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## **Exploring causality in trade and air passenger travel relationships: the case of Asia-Pacific, 1980-2010**

### 1. INTRODUCTION

One of the core research areas in transport geography concerns the conceptual and empirical linkages between the deployment of transport infrastructures and services, and spatial economic development (e.g. Banister and Berechman, 2001). As Meijers et al. (2012) point out, these linkages have been debated ever since the first roads, railways and canals were built (e.g. Jefferson, 1928; Mitchell, 1964; Mohring and Harwitz, 1962; Dodgson, 1974; Chandra and Thompson, 2000), and this research field has remained vibrant in the face of the deployment of more recent infrastructures and services such as high-speed railway and airline networks (e.g. Bowen, 2000; Kasarda and Green, 2005; Levinson, 2012). It seems fair to state that the dominant focus in this literature has been on the analysis of the *generative economic effects of infrastructure developments*, e.g. estimating employment growth after the creation of a railway link as in Hensher et al. (2012).

Overall, this literature clearly demonstrates that the impact of the deployment of transport infrastructures and the introduction of new transport services on spatial economic development is complex to say the least. This is because generative effects depend on numerous contextual and intervening factors (e.g. Button, 1998; Brueckner, 2003; Ishutkina and Hansman, 2009), but also more implicitly because some distributive effects may remain hidden (e.g. Meijers et al., 2012). An additional problem is that in analyses of the effects of transport infrastructures and services, spatial economic development – however conceived – is an endogenous variable, i.e. it is an influence upon the distribution and operation of transport infrastructures and services in its own right. This effect can especially be seen in cases where transport investments can be realized relatively quickly and efficiently, such as the creation of an extra air passenger connection between cities. Here the new connection

can be both *cause and outcome* of spatial economic developments. Or, as O'Connor and Scott (1992, p. 251) noticed in an analysis of the evolution of airline services between metropolitan areas in the Asia-Pacific region between 1970 and 1990: the relationships between economic development and airline connectivity are “circular and cumulative” (see also Shin & Timberlake, 2000; Doganis, 2010). The implication, then, is that it can be assumed that the linkages between spatial economic development and the deployment of transport infrastructure and services work in two directions, reflecting a two-way relation that takes the form of co-evolution through feedback loops (see Ishutkina and Hansman, 2009).

Although regression-type analyses of the generative effects of transport infrastructures and services on economic developments are able to tackle this endogeneity problem, the more fundamental question of the dominant causality is not addressed in such analyses as the focus remains on how transport influences the economy. The purpose of this paper is to develop and test a possible empirical verification of the premise of co-evolution through feedback loops. In particular, we aim to show that recent advances in Granger causality analysis are particularly suited to analyse the linkages between the deployment of transport infrastructures and services on the one hand, and spatial economic development on the other hand. Originally presented in 1969, Granger causality analysis has developed into a broader suite of techniques that now for example allow analysing data that have both temporal *and* heterogeneous spatial components. The inclusion of spatial heterogeneity in the framework allows assessing regional variation of cause/effect relations in a single framework, and is therefore of special interest to geographers and regional scientists. Using the general observation of O'Connor and Scott (1992) as our starting point, in this paper we apply this altered Granger framework to assess the causality in the evolving geographies of air passenger transport and trade connections. Our empirical focus is on the developments in Asia-Pacific between 1980 and 2010, a period in which the region experienced rapid growth in both trade and air transport connections, fuelled by rapid but uneven economic liberalization and deregulation.

Previous research on the trade/air passenger transport-nexus suggests that different forms of interrelations may indeed be expected. The impact of air travel on trade can be explained

based on the de facto importance of face-to-face contact in trade negotiations as discussed by Leamer and Storper (2001). These arguments are part of a much wider literature showing how declining communication costs and growing communication opportunities impact international trade and operations (see Fink et al., 2002; Orozco-Pereira and Derudder, 2010) . In the case of air travel, it can be argued that as trade has boomed and become more complex as it began to incorporate the movement of components along global production networks, the co-ordination tasks grew, and strengthened the need for face-to-face contact (Storper and Venables, 2004). Thus better and more air services can be expected to help overcoming the difficulties of coordinating and running increasingly complex production networks, which is consistent with Poole's (2013, p. 24) observation that business air travel "helps to overcome informational asymmetries in international trade, generating international sales in the form of new export relationships". Similarly, in their article on the business travel patterns of professionals in the Irish ICT-cluster, Wickham and Vecchi (2008) state that air travel enables firms to build up trust relations with distant customers and suppliers. The effect of travel on trade may vary, however, as the effect "is stronger for differentiated products and for higher-skilled travelers, reflecting the information-intensive nature of differentiated products and that higher-skilled travelers are better able to transfer information about trading opportunities" (Poole, 2013, p.24).

Meanwhile, growing volumes of trade and the associated rise in deal-making, follow-up, etc. may in turn lead to heightened demand for air travel (see Ishutkina and Hansman, 2009). Cristea (2011), for instance, finds robust evidence that the demand for air travel is directly related to the export of U.S. states: an increase in the volume of exports has been shown to raise the local demand for business air travel. Simultaneously, she shows that that close communication between trade partners, via face-to-face-interactions, is essential for successful trade transactions, because these meetings have the potential to both improve the transaction and add value to the exported products. Furthermore, Frankel (1997, p.45) stresses the importance of the reciprocal relationship between travel and exports in the high-tech capital goods sector: "to begin sales in a foreign country may involve many trips by engineers, marketing people, higher ranking executives to clinch a deal", but at the same time it may involve the movement of "technical support staff to help install the equipment or to service it when it malfunctions", implying export can also precede additional travel. Again, this proves that the strength of the relationship may depend on the nature of the

products involved, with for instance high-end services being particularly travel-intensive (Van De Vijver et al., 2013; Bel and Fageda, 2008). In addition, it is clear that the impact of trade on travel is complicated by the fact that, especially compared to air freight connections, trade-related air travel is but one of the many motivations for air travel, alongside tourism, visiting friends and relatives, and non-trade related business travel (Kulendran and Wilson, 2000).

