of air passengers and air cargo on the economy and avoid endogeneity from omitted variables bias. To this end we include a set of macroeconomic variables as controls which include the following: (i) Percentage of Agriculture, Industry and Services over GDP, (ii) education as a percentage of population with tertiary studies, (iii) investment as a percentage of gross capital formation over GDP and (iv) unemployment rates.

Descriptive statistics in Table 2 below shows that the distribution of macroeconomic variables changes across continents. In all areas except Sub-Saharan countries, services represent the largest share of GDP.

5 | METHODOLOGY

5.1 | Fixed effects

In order to model the effect of air transport on the economy, we resort to a specification that builds upon a framework widely used in the literature (Gibbons & Wu, 2017; Banerjee, Duflo, & Qian, 2020; Brueckner, 2003; Percoco, 2010). We estimate the following fixed effect (FE) model specification:

$$Y_{st} = \alpha_s + \lambda_t + X'_{st}\beta + \delta_1 Cargo_{st} + \delta_2 Passengers_{st} + e_{st}, \tag{1}$$

where the dependent variable Y_{it} is log of productivity in region s at time t, e_{st} is the error term, α_s and λ_t are region and time fixed effects. X_{st} represents a vector of macroeconomic variables that literature uses as determinants of economic growth: investment, education, sectoral decomposition of GDP, and unemployment. [2]Additional determinants of the GDP have also been included in the vector X_{st}, namely the GDP per worker, trade-to-GDP ratio, and FDI. GDP per workers come from the Penn World Table while trade-to-GDP ratio and FDI are available in the Civil Aviation Statistics of the World, produced by the World Bank.

In this study, the specification used follows the Solow (1999) framework used in the literature on the determinants of growth, where dependent variables control namely for the impact of capital and labour on GDP growth. Therefore, we include information on physical capital stock, trade-to-GDP ratio and foreign direct investments as controls for capital. Macroeconomic variables (*e.g.*, unemployment) represent the state of the labour market. Additional

[1] See: https://data.oecd.org/lprdty/gdp-per-hour-worked.htm
[2] In order to avoid perfect multicollinearity, we precise that we included two out of the total of three sectors in the regressions.

TABLE 2 Descriptive statistics by geographical area

	Geographical Areas					
	World	Europe / Central Asia	Sub-Sahara	Asia and Oceania	Arab Countries / Middle East	Latin America
Passengers (logs)	14.08	14.64	12.32	14.42	14.75	14.70
	(2.18)	(2.02)	(1.48)	(2.48)	(1.16)	(2.06)
Cargo (logs)	10.45	10.62	9.02	11.07	11.29	10.63
	(3.04)	(3.14)	(2.38)	(3.47)	(2.21)	(2.86)
Education	30.75	47.42	5.72	26.75	26.01	34.29
	(24.65)	(21.36)	(6.16)	(24.52)	(15.54)	(22.82)
Unemployment rates	8.72	10.04	9.02	4.89	10.91	9.23
	(6.37)	(6.60)	(7.45)	(3.66)	(6.58)	(4.61)
% of Agriculture over GDP	31.47	16.77	60.65	36.58	14.85	17.12
	(26.59)	(15.69)	(21.61)	(26.87)	(13.42)	(12.43)
% of Industry over GDP	19.93	26.36	11.61	17.67	26.97	20.04
	(9.39)	(7.59)	(7.23)	(8.37)	(8.63)	(4.35)
% of Services over GDP	48.60	56.87	27.74	45.75	58.18	62.84
	(20.90)	(14.63)	(16.49)	(21.92)	(13.94)	(11.99)
Investment	23.72	23.69	21.69	26.9	24.66	21.96
	(9.43)	(5.75)	(14.47)	(8.98)	(7.66)	(7.83)
Trade (in %)	86.6	93.8	75.82	98.01	92.29	68.61
	(54.65)	(45.84)	(40.73)	(79.71)	(51.46)	(39.2)
FDI over GDP (in %)	2.90	4.12	1.48	2.24	4.57	2.12
	(11.35)	(10.91)	(2.97)	(4.51)	(27.03)	(2.33)
Capital per capita	73322.13	108716.9	19034.38	67977.95	101477.8	58979.11
	(77224.15)	(74509.17)	(26745.31)	(81526.98)	(104793.6)	(43728.5)

Notes: t statistics in parentheses $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Standard errors in parentheses. Investment is measured as Gross Capital Formation. GDP is in PPP. *Source:* World Bank data, own calculations.

controls include the distribution of industries, similar to Percoco (2010). Variables chosen reflect potential economic determinants of air traffic, following Bourguignon and Darpeix (2016).

