Airplanes and Income: A Shrinking World Has No Impact

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Abstract

The recent evidence that air transport prices plummeted relative to ocean transport prices over the period 1965-2000 provides an exogenous shock to world trade patterns. Previous papers showed that this relative decrease led to faster trade growth for varieties more suitable for air transport, especially on longer routes. This paper examines the relationship between this trade shock at the country level and changes in real income. Contradicting other work that purports to find such a connection, I show that there is no significant relationship between changes in trade and income growth. This is the first paper to produce long run figures for exogenous trade changes. These are constructed both by direct estimation of the impact of the relative price shift and by a time-varying geographic instrument. By using an exogenous, dynamic trade change, and removing omitted variable concerns, such as institutional capacity, I am able to show that on average increasing trade does not raise the rate of income growth.

1 Introduction

The relationship between trade and income has long been debated in economics. Wealthier countries tend to trade more, as measured by the ratio of the sum of exports and imports to GDP, than do poorer countries. This could reflect the impact of competition on local productivity and efficiency. It could also imply reverse causation or simply point to an underlying factor driving both, such as the strength of institutions. A recent and significant contribution to this literature was Frankel and Romer (1999) which used geographic variables to instrument for bilateral trade. The fitted values of bilateral trade were summed to provide an estimate of trade openness free from

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some of the mentioned endogeneity problems. While a useful contribution to the literature, this geographic instrument is based primarily on static characteristics[1] and cannot address changes in trade over time or income growth. Instead it demonstrated a correlation between the degree of trade openness[2] and the level of income.

More recently, papers have attempted to use the massive relative decline in air to ocean transport prices to provide an exogenous source of trade variation. From 1960-2000, air transport prices fell by 71-88% relative to ocean transport[3]. The decline in the relative air to ocean transport price should differentially benefit varieties[4] that are suitable for air shipment relative to those that are not. This benefit should increase with the length of the trading route as the amount of time avoided by using air transport increases with this length. More specifically, the benefits of cheaper air transport increase in the amount of time in transit avoided, and this latter figure is related to the nautical shipping distance along the route[5]. One example of the potential benefits of cheaper air transport costs is trade between Japan and Germany. Before air transport became affordable, the distance between these two countries was nearly 23,000km by sea, while afterwards the effective distance fell to 8,920km[6]. Affordable air transport reduces the distance along this route by 61%.

The reduction in measured distance vastly understates the reduction in time of transport. Assuming that the vessel maintains an average speed of 20 knots/hour, the trip would take nearly 26 days[7]. By contrast, goods shipped by air can make the trip in under one day. This reduction in transport time will directly reduce the inventory costs of goods in transit. It would also have indirect effects through reductions in delivery and demand uncertainty. Estimates by Hummels

[1] Country population being the lone exception.

[2] Throughout this paper openness refers to the ratio of imports plus exports over GDP.

[3] All transport price figures unless otherwise specified from Hummels (2007). The range in the estimated price arises from the way in which the ocean price index is constructed. The longer run relative price decline is 68-93% from 1954-2000, but the pre-1960 figures are noisier so the shorter period will be used.

[4] Throughout this paper a variety will refer to a combination of a good and a bilateral route.

[5] This does not apply to neighboring countries, and may not be applicable for intra-regional trading partners. Both of these problems will be examined in robustness checks.

[6] Both figures are my calculations.

[7] This figure ignores both ocean currents and the problems posed by congestion. For example, the Suez Canal may only be used at certain times of the day requiring queueing for substantial time to ensure the vessel gets to pass through. It is unclear how accounting for these factors would alter the time of transit, but the difference between the two modes would remain substantial.

indicate that the indirect effects are of greater importance and have substantial magnitude. These advantages of air transport, combined with declining relative prices led to a large increase in the proportion of world trade shipped by air. While air share figures for the world are not available, the American record aptly demonstrates this change. In 1965 Hummels reports that 8% by value of US imports came by air. This figure reached a maximum in 2000 at 36%[8]. Exports followed a similar pattern.

This discussion points to two approaches for estimating the trade impact of declining relative air to ocean transport prices. The first follows Choate (2008) and Choate (2009) by estimating the impact as a function of variety characteristics and route lengths. As this approach may be open to endogeneity concerns related to the choice of varieties traded, a geographic approach is also taken. Following the lines of Feyrer (2008) route level geographic characteristics are used to capture the route level impact of the relative transport price change. These impacts are then aggregated to the country level to estimate the changes in trade openness caused by cheaper air transport costs.

Across both approaches, the results are consistently null. I find no relationship between transport induced trade changes and subsequent changes in income. Like previous work, I do find a relationship in levels, countries with higher fitted figures for trade openness have higher levels of income. This is consistent with an omitted variable problem such as the institutional capacity of each country. Once this heterogeneity is accounted for, there is no significant relationship between changes in trade and changes in income level. This null result is robust to numerous methodologies and sample restrictions. By using a dynamic instrument for trade changes, this paper removes all omitted variable concerns, and demonstrates that trade growth does not lead to income growth. This paper proceeds by discussing the literature and the methodology for constructing the instruments in Section 2. Section 3 presents the estimated instruments and discusses. Initial results and robustness checks are shown in Section 4, and Section 5 concludes.