This brief literature review suggests that the relationship between trade and air services may be complex and varied. These potentially wide-ranging relationships between trade and air travel services can be summarized in four possible ‘causality scenarios’: (1) trade and air passenger geographies develop independently, i.e. both geographies chiefly develop according to different rationales and processes (e.g. air travel being only of secondary importance for trade and/or primarily being driven by other motivations); (2) there is ‘real’ co-evolution in that both patterns influence each other through feedback loops; (3) air passenger traffic is facilitated by trade, but does not facilitate trade; and (4) trade is facilitated by air passenger traffic, but does not facilitate air passenger traffic. Using a Granger framework, these four scenarios will be statistically tested for the Asia-Pacific region as a whole as well as for individual country-pairs within the region. Our chief purpose is hereby to methodologically address and indicate the heterogeneous relationships that can occur between trade and air passenger travel, i.e. no comprehensive analysis of the development of the air transport and trade geographies in this the region is intended.

The remainder of this paper is organized as follows. The next section describes the previous use of Granger causality analysis in air transport-related studies, and uses this discussion to advance the case for using a version that allows for (spatial) heterogeneity. The third section describes our empirical framework: we review why Asia-Pacific is a good test case, discuss our data, and the preparatory steps towards Granger causality testing. The detailed procedure, the results of the analysis, and some interpretations are discussed in the fourth section, after which the paper is concluded with an overview of the main implications and potential avenues for further research.

## 2. SPATIALLY HETEROGENEOUS GRANGER CAUSALITY ANALYSIS

Granger causality tests are the most widely used methods for empirically examining causal relationships between variables. ‘Causality’ is, of course, an elusive concept, and Granger analysis basically adds to our empirical understanding by providing a statistical indication of the *precedence* of change in one variable to change in another variable. Put differently: Granger testing is a statistical technique that can help with the uncovering of causality through a systematic appraisal of the chronological order in which change unfolds. In the remainder of this paper, we therefore use ‘cause’/‘causality’ as a narrowed-down shorthand for situations where taking into account past values of X leads to better predictions of Y than merely taking into account past values of Y. The observation that past changes in X help forecasting the evolution of Y is therefore taken as a statistical sign that change in X ‘causes’ change in Y, which can be expressed as:

$$y_t = a + \sum_{k=1}^p \gamma_k y_{t-k} + \sum_{k=1}^p \beta_k x_{t-k} + u_t \quad (1)$$

where:  $a$  represents fixed effects;  $\gamma_k$  and  $\beta_k$  are autoregressive and regression coefficients, respectively;  $y_{t-k}$  and  $x_{t-k}$  are lagged values of the dependent and independent variables, respectively;  $k$  is the number of preceding time units taken into account;  $u_t$  is an error term and  $p$  is the number of time lags.

The null hypothesis in Granger testing is that X does not cause Y. If one or more lagged values of X are significant, then the null hypothesis can be rejected, implying that Granger causality runs from X to Y. Note that in research that wishes to establish the direction of causality, X and Y can be reversed in the next step, thus leading to the four possibilities of (1) X ‘causing’ Y (but not the other way round), (2) Y ‘causing’ X (but not the other way round), (3) no causality, or (4) causality running in both directions. This traditional approach to Granger analysis has been most commonly applied to time series data, where the causal relationship between two characteristics of a single unit is monitored over a certain time period (Hood III et al., 2008).

To date, traditional Granger analysis has been applied to link air transport flows with specific economic developments on a number of occasions, most commonly at the metropolitan scale. Button et al. (1999) and Button and Lall (1999), for example, use this method in their analysis of the influence of hub airports on high technology employment in the United States. More recently, Neal (2012) uses a method inspired by Granger analysis to tease out the reciprocal influence of passenger air travel and the level of 'creative employment' in American urban areas. Meanwhile, at the national scale, Granger analysis has predominantly been used to explore the causality in the evolution of tourism, often facilitated by air transport, and trade (e.g. Shan and Wilson, 2001; Kadir and Jusoff, 2010).

Kulendran and Wilson (2000) study the co-evolution of trade and air passenger transport for four country-pairs, i.e. for the connections between Australia and four of its largest travel and trading partners (the United States, the United Kingdom, Japan and New Zealand) based on this traditional Granger approach. The authors thereby present a separate Granger analysis for each of the country-pairs. Collectively, these four analyses suggest variation in the trade/travel causality: results include a reciprocal relationship for the Australia-US link, a unilateral relationship where changes in travel precede changes in trade for the Japan-Australia link, and the opposite unilateral relationship with changes in trade preceding changes in travel for the UK-Australia link. Another, more recent, study at the national scale investigates the link between domestic air passenger traffic and GDP in Brazil (Fernandes and Pacheco, 2013).

The Kulendran and Wilson (2000) study can be used as starting point to explain the rationale for a revised Granger framework. It can, for instance, be noted that their use of traditional time series limits the remit of the analysis to pairwise comparisons between each of the separate analyses. An extension of the number of countries/country-pairs would quickly lead to rising numbers of Granger analyses to be carried out. A Granger framework for time series cross-sections (TSCS), incorporating the possibility of heterogeneous causality has been specifically developed to address this limitation<sup>i</sup>.