Our interest lies in estimating the effect of air transport on economic growth. In this study, we focus on the estimates of δ_1 and δ_2. Cargo and Passengers are also measured in logs. Therefore, δ_1 and δ_2 represent elasticities of the demand with respect to air passengers or air cargo. The fixed effects model can account for the possible correlation between the regressors and the time invariant heterogeneity at the unit level.

5.2 | Instrumental variables

The main problem with the FE model is that the regressors could be also correlated with time varying unobserved components that could appear in the error term of regression (1), implying that, $E[X_t'e_t] \neq 0$, $E[Passengers_t e_t] \neq 0$, $E[Cargo_t e_t] \neq 0$. If that is the case, FE estimates would yield biased estimates of the causal effect of air transport on the economy. A viable solution is to supplement the panel model with instrumentation for potentially endogenous regressors. [3]

In this study, we propose to use lags of first differences of the endogenous variables as instruments. We use second to fifth lags of first differences of all regressors, including passenger and cargo. These instruments are relevant, as we show in the results section, since they are correlated significantly with the endogenous

[3] An instrumental variable is a variable $Z_s t$ which satisfies both the relevance and exogenous conditions. The relevance assumption means that the potential instrumental variable should be correlated with the endogenous variable: $E[X_{st}' Z_s t] \neq 0$. The exogeneity assumption implies that the potential instrumental variable is not correlated with the time variant component of the error: $E[Z_t' e_t] = 0$.

variables. We argue that they are exogenous, because growth rates from two periods before and beyond should not be correlated with present time variant unobservable elements. In addition, we provide Sargan-Hansen test results that suggest that our instruments are exogenous. Consequently, following the assumption that: $E[\delta X'_{t-i}e_t] = 0, i = 2,3,4, E[\delta Passengers_{t-i}e_t] = 0, i = 2,3,4 and E[\delta Cargo_{t-i}e_t] = 0, i = 2,3,4$, we can use second to fourth lags of first differences of the regressors, passengers and cargo to obtain causal estimates of regression 1.

This decision has both theoretical and empirical underlying motives. Firstly, we assume that the growth passengers over the 5 previous years affects the growth of passengers at date t. We acknowledge that due to inertia in habit formation (Cherchi, Meloni, & Dios Ortúzar, 2014), it might take up to 5 years for the growth of passengers to have an effect on the level of passengers. In addition, there is a need to use lags going as far as 5 years backwards because of the nature of the investment. Investments in the aviation sector are capital-intensive, which fall into the category of long-run investments according to Solow (1999) framework. Considering aviation sector investments as long-run investments is common in the literature (see Bernardo & Fageda, 2017). A key aspect is the assumption that the necessary instruments are 'internal'. In other words, this means that instruments are based on lagged values of the instrumented variable(s).

This study provides a cross-country estimation for several reasons. Firstly, a cross-country analysis generates average estimates of the economic impacts of aviation that are not context-specific and produces instead a generic indication of its economic value. Secondly, cross-country studies provide a comprehensive coverage of economic impacts both across time and space. A third argument is that by sub-sampling, we can analyse geographical heterogeneity in the economic impacts of air transport for world regions. And finally, this worldwide sample provides us with information embedded in the data that allows us to address endogeneity concerns in effective ways.

6 | RESULTS

6.1 | Baseline results

6.1.1 | Instrumental variables

The need for instrumental variables is rooted in the observation of estimates from the fixed effects model. Table 3 shows results for obtained using fixed effects specification of regression 1 for 6 different samples, one in each column: all countries; Europe and Central Asia; Sub-Saharan countries; East Asia, South Asia and Oceania; North Africa and the Middle East; and Latin American. The main finding from Table 3 is that air passenger-based aviation consistently appears to have a larger and more significant effect on labour productivity than air cargo. Using the sample with all countries, we find that a 10% increase in air passengers is associated with an increase of 0.6% of GDP per employee. When using sub samples for different geographic zones, we find ballpark of estimates that range from 0.37% in Europe and Central Asia to 0.13% in South Asia and Eastern Asia. Air transport is significant at 1% for all samples except for North Africa and the Middle East. This subgroup's size is much smaller with less countries and less observations, which ultimately impairs the robustness of our results.

Results for air cargo are consistently less significant and more difficult to interpret than those for passengers. Air cargo has a positive and significant effect on labour productivity for Latin America and Asia, and a negative and significant effect for Europe and Central Asia as well as North Africa and Middle East. One possible explanation is that trade volumes are negatively correlated with GDP levels, indicating that the share of the industry sector is larger for countries with a lower level of GDP/employee. Estimates are insignificant both for the full sample and for sub-Saharan countries.