[8]These figures exclude trade with Canada and Mexico.

2 Literature Review and Methodology

Properly examining the relationship between changes in trade and changes in the rate of income growth requires constructing an exogenous measurement of country level changes in trade. This paper will take two approaches to this problem: a geographic approach and a variety characteristics approach. The geographic approach modifies Frankel and Romer (1999) which used geographic variables to instrument for bilateral trade:

$$ln(\tau_{ij}/GDP_i) = \alpha + \beta_1 X_{ij} + \beta_2 B_{ij} + \beta_3 B_{ij} X_{ij} + \epsilon_{ij} \tag{1}$$

Where X_{ij} is a vector of controls including the Great Circle distance between the main cities of the two countries on a given route, the sizes of both countries in population and area, and a count of the number of landlocked countries in the pair. These controls enter both by themselves and interacted with a binary variable for whether the two countries share a border, B_{ij}. The dependent variable in this equation is bilateral trade between countries i and j, normalized by the size of country i's economy[9].

The dependent variable can be thought of as the share of a country's GDP accounted for by trade on a given route. Using this figure instead of logged trade has three benefits. First it controls for expected heterogeneity with respect to economy size. There is a wider range of possible trade values for larger economies, so the errors associated with these observations are likely to be larger and thus given greater weight in the regression. Normalizing by the economy size resolves this problem. It also reshapes the analysis in terms of relative importance of trade partners as opposed to absolute levels of trade. The notion that geography influences the relative importance of partners is more in keeping with theory than geography determining the level of trade. This view of geography is also more consistent across development levels. The final advantage of using this figure is that it breaks the mechanical relationship between trade and GDP. If trade makes up 20% of an economy and GDP grows by 3%, then we would expect trade to grow nearly 3% as well. An examination of the relationship between trade and GDP would be expected to produce an almost

[9] Note that the normalization implies that each bilateral pair can enter as two observations. There would only be one observation per pair if trade alone was the dependent variable.

1-to-1 relationship for purely mechanical reasons.

Frankel and Romer estimated Equation 1 using data from 1985. Since the independent variables are available for all country pairs, fitted estimates are available even for routes that did not report trade figures[10]. Summing the exponentiated fitted values across all possible trading partners produces a country level estimate of trade openness:

$$\hat{T}_i = \sum_j e^{ln(\hat{\tau_{ij}}/GDP_i)} \tag{2}$$

The estimated trade openness then instruments for actual trade openness in a regression with logged income as the dependent variable. Using this methodology, Frankel and Romer estimated the elasticity of income to trade as between 2-3 depending on the sample selection.

Since its publication, the methodology has been applied to and found similar results for previous periods in the 20th century (Irwin and Tervio (2002)). It was also modified to include additional geographical variables including country distance from the equator (Rodrik and Francisco (2000)) and instruments for institutional capacity (Rodrik et al (2004)) in the second stage regression. In both of these papers the relationship between trade and income levels was not robust to their inclusion. This suggests that some omitted country level heterogeneity is driving the positive results in the other papers. Using updated trade figures and additional countries, Noguer and Siscart (2005) addressed the former of these criticisms but not the latter. In each of these extensions, though, the instrument remained static.

In moving from a static to a dynamic trade instrument, the omitted variable problems are mitigated[11]. However, the geographic methodology outlined above is static by construction. To construct a dynamic geographic trade instrument, one must look for an external shock whose impact will vary based on geography. The decline of air transport prices relative to ocean transport prices is one such shock. Hummels (2007) showed that the cost of air shipment fell by 71-88% relative to ocean transport from 1960-2000. To the extent that this relative price movement is

[10]Note that observations reporting 0 trade are excluded from the first stage regression. I follow this procedure. Including those observations in the first stage produce perverse instruments and are not reported here.

[11]More specifically, time-constant country level heterogeneity is removed. Time-varying heterogeneity will remain, but this may be a smaller problem.

driven by technological progress, it provides an exogenous shock to trade with an impact that will vary based on route specific geography.

As mentioned in the introduction, the effective distance from Japan to Germany falls from 23,000km to 8,900km if the transport mode is switched from sea to air, and the time reduction is even more dramatic. This reduction in the effective distance by 61% is one of the largest in the sample, but *a priori* it is not unreasonable to expect that the shift in relative prices will have differential route level impacts and that these impacts could aggregate to substantial country level impacts. The reduction in relative prices also produces time-variation in the instrument since the proportion of varieties than can switch transport modes increases as the relative price falls. This is consistent with the documented rise in the proportion of world trade shipped by air over the time period. The following approach, adapted from Feyrer (2008), is used to estimate the time-varying impact of the price shift on route level bilateral trade:

$$ln(\tau_{ijt}/GDP_{it}) = \alpha_i + \alpha_j + \gamma_t + \sum_{k=1965}^{2005} \delta_k(\beta_1 ln(sea_{ij}) + \beta_2 ln(air_{ij})) + \beta_3 X_{ij} + \epsilon_{ijt} \quad (3)$$

The δ_k's are dummies for five year periods[12], α_i and α_j are country fixed effects, and γ_t is a year fixed effect. X_{ij} is a vector of time-constant route level characteristics including whether the countries share a border and the number of landlocked countries in the pair. This specification pushes all time variation onto the coefficients of the sea and air route lengths which are captured by sea_{ij} and air_{ij} respectively.