In contrast to traditional Granger causality analysis, TSCS analysis allows monitoring multiple cross-sections in a single analytical framework, making it well suited for analysing larger numbers of cross-sections. Meanwhile, the heterogeneous causality extension of TSCS-testing allows for the possibility of dissimilar causation across different cross-sections (see

Hurlin and Venet, 2001; Hood III et al., 2008), so that – in addition to the overall causality – the diversity across cross-sections can be assessed. The method entails the following extension of the traditional Granger model:

$$y_{i,t} = a_i + \sum_{k=1}^p \gamma_k y_{i,t-k} + \sum_{k=1}^p \beta_{i,k} x_{i,t-k} + u_{i,t} \quad (2)$$

where  $a_i$  represents fixed effects;  $\gamma_k$  and  $\beta_{i,k}$  are autoregressive and regression coefficients, respectively;  $y_{i,t-k}$  and  $x_{i,t-k}$  are lagged values of the dependent and independent variables, respectively;  $k$  is the number of preceding time units taken into account;  $u_{i,t}$  are error terms; and  $p$  the number of time lags.

The assumption underlying this extension is that the autoregressive coefficient is constant for all cross-sections, while the regression coefficient is constant for all time lags but can vary across the cross-sections. This addresses the problem of causal heterogeneity at the level of cross-sections because it allows for dissimilar causal relationships to occur among – in this case – trade and air travel flows for each of the country-pairs under scrutiny. Technical details regarding the necessary steps to be taken when carrying out such an analysis will be provided in the results section.

This revised Granger framework has recently been picked in analyses of infrastructure networks. Button and Yuan (2012), for instance, recently used TSCS analysis (albeit without the heterogeneous extension) to decipher the causality in the relation between changes in airfreight transportation and economic development amongst 32 metropolitan areas in the United States. Based on their analysis, the authors conclude that, across the US metropolitan system, changes in airfreight volumes cause changes in personal income and in per capita income in metropolitan areas. Meanwhile, the relationship between airfreight volumes and metropolitan employment was found to be bi-directional.

The only ‘geographical’ example of the heterogeneous TSCS approach we are aware of is the research by Tranos (2012) in an analysis of the causality in the relation between the deployment of critical Internet infrastructures and metropolitan economic development in Europe. All four causality scenarios emerged across cross-sections, with an overarching geographical pattern of a (complex) North-South division with Internet infrastructure

deployment preceding economic development in Northern European cities (and the other way round in Southern European cities).

### 3. EMPIRICAL FRAMEWORK

The rationale for our particular empirical focus on trade/air transport linkages in the Asia-Pacific region is that this region seems to offer an appropriate test case for this methodology for at least two reasons. First, Asia-Pacific is an obvious case study for assessing the co-evolution in both patterns given the fast-paced developments in both trade and air transport, in part facilitated by a host of deregulation and liberalization trends. Since the 1980s, the region has witnessed strong overall economic growth figures, occasionally interrupted by short – but sometimes sharp – declines. Evidently, the region's wholesale economic growth has gone hand in hand with various forms and levels of deepening spatial integration. This integration is, for instance, clearly visible in growing volumes of transnational trade and investment (Hiratsuka and Kimura, 2008; Athukorala, 2010), but also in rising levels of connectivity in infrastructure networks as evidenced by the dramatic expansion of air traffic and Internet backbone networks (Malecki and Wei, 2009; Fuellhart and O'Connor, 2013). The 'flying geese paradigm', whereby Japanese companies started outsourcing labour-intensive production to the wider region from the 1960s onwards would be a case in point: the emergence of this particular regional division of labour centred in parts of Asia-Pacific involved a relatively rapid rise of complex regional investment and trade relations, which are to varying degrees matched by new air passenger connections.

And second, in spite of the region's quasi-continuous economic growth and the concomitant trends of liberalization of trade in general and the air transport industry in particular, these processes have developed uneven in space and time to say the least. Because of the relative absence of efficient and homogeneous de jure integration in trade and air transportation, bilateral agreements among country-pairs have been norm rather than exception over the past few decades. The formation of the AFTA (ASEAN Free Trade Agreement) in 1992 was a first step towards a de jure integration in the Pacific Asian region, but due to a lack of political will from its member states and the greater importance of economic relationships of each individual economy with states outside the ASEAN region, a true integration has not yet been attained (Yamazawa, 1992; Fouquin, 2008). Especially during the 1990s the AFTA was



quite fragile (Kimura, 2008), although progress has been made in the late 1990s and the beginning of the 21<sup>st</sup> century. The realization of a complete free trade area is scheduled for 2015. In the same way, attempts at liberalization of the air transport industry in the region are still often localized and haphazard, for example between neighbouring countries, thus limiting their impact (Swan, 2002; Doganis, 2010). The temporal and spatial diversity of trade and air transport deregulation in the Asia-Pacific thus provides us with a good test case for Granger analysis that allows for spatial heterogeneity, as the causality may be different for individual countries and country-pairs. For instance, a policy conducive to the creation of air travel as in the case of Singapore's longstanding 'open skies' policies (Bowen, 2000) may result in a different causality pattern than in the case of Japan, which has traditionally adopted a more protectionist stance in the air transport industry (Findlay and Forsyth, 1992). Similarly, the Singapore-Malaysia link, which has long been under-served because of (geo)political tensions between both countries (Ng, 2009) may be characterized by a different causality pattern than the Singapore-New Zealand link, which has been bolstered by early bilateral air service agreements between both countries.