Estimates from the fixed effects specification in Column (1) in Table 4 could be biased for the reasons stated in Section 4. IV estimates from regression (1) are presented in Table 4 below. Each column presents results for each estimation by geographical area. These IV estimates suggest that our main results still hold: air transport passenger activity has a more significant and larger effect on labour productivity than air cargo. Additionally, we find evidence suggesting that our fixed effects estimates may be downwards biased. Effect estimates of air transport passengers

TABLE 3 Productivity estimates from the fixed effects specification, by area

	GDP per employee					
	World	Europe / Central Asia	Sub-Sahara	Asia and Oceania	Arab Countries / Middle East	Latin America
Cargo	-0.000793	-0.00619	-0.00156	0.0371***	-0.113***	0.0123**
	(-0.26)	(-1.22)	(-0.25)	(4.57)	(-7.75)	(2.61)
Passengers	0.0407***	0.0519***	0.0567***	0.0630 ***	0.0659*	0.0323**
	(6.22)	(5.14)	(3.96)	(4.32)	(2.36)	(3.14)
Nb. Countries	154	47	37	28	18	25
Nb. Obs.	2866	968	554	541	306	483
R-squared	0.889	0.925	0.892	0.960	0.890	0.938

Note: t statistics in parentheses *p<0.05, **p<0.01, ***p<0.001. *Source:* World Bank data, own calculations.

TABLE 4 Productivity estimates from the instrumental variables specification, by area

	GDP per employee					
	World	Europe / Central Asia	Sub-Sahara	Asia and Oceania	Arab Countries / Middle East	Latin America
Cargo	-0.0601**	-0.0511*	0.0130	-0.111**	-0.124*	0.00996
	(-2.94)	(-2.22)	(0.25)	(-2.74)	(-2.02)	(0.58)
Passengers	0.118***	0.0706*	0.120***	0.171*	0.0785	0.0815*
	(4.88)	(2.19)	(3.98)	(2.16)	(0.30)	(1.99)
Nb. of observations	2082	728	333	427	237	354
R-squared	0.872	0.917	0.857	0.923	0.871	0.937
Cragg-Donald F statistic	7.252	4.911	0.664	3.008	0.251	3.154
Sargan test	0.568	0.675	0.294	0.431	0.6505	0.9562
Hausman test	0.0036	0.227	0.169	0.000	0.8614	0.3650
t statistics in parentheses						

Notes: *p<0.05, **p<0.01, ***p<0.001. *Source:* World Bank data, own calculations.

on GDP employee obtained by IV are larger than those in the FE models. Using the worldwide sample, we find that a 1% increase in air passengers is associated with an increase of 0.12% of GDP per employee. When using subsamples for different geographic zones, estimates range from 0.07% in Europe and Central Asia to 0.171% in South Asia and Eastern Asia. Air transport is significant at 10% for all samples except for North Africa and the Middle East. The range of estimates suggest that the coefficients are comparable across regions, and the range of estimates holds with an interpretation that corroborates the previous findings in the literature. We notice that the elasticities are smaller for areas where the railway and road systems are more developed and constitute stronger alternatives.

Estimates in Table 4 indicate that a larger number of passengers increases the levels of productivity (GDP/employee) both worldwide and for all geographical regions. As such, our results suggest the development of the aviation section generates overall economic gains for both developed, developing and emerging economies. This corroborates previous findings from the literature (see Bourguignon & Darpeix, 2016). In addition, results are larger for areas including more emerging economies (*e.g.*, Asia), which implies that there are incentives for policymakers to invest in the aviation sector as returns to these policies would be of a larger magnitude. Policies in favour of the development of the aviation sector and the volume of passengers range from infrastructure investments (*e.g.*, airport extensions) to the creation of open-skies agreements for new markets to open and develop both within and between emerging and developing economies. Although overall orders of magnitude are generally comparable, estimates are not significant for the Arab Countries/Middle East region. For the Middle-East, the GDP per employee appears to

TABLE 5 European estimates, fixed effects and instrumental variables

	GDP/emp FE	GDP/emp IV
Cargo	0.0241***	0.0537***
	(6.90)	(3.89)
Passengers	0.109***	0.141*
	(19.39)	(2.26)
Nb. Obs.	2,657	1,444
Nb. regions	239	189
R^2	0.613	0.595
R^2_w	0.613	-
R^2_b	0.134	-
Cragg-Donald F statistic	-	3.585
Sargan test	-	0.9046
Hausman test	-	0.0048

Notes: t statistics in parentheses; *p<0.05, **p<0.01, ***p<0.001. *Source:* Europe NUTS2 data, own calculations.

be either decreasing or stagnant over the majority of the period covered in our data [4]. Thus, the insignificance of coefficient implies that there exists a shift towards more labour intensive industries for these countries such that, despite the development of the aviation sector, the GDP per employee does not significantly change.