This approach differs in significant ways from that followed by Feyrer (2008), which uses the same transport price shock to try to produce a dynamic geographic instrument. The most significant difference between that paper and this one is the choice of dependent variable. Feyrer uses the logged level of bilateral trade rather than the normalized bilateral trade used in my approach and Frankel and Romer. As mentioned previously, using the level of bilateral trade leads to heterogeneity in the errors and a mechanical relationship between trade and GDP. This latter problem leads to spurious correlation between the estimated trade level and per capita income. Switching from Feyrer's to my dependent variable eliminates the significant results found in his paper.

[12]The first period is 1965-1970, and the final one is 2001-2005

The bilateral trade data to estimate Equation 3 comes from the IMF's Direction of Trade (DOT) database[13]. Each bilateral pair reports up to 4 observations corresponding to imports and exports measured by each of the countries. These are separated into two flows: goods moving from country A to B and vice versa. For each of these flows, the mean is calculated and these means summed to find the total trade on the route[14]. Current $ GDP comes from the World Bank's World Development Indicators. Both the sea and air distances are calculated by the author, and the details of their construction are laid out in Appendix A. These distance measures are also available from the author upon request. The fitted values from estimating Equation 3 are summed up following Equation 2 to produce a country level instrument for trade openness and changes in trade openness.

The second approach to constructing this instrument follows Choate (2008) and Choate (2009). These papers use a combination of variety and route level characteristics to estimate the impact of declining relative transport prices on variety level trade growth. For world trade, these estimates are constructed via:

$$\Delta_m T_{ijkt} = \alpha_{ijt} + \alpha_k + \beta_1 ln(\hat{vpw}_{ijkt}) + \beta_2 ln(\hat{vpw}_{ijkt}) * ln(air)_{ij} + \beta_3 IShare_{ijkt} + \epsilon_{ijkt} \qquad (4)$$

This equation relates the bound growth rate of trade in a variety from t to t+1 to the ratio of value to weight of that variety at time t. This latter figure is correlated with the suitability of the variety for air transport. It is covered with a ˆ to indicate that the 2-digit industry mean has been subtracted from the 4-digit variety ratio. Finally the share of trade in a given industry, $IShare$, accounted for by the variety is included to control for the inverse relationship between size and growth rate. This approach effectively compares intra-industry growth rates to intra-industry variation in the suitability for air transport[15]. Varieties more suitable for air transport, which is to say more valuable or lighter, grew faster in every period post-1975 than did varieties less suitable.

[13]All Liberia observations are dropped as the data indicates Liberia trades 14x more than its GDP.

[14]Missing observations are skipped during averages but counted as 0 during sums.

[15]This equation is estimated only for intensive margin data, but given the level of aggregation this accounts for more than 90% of trade value in each period.

This growth differential increased rapidly with the length of the route.

Bilateral trade data at the 4-digit level is available from the UN's Comtrade database[16]. Combined with the air distance along the route, this is sufficient to estimate Equation 4. The results from this estimation are used to construct measures of the trade impact of the relative price shift. These estimates are orthogonal to country and industry growth trends, and they represent the portion of trade changes caused directly by the relative price movement. Three approaches to measuring the direct impact are detailed in Choate (2009), and the following results generalize across all three. The main measure used in this paper is the estimated difference in trade between periods t and t+1 caused by the transport price movement:

$$\text{Air\_Effect}_{it} = \sum_{jk} (\hat{\beta_{1t}} \ln(\hat{\text{vpw}})_{ijkt} + \hat{\beta_{2t}} \ln(\hat{\text{vpw}})_{ijkt} * \ln(\text{distance})_{ij}) * \frac{\text{value}_{ijk,t} + \text{value}_{ijk,t+1}}{200} \quad (5)$$

Dividing this figure by the actual growth in trade along a route produces an estimate of the route level trade growth driven by transport price movements. These trade movements are exogenous and orthogonal to the typical rate of trade growth. They tend to lie between -7% to 7% and should be directly compared to income growth. Labeling the country level air effect, AFX_{it}, and per capita income, y_{it}, the "second stage" regression is:

$$\gamma y_{it} = \beta_1 AFX_{it} + \epsilon_{it} \quad (6)$$

Where the dependent variable is the annualized rate of per capita income growth from period t to t+1. The independent variable is the air effect over the relevant period expressed as a proportion of the change in the level of trade over that period. For countries that benefit from the relative transport price shift this figure will be positive, while for those adversely affected, it will be negative.