In our empirical analysis, we focus on 9 countries in the Asia-Pacific region: Australia, New Zealand, China, South Korea, Malaysia, Indonesia, Thailand, Philippines and Singapore. The latter five countries are the founding members of the Association of Southeast Asian Nations (ASEAN), and have – in comparison with other ASEAN members – over time adopted clear and increasingly liberal policies towards trade and the airline industry. For instance, over time these countries have moved beyond tedious and ad hoc bilateral airline service agreements (O'Connor and Scott, 1992; Forsyth et al., 2006), while all sorts of explicit and implicit trade barriers have diminished sharply (Hiratsuka, 2006).

The other four countries in our analysis are Japan, South Korea, Australia and New Zealand, which constitute the other key economic players in the Asia-Pacific region. Japan and – albeit somewhat later on – South Korea have undeniably played a key role in the region's economic integration, in large part because of their 'flying geese'-like history of outsourcing of industrial activities to other countries in the region, thus creating large regional trade flows. New Zealand and Australia, in turn, have always been (pro)actively involved in regional trade agreements, in part out of fear of becoming economically isolated from the wider region (Lee and Park, 2005).

Given that our selection consists of 9 countries, our analytical framework does in principle comprise  $n(n-1)/2 = 36$  country-pairs as cross-sections. However, as we do not have sufficient data for 3 of the cross-sections (Thailand-New Zealand, Indonesia-New Zealand and Philippines-New Zealand), these were not included in the analysis. For each of the 33 remaining country-pairs, we calculated the yearly evolution in the number of scheduled seats between their airports as well as the development of total trade between 1980 and 2010.

The trade data were collected through the United Nations Commodity trade (Comtrade) statistics database (<http://comtrade.un.org>). This database contains detailed import and export statistics, reported by the statistical authorities of about 200 countries worldwide. We aggregated the value of exports and imports of both finished goods and parts and components for each of the country-pairs to estimate the total volume of trade.

Air passenger data were derived from the Official Airline Guides (OAG) database, which contains the number of scheduled seats on direct flights between airports. Information on the connections of low-cost carriers, a sector that continues to rapidly expand in Asia-Pacific, is included. In order to obtain passenger flows between the different countries from our analysis, we aggregated the available seats from/to all of the airports in a given country (e.g. aggregating Osaka-Singapore and Tokyo-Singapore seats). Using OAG-data entails some disadvantages, which might impact the results of our analysis. First, there is no distinction between business and leisure travel. However, this does not necessarily lead to incorrect results, as Poole (2013) reveals that both business travel and leisure travel have strong positive associations with exports from the United States. Second, OAG-data include scheduled flights rather than actual routes flown by passengers. This can bias the results for countries containing international or regional switching points for traffic (see Derudder et al., 2007). Singapore is the clearest case in point: many of the scheduled seats between Singapore and some of the other countries in our dataset (notably Australia and New Zealand) are in fact used by passengers traveling to or from Europe. As a consequence, changes in scheduled seats in these cases are only partly influenced by/influencing changes in trade between Singapore and Australia/New Zealand, as they are also a result of changing demand and supply levels outside the Asia-Pacific region. In addition to the possible presence of intervening variables that our outside the model, both data caveats imply that

our results should be treated as general indications of the causality and how it can be assessed rather than as a definitive analysis

Figure 1 plots the relative increase in trade and scheduled seats in the Asia-Pacific region (i.e. between the 9 countries). In the period 1980-2010, the intra-regional number of scheduled seats and trade volumes grew fivefold and tenfold, respectively. Overall, both variables increased at a similar pace until the beginning of the 1990s, after which trade started growing faster, especially from the 21<sup>st</sup> century onwards. At the same, fluctuations are more apparent in trade than in seats.

To better illustrate the topic addressed in this paper, Figures 2 and 3 plots the evolution of scheduled seats and trade volumes between Australia and Malaysia (Figure 2) and South Korea and the Philippines (Figure 3). In Figure 2, we see a relative surge in trade between 1993 and 1997, which is followed by a similar surge in scheduled seats some years later (1998-2002). Similarly, there was a very steep increase in trade in 2006, after which there was a similar sharp surge in seats in 2008-2009. For this specific country-pair, then, this would point to a pattern where change in trade often precedes, and therefore 'causes' change in seats. In Figure 3, one can observe the opposite effect: a 1996-1998 slump in seats seems to precedes a leveling out of trade, just as the subsequent rise of seats (from 2000 onwards) takes a while to be translated into extra trade. For this specific country-pair, then, this would point to a pattern where change in seats precedes, and therefore 'causes' change in trade. In both cases, the presence of a temporal lag suggests a possible causal influence, and Granger causality analysis allows us to systematically evaluate this influence.

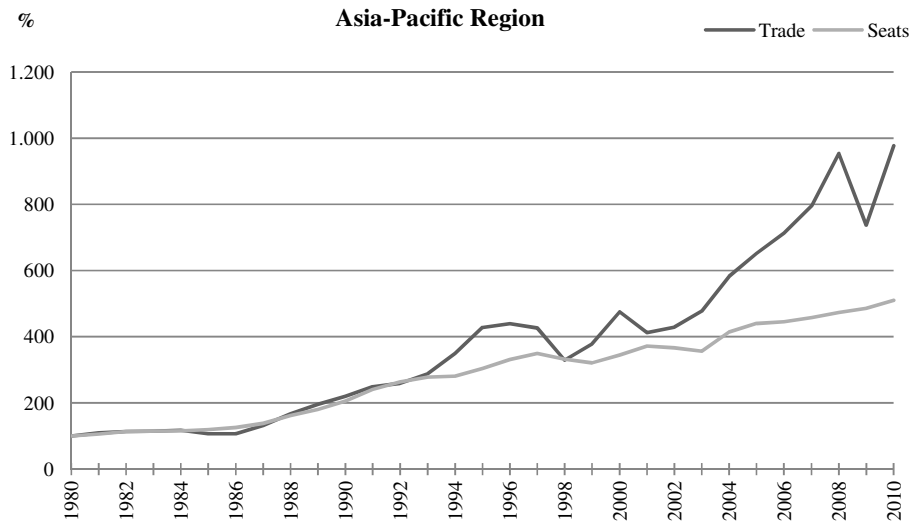


Fig. 1. Relative growth of total trade and scheduled seats in the Asia-Pacific region