Regarding coefficients attached to cargo transport, we notice they are insignificant for the Sub-Sahara and Latin America areas. For all other cases, coefficients are negative and significant. When using IV, we obtain smaller sample sizes than with fixed effects estimations because, due to differencing, instruments become unavailable for all countries for all years. For example, the sub-sample with all countries had 3,284 observations and 155 countries in the fixed effects estimation, but 2,359 observations and 151 countries in the IV estimation.

In order to establish that instruments are not weak, we perform Cragg-Donald tests and compare the statistic obtained to the Yogo critical values. The rule is that instruments are not considered weak if the Cragg statistic is larger than the Yogo critical value of 4.66 for a maximum bias of 30% relative to the OLS estimation (Stock & Yogo, 2002). Table 4 indicates that for the full sample and Europe (Column (1) and (2)), the Cragg-Donald test implies that the instruments are not weak. This table also includes Hausman tests for endogeneity. For this test, the null hypothesis means that the specified endogenous regressors (passengers and cargo) can actually be treated as exogenous. Estimates from the Hausman test for the full sample ("World") indicate that we can reject the null of the test in the overwhelming majority of specifications which justifies the use of instruments in order to deal with the endogeneity issues of passengers and cargo.

We instrument all regressors that were included in regression (1) and we report F-statistics of the first stage regression (respectively for air passengers and air cargo). It can be seen that instruments are always relevant except for air cargo in the sub samples of North Africa and Middle East and Latin America. For those two sub-samples, our instruments for air cargo are weak. For all other variables, the instruments are strong and relevant. We also test for over-identification. Table 4 reports the p-value associated with the Sargan-Hansen test. The only sample with risk of being over identified is the one with all countries. This can be solved by including the fifth lag of growth rates to the existing instruments. Our main results do not change after these modifications were implemented in the specification.

Table 4 also includes results from Sargan tests. Using Sargan tests imply that we make the assumption that errors are homoskedatic. This is motivated by the fact that we expect measurement errors to be small and of a similar magnitude over time as the data collection follows the same unified method over time and is from a reliable and detailed source. Results from the Sargan test indicate that we do not reject the null hypothesis. Therefore,

[4] See the World Bank data on GDP per employee available here: https://data.worldbank.org/indicator/SL.GDP.PCAP.EM.KD?locations=QA-BH-AE-SA

instruments are valid and uncorrelated with the error term and there is no overidentification. This also implies that we correctly excluded instruments from our specification.

6.1.2 | Supplementary analysis – the case of Europe

Table 5 reports results from fixed effects estimation and IV estimation of regression (1) using European NUTS 2 data. We observe similar results to the ones obtained using the sample of data from the World Bank. Air transport has a positive, stronger and more significant effect on GDP per employee than air cargo. A 10% increase in air passengers is associated with an increase of 1.09% of GDP per employee. This result is potentially negatively biased, as the IV estimation show in the second column of Table 5. When we use instruments to tackle the endogeneity problem, we find that a 10% increase in air passengers is associated with an increase of 1.41%. As for the results when World Bank data in the previous section, application of IV drops the number of observations and units. Again, we show in the appendix that differences in sample composition cannot explain the difference in effect sizes, since when we compare FE estimation with all observations to FE estimates with units present on the IV estimation, the magnitude of the estimate does not increase. Table 5 also shows that the instruments are significant for air passengers and cargo and that over-identification does do not appear to be a concern. Sargan and Hausman tests indicate respectively that the specification is not over-identified and instruments are exogeneous.

7 | CONCLUSION

This paper provides an analysis of the economic impact of air traffic (air passengers and air cargo) on productivity. Our results suggest that air transport has a positive effect on productivity, but with a larger and more significant effect from air passenger traffic than air cargo. We find that a 1% increase in air passengers is associated with an increase of 0.86% of GDP per employee. When using sub samples of data for different geographic zones, we find a range of estimates between 0.88% in Europe and Central Asia and 1.6% in South Asia and Eastern Asia. The only geographical area for which air passengers do not have a significant effect is the Arab World and the Middle East. Results are robust across fixed effects and instrumental variables specifications, and instruments are robust to relevance tests. In a second step, we use panel data from Eurostat for all the 300 European NUTS2 sub-regions and perform a similar exercise. The results are consistent with those obtained using the World Bank data.

Our findings indicate that air transportation has a significant effect on the economy. Furthermore, the effects are reasonably homogeneous across both developing and developed regions worldwide. Our main finding is that developing the aviation sector appear to generate economic gains. Yet, we acknowledge that the development of the aviation sector also requires the consideration of environmental issues (*e.g.*, concerns regarding the increase in pollution associated with the creation of a third runway in Heathrow). However, it is crucial important to have a detailed understanding and a quantification of economic gains associated to aviation projects in order to do comprehensive and efficient transport appraisal.

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