This approach will work for a direct measure of the exogenous trade shift, but when using geography to address endogeneity concerns, an instrumental variable approach is required. Fol-

[16]Details on the cleaning of this data are available in Choate (2009).

lowing Frankel and Romer, the fitted values from Equation 3 are used to construct measures of the country's trade openness. Differences in these measures from period t to t+1 are then used to instrument for the actual differences in trade openness over that period in the following regression:

$$\gamma y_{it} = \beta_1 (T_{i,t+1} - T_{it}) + \epsilon_{it} \tag{7}$$

The dependent variable remains the annualized rate of per capita income growth, but the independent variable is now the difference in trade openness from period t to t+1[17]. This figure is instrumented for with the predicted change in trade openness. The difference is used rather than a growth rate because trade openness tends to display smaller movements across time.

Each of these second stage regressions examines the same question. Does the exogenous trade shock brought about by decreasing relative transport prices correlate with changes in per capita income? In the first case, the shock, as a percentage of the actual trade change, is measured directly. In the second, the shock is captured by the difference in predicted trade openness. This latter approach is an instrumental variable approach while the former is an OLS approach. Across both methods no relationship is found between trade growth and income growth.

3 First Stage Results

Table 1 presents the first stage results from estimating Equations 2 and 4. The first two columns show the estimated coefficient on the value per weight ratio and its interaction with distance. These results demonstrate that for each period post-1975 the rate of trade growth rises quickly with the interaction of value to weight and the route length. The non-interacted coefficient is significantly negative for most time periods, indicating that for the shortest routes, trade in varieties suitable for surface transport grew faster. Route fixed effects are included in these estimates, but year fixed effects are excluded as each 5-year period is estimated independently. For this reason the number of observations is not included since it varies by period from 158,000 in the earliest

[17]This figure could also be put in per year terms without altering the results. The overall difference was chosen as it is slightly easier to interpret.

period to more than 700,000 in the final. Likewise, the R-squared figures are not reported but lie between 0.09 and 0.12 for each period.

The final four columns report the estimated coefficient on the sea distance by period. Each of these regressions is pooled across all periods as shown in Equation 2. The first three of these are my calculation, while the final column comes from Feyrer and is included for comparison purposes[18]. The first column includes country fixed effects, while the second column also includes variables indicating whether the countries share a border and the number of landlocked countries in the pair. The third column excludes country fixed effects and in addition to the route specific variables includes area, population, and latitude controls for each country. Across each regression the same pattern holds. The estimated elasticity of trade to sea distance becomes more negative from as time progresses. The evolution is not monotonic, but it is consistent across all specifications. This differs from the Feyrer results which become less negative as time progresses. This difference is driven by the choice of dependent variable.

One immediate question that must be examined is whether the first stage results for the geographic framework are consistent with expectations of the impact of declining relative transport costs. Not shown in Table 1 is the evolution of the air distance coefficient, but it follows a similar path to that of the sea distance coefficient. The movements are so similar that the predicted difference in trade share along a route from 1965 to 2005 is:

$$\Delta(\tau_{ij}/\hat{G}DP_i) = -0.117\text{ln(sea)}_{ij} - 0.135\text{ln(air)}_{ij}$$

This implies that trade is not predicted to increase on any route due to changes in the distance coefficients[19]. All positive growth in trade is loaded into the year fixed effects. Trade, also, is predicted to decline faster on longer routes; yet these are the routes where cheaper air transport is expected to have the largest benefit. Hummels (2007) reports that air prices fell the most on these longer routes, and Choate (2009) showed that trade in air suitable goods grew faster on longer

[18] The Feyrer result reproduced here is column 1 of his Table 8.

[19] This same pattern holds for the period 1975-2005. There are some periods when trade is predicted to grow faster due to the changing distance coefficients such as 1975-2000 and 1975-1985, but these are the exceptions to the general rule.

routes. So it is not clear that the evolution of the distance coefficients is capturing the changing relative price story. The evidence may be more indicative of the rise of regional trading blocs, and the shortening of world trade distances. Choate (2009) also provides evidence that the trade weighted average distance of trading partner route lengths fell for most countries from 1965-2000. This aggregate effect could be dominating the smaller relative transport price effect which is why the latter story does not explicitly emerge from the estimates in Table 1. Even if the geographic estimates in Table 1 are not capturing the impact of changing relative transport prices, the variety characteristic estimates explicitly do measure this impact. The predictions from using their fitted values will thus be given more weight throughout the rest of this paper.

The estimates in Table 1 are used to build country level impacts of the air transport price shock. In the case of the variety characteristics estimates, a trade openness figure cannot be constructed since the estimates are in terms of growth rates. Rather, the approach taken estimates the difference in trade between period t and t+1 that can be attributed to the transport price shock. This figure, which overwhelmingly tends to be negative, is plotted in Figure 1 against the actual change in trade openness[20]. Figure 1 shows that there is almost no relationship between the change in trade openness and the estimated air effect[21]. As in the geographic estimates, the change in trade openness is captured predominantly by the year fixed effects. The variables that measure the impact of changing relative transport costs only pick up movements orthogonal to that story. Since changes in trade openness may be connected with the level of development or strength of institutions, having an orthogonal, exogenous shock permits me to examine the relationship between unexpected trade changes and subsequent income changes.