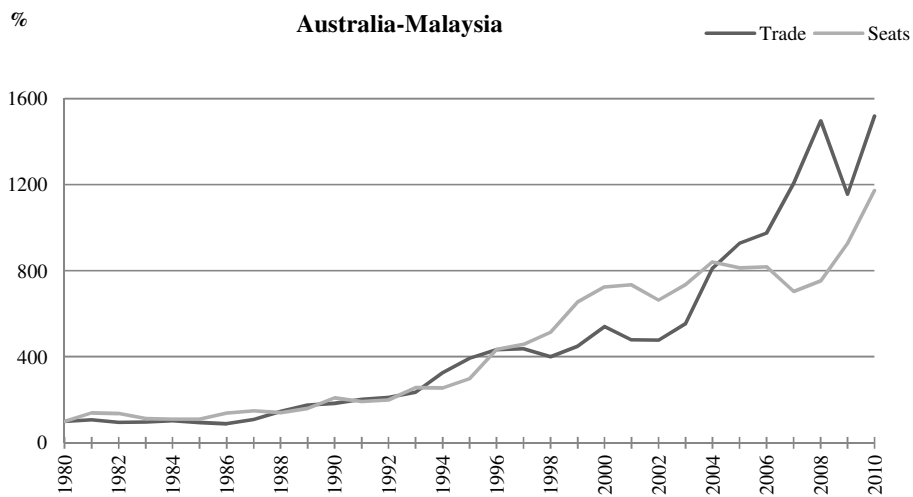


Fig. 2. Relative growth of total trade and scheduled seats between Australia and Malaysia

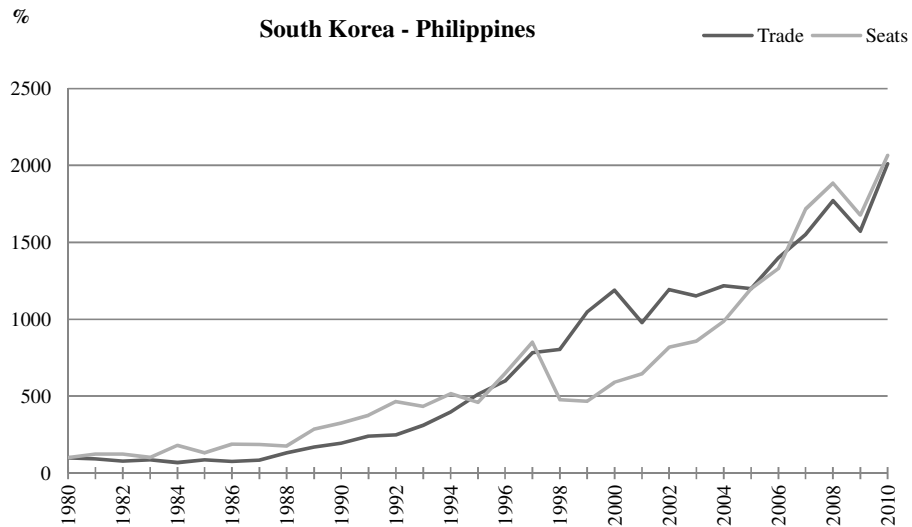


Fig. 3. Relative growth of total trade and scheduled seats between South Korea and Philippines

Before we proceed with the Granger analysis, two preliminary steps need to be taken. First, Granger analysis requires time series that are stationary, implying that they have a constant mean and variance (Lütkepohl and Krätzig, 2004). Data series that are non-stationary contain a so-called 'unit root', a trend that causes a spurious regression and generates unreliable results. Additionally, the time series need to have the same order of integration. Two different unit root tests, specifically designed for TSCS-data, were implemented: the Levin, Lin and Chu test (Levin et al., 2002), and the Im, Pesaran and Shin procedure (Im et al., 2003). Both tests suggest that the original data for total trade and number of seats are indeed non-stationary. This is due to the often-sharp changes in the volume of trade and the number of scheduled seats between the different countries throughout the 1980-2010 period (see Figure 1). The standard way of dealing with this problem is using first differences to make the time series stationary, representing yearly *growth* in total trade and yearly *increase* in scheduled number of seats between two Pacific Asian countries in the period 1981-2010.