The geographic predictions differ from those above by showing a clearer relationship between changes in predicted and actual trade openness as can be seen in Figure 2[22]. Previously I discussed how the evolution of the coefficients on the distance measures generated predictions of smaller trade for all routes. Figure 2 shows that the year and country fixed effects adequately capture

[20]Here and throughout the rest of this paper, the change in trade openness is calculated as a simple difference between start and end period values.

[21]The figures for Egypt and Liberia are excluded since they are outliers and prevent the relationship between the rest of the observations from being observed.

[22]Note that the actual change in trade openness varies between Figure 1 and 2 since the measures come from the different datasets.

the trend in changing trade openness[23]. Since the contributions of these controls are excluded in Figure 1 to present a more direct measurement of the air impact, the relationship is less clear. The results in both figures are robust to alternate time periods such as 1975-2000.

These two figures demonstrate the relationship between the air impact measures and the actual change in trade openness. Though not shown here, regressing the predicted change in trade openness from the second figure on the actual change produces a significantly positive coefficient of 0.31. Repeating this process for the data from Figure 1 produces an insignificant coefficient on the predicted air impact. These results reinforce that the air impact variable is orthogonal to trade growth, while the geographic instrument is significantly correlated with actual trade growth. The following section examines what these two variables imply for the relationship between trade growth and income growth.

4 Second Stage Results

The previous sections described two approaches for constructing measures of the impact of changing relative transport prices on trade flows. The first version uses variety characteristics to directly construct a measure of the air impact. The second uses geographic variables to calculate how the predicted trade openness varies across time. Equations 6 and 7 showed the ”second stage” regressions for each approach, and the estimates of these equations over the period 1965-2000 are shown in Tables 2 and 3. In these tables and all subsequent ones, GDP figures, when they appear as the dependent variable, are in real terms and come from the Penn World Table version 6.2[24]. The latitude control comes from the Harvard Center for International Development database[25].

Table 2 compares the annual per capita GDP growth of a country to the difference in trade openness over the period. Both the first and third column use OLS to analyze the question and find a significantly positive relationship between the two. Income growth is 0.25-0.31% higher

[23]Liberia, the Netherlands, and Oman have all been excluded since they are outliers.

[24]Specifically the rgdpch variable.

[25]The latitude control is the absolute value of the actual latitude of the main city divided by 90 so that tropical countries have scores near 0 while temperate countries are nearer to 1.

per year for a country that raises its trade openness by 10 points over the time period. If the trade openness of a country rises from 50% to 60% of GDP, the income level is 9-10% higher at the end of the period than it would have been had trade openness remained constant. This is quite substantial, but this result is open to the standard endogeneity claims. The second and fourth columns use the geographic instrument for the change in trade openness[26] to address this problem. For the period 1966-2000 a significantly positive effect is found when using the instrument, but this significance disappears when the period is shortened to 1966-1995. Though not shown in this table, the significance also goes away when the time period is lengthened to 1965-2005.

This lack of robustness across time periods indicates that the significant results in column two may be spurious. An additional indication of this is the results in Table 3. This table uses the directly estimated impact of declining relative air transport prices on trade flows as its measure of exogenous trade changes. This variable is expressed as a percent of the overall change in trade over the period. For the longer period, 1965-2000[27], there is no estimated correlation between transport price induced changes in trade and income growth. There is minimal significance, however, when the period is shortened to 1965-1995. This significance is slightly stronger when the period is lengthened to 1965-2005.

The results in Tables 2 and 3 follow opposite patterns with respect to time. This, combined with their failure to demonstrate consistency across time, indicates that a more granular approach may be called for. Tables 4 and 5 break the sample into 5 year intervals and calculate all relevant figures for each period. Since some countries do not report trade figures in the earliest periods, this regression is on an unbalanced panel. In the first two columns of each table, the dependent variable is the annual rate of income growth, while in the last two columns it is the difference in logged income across periods. These latter columns are included to ensure that the null result is not driven by the choice of growth variable. Each regression includes year fixed effects and clusters the errors at the country level when appropriate[28].

[26]Specifically the instrument is constructed using the results in the fourth column of Table 1.

[27]The timelines do not exactly match up because the openness figures were calculated in a manner analogous to Feyrer, while the air effect figures were calculated independently.

[28]Country fixed effects are excluded to take advantage of the full cross-sectional variation. Introducing them does not alter the findings.

In both tables, across all specifications there is no significant relationship between the change in trade openness and income growth. The estimated coefficient does increase in the instrumented regression, but it remains small relative to the standard error. This same story holds when the air effect is used for the exogenous change in trade rather than the geographic instrument. Table 5 shows that the estimated coefficients are positive, but they fail to reach significance. The results in both of these tables imply that the positive results in Tables 2 and 3 were spurious as thought. Once the time periods are shortened, introducing more observations, the relationship is no longer significant[29].

To check that the null result is not driven by the exclusion of climate variables, Table 6 introduces region fixed effects and latitude controls. These were suggested by Francisco and Rodrik who pointed out that including either of them would remove the significance of Frankel and Romer's estimates. Table 6 shows that excluding them does bias the results upwards. However, the downward shift of the estimated impact of changing trade on income growth is insufficient to generate significantly negative results. Instead the results presented here merely reinforce those of the previous tables.

Though not presented here, the results are robust to the alternate specifications of the geographic instrument from Table 1. They are also robust to different measures of the air effect. If the proportion of varieties a country trades that are positively impacted by the shift in relative prices is used in place of the air effect defined above, the results remain insignificant. Likewise, if intra-regional trade is excluded due to concerns about the sea distance measures for such routes the estimated relationship between changes and trade and changes in income is insignificant. The only positive, significant estimates arose when I compared the level of income to the level of trade as implied by the geographic instrument. This indicates that the Frankel and Romer result relating the level of income to the level of trade is robust to the inclusion of the measure of sea distance. However, the lack of significance in the dynamic results implies that this is the result of an omitted variable, such as institutional capacity.

[29]Intermediate period lengths such as 10-years were not evaluated.

5 Conclusion

By using the decline in relative air to ocean transport prices from 1965-2000 as an exogenous source of trade variation, this paper showed that there is no significant relationship between changes in trade and changes in income. This expands on the existing literature of geographic trade instruments and contradicts recent works that purport to find such a connection. The use of a dynamic trade instrument removes omitted variable concerns, such as institutional capacity, and directly examines the question of how income varies in response to trade shocks.

The exogenous shock was measured two different ways, and the results were consistently null across each methodology. The first approach used disaggregated bilateral trade data to estimate how trade growth varied based on the suitability of a variety for air transport and the route length. These variety level estimates were aggregated to country level air impacts which were by construction orthogonal to country and industry level trends in trade growth. The air impact variable captured only the growth changes brought about by the decline in relative transport prices. When regressed against concomitant changes in per capita income, the estimated relationship was positive but was never significant. This result was robust to different constructions of the air impact figure, different methods for calculating income growth, and different time periods.

The same held for a geographic instrument for trade changes. Introducing time variation in sea and air distance measures in the Frankel and Romer framework produced an estimate of country level trade openness that varied across time. There are some concerns about whether this instrument captures the impact of changing relative transport prices as opposed to the rise of regional trading blocs, but its results mirror those of the direct measurement of the air effect. Across all methods of calculating income growth, all time periods, and the inclusion of climate controls, the estimated impact of changes in trade on changes in income was insignificant. The level of the instrument was positively related to the level of income, but there was no dynamic relationship. This underscores that previous examinations have insufficiently removed country level heterogeneity when analyzing the relationship between trade and income.

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A Sea and Air Distance Constructions

There is no standard sea distance measure available to the economics community in the same way there is a dataset for Great Circle distances[30]. Because of this gap in data, authors over the years have constructed their own measures of varying accuracy[31]. Feyrer follows this tradition by finding the minimal length path between two ports over a 1x1 degree chart of the world.

The approach followed in this paper improves on all previous attempts by using a geographical information system (GIS) with very fine resolution. The GIS I use to construct the sea distance measures comes from the Oak Ridge National Laboratory's Intermodal Transportation Network[32]. This GIS contains incredibly precise data on all modes of transportation within NAFTA as well as all shipping routes. The minimum distance between any two ports may be calculated through a standard minimal path network analysis.

There are a few caveats that apply to this step. First, since the GIS was originally constructed to analyze NAFTA, each of the NAFTA countries is treated distinctly from the rest of the countries. For every non-NAFTA country, there is at least one route connecting the capital city of a country to the nearest ocean network link. This means the calculated sea distance is a hybrid of actual sea distance and the overland distance to the capital city. It also means that landlocked countries can be included in the calculation since their capital cities are connected to the ocean network in a similar manner. For some countries the capital is connected to the ocean network in multiple points. Spain, for instance, is connected directly to the North Atlantic and to the Mediterranean which is to be expected owing to its bordering both bodies of water[33]. Since for most non-NAFTA countries the distance from the capital city to ports is small relative to the total length of a shipping route, this construction is unlikely to impact the results significantly.

The NAFTA countries have both more and less detail than the other countries in the GIS. Both Canada and America have actual ports that are connected to the ocean network. For each country multiple ports are used and the minimal distance among the ports is selected. For Canada the ports are Vancouver and Montreal, while for America they are Los Angeles, Houston, and New York. This means that when calculating the sea distance from China to America or Canada, the ports of Vancouver and Los Angeles are used.

Mexico is treated in a unique manner since no port information is included, and it is not connected to the ocean network as is the rest of the world. For Mexico, then, the points of closest approach of the ocean network in the Caribbean and the Pacific stand in for nearby Mexican ports. Again, the additional distance between these points and Mexico City is assumed to be small relative to the length of the overall route.

Once the termini have been established for the GIS, then the minimum distance between any two countries can be determined. This minimum distance is calculated accounting for the impedance of each segment of the route. Impedance is a measure that controls for the congestion on a route segment by converting it into an equivalent open ocean distance. For instance, the Panama Canal is effectively much longer than its physical length due to congestion, its narrow nature, and the series of locks that must be traversed to pass through it. However, impedance is only taken into account to determine the route that will be followed, the actual length of the route

[30]Available at http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

[31]Hummels (1999) and Frink et al (2002) both produce or obtain measures for routes that terminate in America.