Second, an appropriate time lag needs to be chosen from the yearly data. This time lag is specified as the time difference with the maximum level of 'causality'. This can be calculated through the Schwarz-information criterion, which indicates that a time lag of 4 years in both directions yields the best results. This corresponds with the findings of Poole (2013) that

face-to-face meetings not simply occur ‘alongside’ trade in temporal terms. For instance, in her research she finds that “businesspeople may fly to destinations to set up trade months or years before trade takes place” (Poole, 2013, p. 15)

#### 4. RESULTS AND DISCUSSION

Using the EViews-software and these transformed data, we carried out a heterogeneous TSCS Granger analysis on the 33 country-pairs. Based on equation (2), the use of first-order differences, and a 4-year time lag, the four possible causality scenarios are captured by linking the results of the following two equations:

$$\begin{aligned} \Delta seats_{i,t} = & \\ & a_i + \gamma_{i,t-1} \Delta seats_{i,t-1} + \gamma_{i,t-2} \Delta seats_{i,t-2} + \gamma_{i,t-3} \Delta seats_{i,t-3} + \\ & \gamma_{i,t-4} \Delta seats_{i,t-4} + \beta_{i,t-1} FE_i \Delta trade_{i,t-1} + \beta_{i,t-2} FE_i \Delta trade_{i,t-2} + \beta_{i,t-3} FE_i \Delta trade_{i,t-3} + \\ & \beta_{i,t-4} FE_i \Delta trade_{i,t-4} + u_{i,t-1} + u_{i,t-2} + u_{i,t-3} + u_{i,t-4} \quad (3a) \end{aligned}$$

$$\begin{aligned} \Delta trade_{i,t} = & \\ & a_i + \gamma_{i,t-1} \Delta trade_{i,t-1} + \gamma_{i,t-2} \Delta trade_{i,t-2} + \gamma_{i,t-3} \Delta trade_{i,t-3} + \\ & \gamma_{i,t-4} \Delta trade_{i,t-4} + \beta_{i,t-1} FE_i \Delta seats_{i,t-1} + \beta_{i,t-2} FE_i \Delta seats_{i,t-2} + \beta_{i,t-3} FE_i \Delta seats_{i,t-3} + \\ & \beta_{i,t-4} FE_i \Delta seats_{i,t-4} + u_{i,t-1} + u_{i,t-2} + u_{i,t-3} + u_{i,t-4} \quad (3b) \end{aligned}$$

where  $FE_i$  is an array of dummy variables (fixed effects) for each cross-section.

Heterogeneous TSCS Granger analysis proceeds in three steps: homogeneous causality testing, followed by heterogeneous causality testing, and - if heterogeneity is present - the causality testing of individual cross-sections.

The first step tests the ‘homogeneous non-causality’ across Asia-Pacific: the very presence of causality is tested across an aggregation of all cross-sections. This implies formulating a null hypothesis for both equations, stating that there is no causal relationship between the evolution in trade (seats) and the evolution in seats (trade) across Asia-Pacific.

*H<sub>1a</sub>: For all country-pairs,  $\Delta trade$  does not Granger cause  $\Delta seats$*

*H<sub>1b</sub>: For all country-pairs,  $\Delta seats$  does not Granger cause  $\Delta trade$*

The rejection of the null hypothesis indicates a statistically significant impact of previous change in X on change in Y (i.e. X Granger causes Y), and is tested through an F-statistic, here specified as:

$$F = \frac{(RSS_2 - RSS_1)/(Np)}{RSS_1/[NT - N(1+p) - p]} \quad (4)$$

where  $N$  = the number of country-pairs;  $p$  = the number of time lags; and  $T$  = number of time periods.

An interpretation of the test relies on cross-checking this value with an F-distribution with  $Np$  and  $NT - N(1+p) - p$  degrees of freedom for the numerator and the denominator respectively. As commonly the case with F-statistics, the test compares the sum of squared residuals of a restricted model (=  $RSS_2$ , i.e. without taking change in X into account by assuming that the regression coefficients  $\beta_{i,t-k}=0$ ) with the sum of squared residuals of the unrestricted model ( $RSS_1$ , i.e. taking change in X into account) presented in equations (3a) and (3b).

Our analysis shows that both null hypotheses can be rejected at the 1% significance level ( $p=0.00$ ), implying that there is bi-directional causality present in the dataset: for the Asia-Pacific region as a whole, there is evidence that growth in total trade precedes growth in number of seats *and vice versa*, providing statistical evidence for O’Connor and Scott’s (1992) observation of “circular and cumulative” linkages at the level of trade and air passenger travel. However, this causality at the level of the entire dataset does not imply that there is a bidirectional relationship for all country-pairs, and this is where the

heterogeneity extension comes into play. This is established in a second step, in which the (lack of) homogeneity of the causality among the different country-pairs is tested.

In the second step, the null hypothesis states that this causality can be found in *each* of the 33 country-pairs. An F-test is run twice again, but in this case there is a new version of the restricted model ( $RSS_3$ ) that does not set the regression coefficients to zero, but equal to each other ( $\beta_{i,t-1} = \beta_{i,t-k}$ ) for all cross-sections.

*H<sub>2a</sub>: For all country-pairs,  $\Delta trade$  causes  $\Delta seats$*

*H<sub>2b</sub>: For all country-pairs,  $\Delta seats$  causes  $\Delta trade$*

The test results suggest causal heterogeneity in both directions, respectively at the 1% ( $p=0.00$ ) and 10% ( $p=0.07$ ) significance level. This implies that, although Asia-Pacific shows signs of a bi-directional relationship between total trade and air passenger travel, this is not applicable to each country-pair. Additional tests are needed to discover for which country-pairs a Granger causal relationship exists, and in which direction(s) this relationship runs. This implies testing each of the 33 country-pairs separately, which is done in the third and final step.

*H<sub>3a</sub>: For country-pair  $i$ ,  $\Delta trade$  does not cause  $\Delta seats$*

*H<sub>3b</sub>: For country-pair  $i$ ,  $\Delta seats$  does not cause  $\Delta trade$*

In this case F-tests are run with separate versions of the restricted model ( $RSS_2$ ) so that values of  $\beta_{i,t-1}$  can differ across cross-sections. Hence, we test the nullity of each regression coefficient separately (i.e.  $\beta_{i,t-1} = 0$  for every  $i$ ). Tables 1a and 1b give the p-values of the F-tests for all the country-pairs. For those country-pairs where the p-value is smaller than 0.10, we assume a significant causal relationship is present. Table 2 summarizes the results by classifying all country-pairs according to one of the four causality scenarios. Overall, the results indicate that total trade and air travel between Pacific Asian countries do influence each other, albeit in different ways and to varying extents. A total of 19 out of 33 country-pairs show statistically significant signs of causality, of which two (Philippines-Singapore and South Korea-Malaysia) exhibit bi-directional influence<sup>ii</sup>.



Table 1a: P-values from the F-test for the separate cross-sections ( $\beta_{i,t-k} \neq 0$ ); AU = Australia, ID = Indonesia, JP = Japan, KR = South Korea, MY = Malaysia, NZ = New Zealand, PH = Philippines, SG = Singapore, TH = Thailand

	AU	ID	JP	KR	MY	NZ	PH	SG	TH
AU	-	0.25	0.54	0.15	<b>0.01</b>	0.88	0.84	0.24	0.68
ID		-	0.22	0.77	<b>0.00</b>	-	0.99	<b>0.09</b>	0.38
JP			-	0.43	0.93	0.86	0.31	<b>0.01</b>	0.67
KR				-	<b>0.02</b>	0.72	0.84	<b>0.05</b>	0.64
MY					-	<b>0.00</b>	<b>0.05</b>	<b>0.05</b>	<b>0.07</b>
NZ						-	NA	0.14	NA
PH							-	<b>0.01</b>	0.12
SG								-	0.27
TH									-

Null hypothesis: For country-pair i,  $\Delta\text{trade}$  does not cause  $\Delta\text{seats}$

Table 1b: P-values from the F-test for the separate cross-sections ( $\beta_{i,t-k} \neq 0$ ); AU = Australia, ID = Indonesia, JP = Japan, KR = South Korea, MY = Malaysia, NZ = New Zealand, PH = Philippines, SG = Singapore, TH = Thailand

	AU	ID	JP	KR	MY	NZ	PH	SG	TH
AU	-								
ID	<b>0.00</b>	-							
JP	0.99	<b>0.05</b>	-						
KR	0.41	<b>0.10</b>	0.73	-					
MY	0.30	0.55	0.61	<b>0.06</b>	-				
NZ	0.41	NA	0.18	0.78	0.92	-			
PH	<b>0.01</b>	0.92	0.21	<b>0.01</b>	0.60	NA	-		
SG	0.78	0.48	0.85	0.89	0.49	0.13	<b>0.03</b>	-	
TH	<b>0.00</b>	0.16	0.15	0.60	0.41	NA	<b>0.05</b>	<b>0.04</b>	-

Null Hypothesis: For country-pair i,  $\Delta\text{seats}$  does not cause  $\Delta\text{trade}$

Table 2: The 33 country-pairs with their causal relationships

No causal relationship	Trade -> air travel	Air travel -> trade	Bi-directional relationship
Australia – Japan	Australia – Malaysia	Australia – Indonesia	Korea – Malaysia
Australia – Korea	Indonesia – Malaysia	Australia – Philippines	Philippines – Singapore
Australia – New Zealand	Indonesia – Singapore	Australia – Thailand	
Indonesia – Philippines	Japan – Singapore	Indonesia – Japan	
Indonesia – Thailand	Korea – Singapore	Indonesia – Korea	
Japan – Korea	Malaysia – New Zealand	Korea – Philippines	
Japan – Malaysia	Malaysia – Philippines	Philippines – Thailand	
Japan – New Zealand	Malaysia – Singapore	Singapore – Thailand	
Japan – Philippines	Malaysia – Thailand		
Japan – Thailand			
Korea – New Zealand			
Korea – Thailand			
New Zealand – Singapore			

Although a detailed discussion of the various causality patterns is beyond the scope of this paper given its methodological purpose, we briefly discuss two major patterns emerging from our results in order to provide a better understanding of the kinds of interpretative opportunities this kind of analysis can deliver.

The first pattern is the apparent lack of causality for linkages between more economically developed countries versus the more abundant presence of causality for linkages between economically developed and economically less developed countries. Australia and South Korea, for instance, have a series of statistically significant causality linkages (mostly running from seats to trade) with some of the less-developed economies in our sample (Malaysia, the Philippines, Indonesia, and in the Australian case also Thailand). This is in sharp contrast with the observation that there is not a single instance of causality in the evolution of seats and trade between Australia, New Zealand, Japan, and South Korea. There are a number of possible explanations for this bifurcation. First, outsourcing of production leading to fast-paced change in trade has been primarily driven by differences in labour costs (see Ozeki, 2008; Athukorala, 2010). First-order changes in trade have therefore been most outspoken for linkages between relatively developed countries on the one hand and relatively less-developed countries on the other hand. Our analysis suggests that, against this backdrop, the creation of new air passenger connections between, say, Australia and Thailand, has facilitated access to and knowledge about markets that translated into the growth of trade in the subsequent years.