[32]The raw GIS data is available at http://www-cta.ornl.gov/transnet/Intermodal_Network.html.

[33]There are some odd cases, like Belize, where a country is connected directly to a non-neighboring body of water, but these cases are rare.

is then calculated in a way that looks only at the physical length. The impedance information is excluded because it is expected to change over time, and no time dependent data is available.

The final dataset of sea distances is available upon request from the author, or alternatively from http://www.columbia.edu/˜dac2114. One warning for anyone using the dataset is that the sea distance can have odd behaviors for neighboring countries or for countries in the same geographical region. This former problem can be assuaged somewhat through use of border dummies as in the paper. The two Congos, Kinshasa and Brazzaville, serve as an example of the problem. Though neighbors and with capital cities less than 5km apart, the sea route involves trips from each capital to the ocean, and back for a trip of 484km. Similar problems can occur in South America, but in all cases the calculated distances merely reflect the likelihood of using a particular transport mode. Chile is not likely to ship products by sea to Brazil when the trip is so much longer than simply going overland. Modeling these decisions is left to future work.

The construction of the air distance picks up naturally after the sea distance. For all countries in the dataset other than the NAFTA countries, the distance is the minimal distance between the two capitals along an idealized sphere. For the NAFTA countries, the minimum distance is calculated to each port of entry, and then the route with the minimum length is selected. These figures are also available from the author upon request or at the above mentioned website.

Table 1: Time Variation in First Stage Estimates

Period	ln(value / weight)	ln(vpw) X ln(distance)	ln(sea distance) Geographic Instrument			Feyrer
1965-1970	2.314	0.480	-0.339***	-0.382***	-0.764***	-0.616***
	(2.553)	(0.310)	(0.030)	(0.030)	(0.040)	(0.095)
1970-1975	1.121	0.246	-0.434***	-0.469***	-0.857***	-0.496***
	(1.884)	(0.230)	(0.027)	(0.027)	(0.036)	(0.085)
1975-1980	-6.783***	1.305***	-0.409***	-0.442***	-0.801***	-0.437***
	(2.199)	(0.264)	(0.026)	(0.026)	(0.035)	(0.080)
1980-1985	-3.651*	1.154***	-0.365***	-0.396***	-0.791***	-0.29***
	(1.879)	(0.227)	(0.025)	(0.025)	(0.034)	(0.079)
1985-1990	-6.728***	1.256***	-0.358***	-0.386***	-0.775***	-0.065
	(1.914)	(0.230)	(0.024)	(0.024)	(0.032)	(0.084)
1990-1995	-1.520	0.664***	-0.506***	-0.530***	-0.955***	-0.268***
	(1.830)	(0.219)	(0.023)	(0.023)	(0.031)	(0.077)
1995-2000	-5.526***	1.180***	-0.517***	-0.539***	-0.947***	-0.263***
	(1.282)	(0.156)	(0.022)	(0.022)	(0.030)	(0.076)
2000-2005	-7.064***	0.888***	-0.456***	-0.478***	-0.884***	
	(1.063)	(0.129)	(0.024)	(0.024)	(0.032)	
Observations			447,490	447,490	447,490	163,690
R-squared			0.69	0.69	0.40	0.7
Fixed Effects	Route	Route	Country	Country	None	Country
Pair Controls			no	yes	no	no

Standard Errors in parentheses: * significant at 10%; ** significant at 5%; *** significant at 1%.
The final four columns include year fixed effects.

Table 2: Per Capita GDP Growth vs Changes in Trade Openness (1965-2000)

	Annual Per Capita GDP Growth			
Δ Trade Openness	0.025***	0.042**	0.031***	0.067
	(0.005)	(0.020)	(0.006)	(0.043)
Constant	1.070***	0.689	1.078***	0.485
	(0.203)	(0.482)	(0.204)	(0.724)
Observations	77	77	77	77
R-squared	0.23		0.23	
Period	1966-2000		1966-1995	

Standard Errors in parentheses: * significant at 10%;
** significant at 5%; *** significant at 1%.

Table 3: Per Capita GDP Growth vs Air Effect

	Annual Per Capita GDP Growth (1965-2000)			
Air Effect	0.001	0.000	0.049*	0.038*
	(0.008)	(0.006)	(0.029)	(0.022)
Constant	1.651***	1.650***	1.738***	1.744***
	(0.181)	(0.181)	(0.202)	(0.202)
Observations	88	88	88	88
R-squared	0.00	0.00	0.03	0.03
Sample	pooled	split	pooled	split
Period	1965-2000		1965-1995	

Standard Errors in parentheses: * significant at 10%;
** significant at 5%; *** significant at 1%.

Table 4: Income Growth vs Changes in Trade Openness on 5-year Periods

	Income Growth		Δ ln(income)	
Δ Trade Openness	0.185	0.936	0.009	0.048
	(0.325)	(1.180)	(0.016)	(0.058)
Constant	2.978***	2.949***	0.145***	0.143***
	(0.323)	(0.402)	(0.016)	(0.020)
Observations	903	903	903	903
R-Squared	0.05		0.05	
Regression	OLS	Inst.	OLS	Inst.