Second, as indicated in the introduction, any relation between change in trade and change in air passenger connections will be complicated by the fact that the motivation for air travel is multifaceted. Although there will be much trade-related travel between Australia and New Zealand, it seems unlikely that this is the key explanation to the strong air transport connections between cities in Australia and New Zealand. For instance, it is estimated that today more than 650.000 New Zealanders (or about 15% of the New Zealand population) currently live in Australia, making it the second-largest group of foreign-born migrants after the United Kingdom. Moreover, these numbers have quasi-continuously grown over the past decades. This integration has been facilitated by policies such as the 1973 Trans-Tasman Travel Arrangement, which has allowed Australian and New Zealand citizens to enter each

other's country to visit, live and work, without the need to apply for authority to enter the other country before travelling. Given the relative vicinity of both countries and the rising importance of cross-migration (albeit especially from New Zealand to Australia) in the face of rising levels of disposable income, the main reason for air travel between both countries alongside tourism is visiting family and friends. Given this, it should not be a surprise that there is no statistical causality in the trade/seat linkages. The main message here is that although a multifaceted and complex linkage between motivations for air travel and trade is probably present for all country-pairs, the linkage is much more outspoken for some connections, and our spatially heterogeneous TSCS framework is able to capture this by differentiating between different cases as in Tranos (2012).

The second pattern is the causality patterns for Malaysia and Singapore, mostly running from trade to seats. Singapore obviously occupies a central role in the region's trade networks. In addition to its small size, the importance of trade stems from its persistent role as a regional 'entrepôt' economy (Siddiqui, 2010). For instance, Singapore continues to function as Japanese firms' component supply base and service center for the ASEAN region (Watanabe, 2004). In addition, since the 1980s, Singapore has become a regional (financial) service centre as well as a command-and-control centre housing regional headquarters of many multinational enterprises with subsidiaries in neighbouring Asian countries where the more labour intensive parts of the production process are located (Athukorala and Hill, 2010). Table 1 suggests that the enormous trade flows to and from Singapore have been translated into air passenger connections. This could be related to Singapore's early adoption of very liberal approaches towards international air travel connections (Bowen and Leinbach, 1996), which has allowed the quick translation of demand into supply. A similar interpretation can be made for the Malaysian case. Although not as marked as in Singapore, it was one of the region's forerunners in liberalizing its trade policies (Athukorala, 2010), while over the last decade it has also become an important supplier of parts to other countries (Kimura, 2008). From 1993 onwards, the country started with an aggressive deregulation of its international air travel connections. Overall, this provides the basic lens through which we can frame the trade-to-seats causality for Singapore and Malaysia: massive trade flows that created additional demand for air travel, which could be provided because of the adoption of liberal, open skies-type of policies (as well as infrastructure provision to enable this). Strikingly, despite the many significant relations of Singapore,

causal links with Australia and New Zealand are absent. As already highlighted, this may be in part due to the use of OAG-data, which include scheduled flights rather than actual routes flown by passengers. This can bias the results for Singapore in particular given its continued role as major hub in, amongst others, the 'Kangaroo Routes' connection Australia and New Zealand with Europe. As a consequence, facilitated by Singapore's 6<sup>th</sup> freedom rights, many of the scheduled seats between Singapore and especially Australia and New Zealand are in fact used by passengers traveling to or from Europe, which implies that changes in scheduled seats in these cases are less influenced by/influencing changes in trade between Singapore and Australia/New Zealand.

## 5. CONCLUSIONS

The main purpose of this paper was methodological: we have introduced and applied a technique that allows assessing the complex and often heterogeneous causality between the deployment of transport infrastructures and services, and spatial economic developments. The case of changes in the provision of air passenger connections and trade relations in Asia-Pacific provided us with a good test case, given that these relations are complex, change has been fast-paced, and linkages could be assumed to be heterogeneous, in part due to the lack of encompassing, de jure liberalization of trade and air transport. Kulendran and Wilson (2000) already hinted at the often contrasting causal relationships between trade and air passenger transport, and our framework allows assessing such questions for a much larger number of cases in a single analysis. Our results show that:

- there is no significant causality for links between the region's most developed economies (e.g. Australia-New Zealand);
- there is often significant causality running from air passenger connections to trade for relations between more developed and less developed economies (e.g. Australia-Thailand);
- and there is often significant causality running from trade to air passenger connections for countries that have adopted very liberal approaches towards the air transport industry (e.g. Singapore).

We believe these results are credible enough to suggest that this framework may be relevant for future transport geography research. This would imply applying the 3-step method to different operationalizations of the geographies of transport infrastructures and services, and spatial economic development.

In the narrower realm of analysing change in air passenger connectivity, one obvious area for improvement would be to employ origin-destination data. This would give less distorted results, especially when considering hub airports, such as Singapore. Another area for future research would be to include other variables that potentially explain air travel. Grancay (2009) describes the very complex, and as emphasizes here often reciprocal, links between air transport liberalization, the creation of new links and services, and the many factors influencing and influenced by these and this could be used for competing assessments. Furthermore, data on changing reasons for air travel (e.g. as measured through entry cards in countries such as Australia, where air travel is the de facto mode of entry) for different countries can for instance be used to gauge to what extent shifting reasons for visiting have impacted air travel (and vice versa), both in general and for specific countries.

As for the empirical focus of this paper: a comprehensive appraisal of trade/air passenger relations in Asia-Pacific will probably need to break this period down in time intervals that conform to key policy shifts as regards trade and air transport liberalization (e.g. the different timing for Malaysia and Singapore is not really taken into account by focusing on the 1980—2010 period as a whole). Indeed, it can be said that this encompassing empirical framework should be refined to capture the fragmented nature of liberalization tendencies. This may include methodological changes such as differential time lags, but also efforts to more systematically interpret results against policy changes.

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<sup>i</sup> In addition, in a study on the relationship between GDP, exports and FDI among eight countries in Pacific Asia, Hsiao and Hsiao (2006) prove that TSCS data causality analysis yields better results than time series causality analysis.

<sup>ii</sup> It should be noted that the relative lack of statistically significant relations compared to the very clear bi-directional causality at the level of the region may in part be the result of having smaller samples (and therefore degrees of freedom for assessing the F-statistic).