Standard Errors in parentheses: * significant at 10%;
** significant at 5%; *** significant at 1%.
All regressions are on data at 5 year intervals from 1966 to 2004.
Regressions include year dummies. When applicable, errors are clustered at the country level.

Table 5: Income Growth vs Air Effect on 5-year Periods

	Income Growth		Δ ln(income)	
Air Effect	0.013	0.006	0.001	0.000
	(0.020)	(0.011)	(0.001)	(0.001)
Constant	2.960***	2.959***	0.143***	0.143***
	(0.399)	(0.398)	(0.019)	(0.019)
Observations	1028	1028	1028	1028
R-squared	0.05	0.05	0.05	0.05
Sample	pooled	split	pooled	split
Year FX	yes	yes	yes	yes

Standard Errors in parentheses: * significant at 10%;
** significant at 5%; *** significant at 1%.
All regressions are on data at 5 year intervals from 1965 to 2005. Regressions include year dummies, and errors are clustered at the country level.

Table 6: Changing Income vs Changing Openness

	Δ Trade Openness		Air Effect	
Change in Trade	0.167	-0.155	0.010	0.005
	(0.328)	(1.122)	(0.020)	(0.011)
Latitude	0.160	0.117	0.590	0.590
	(1.378)	(1.071)	(1.253)	(1.251)
America	1.015***	1.013***	1.031***	1.035***
	(0.324)	(0.335)	(0.324)	(0.326)
Asia	1.937***	1.949***	2.045***	2.051***
	(0.548)	(0.360)	(0.512)	(0.513)
Europe	2.241***	2.262***	1.974***	1.981***
	(0.697)	(0.568)	(0.627)	(0.625)
Pacific	1.477***	1.496**	1.050**	1.050**
	(0.504)	(0.606)	(0.530)	(0.530)
Constant	1.886***	1.903***	1.782***	1.779***
	(0.391)	(0.452)	(0.479)	(0.479)
Observations	903	903	1028	1028
R-squared	0.10		0.10	0.10
Sample			pooled	split

Standard Errors in parentheses: * significant at 10%;
** significant at 5%; *** significant at 1%.
All regressions are on data at 5 year intervals and include year fixed effects. The dependent variable in all regressions is annual income growth.

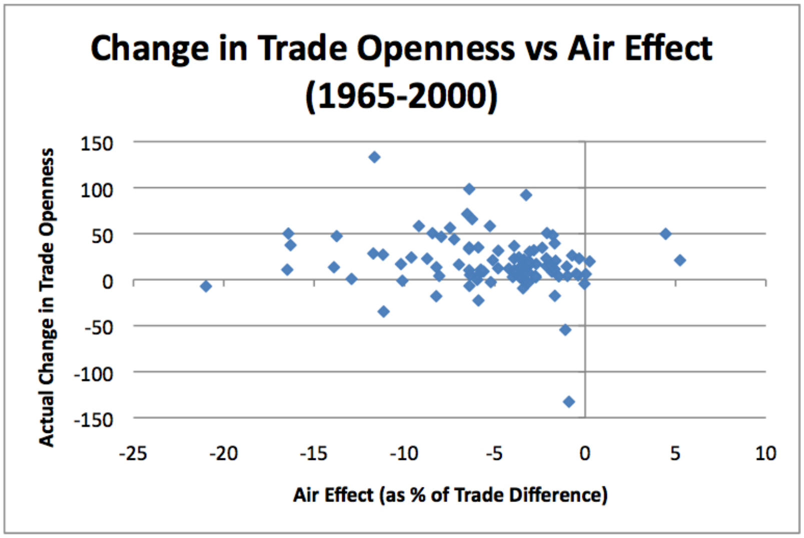

Figure 1: Predicted Trade Impact of Transport Price Movement

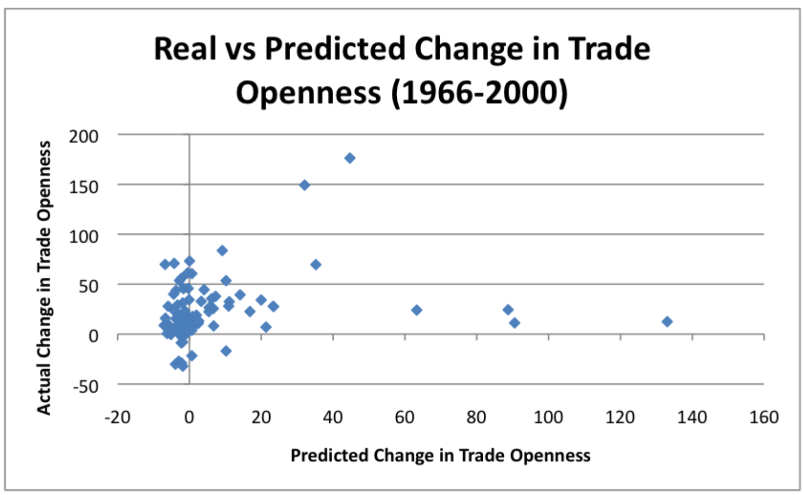

Figure 2: Predicted vs Actual Change in Trade Openness (1965-2000)