Lecture Note 11 - The Gains from International Trade: Aggregate Evidence and Distributional Consequences

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Measuring the Causal Effect of Trade on GDP (James Feyrer, 2019)

Using reliable data from the Penn World Tables, the figure below from James Feyrer's 2019 paper, "Trade and Income—Exploiting Time Series in Geography" shows that countries that experienced rising trade between 1960 and 1995 also experienced rising GDP. Is this relationship causal? Theory clearly predicts that trade increases national income—that is, the bundle of goods and services a country can purchase. But this theory is difficult to test because it's hard to conduct an experiment: we cannot readily manipulate the trade flows of various countries to study the impact this has on their national incomes.

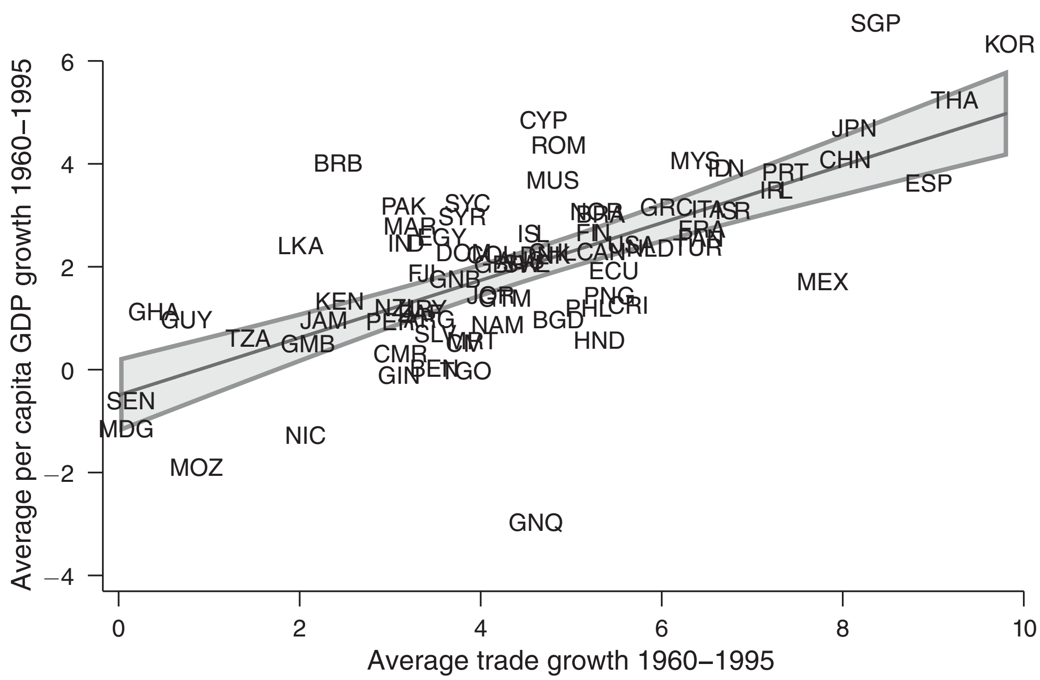


Figure 5. Average Per Capita GDP Growth versus Trade Growth 1960–1995

Thinking back to our causal framework, we would like to measure the causal effect of trade on country j as follows:

$$\gamma_j = Y_j^T - Y_j^A,$$

where Y is some measure of well-being (let's say income per capita), γ_j is the causal effect of trade on Y in country j (where γ stands for Gain from trade), and the superscripts A and T signify Autarky and Trade.

As always, the Fundamental Problem of Causal Inference says that we can never directly observe γ_j, that is, we cannot observe income per capita for country j both under both Autarky and free trade *simultaneously*.

One standard solution would be to contrast incomes of trading and non-trading countries. We could form

$$\hat{\gamma} = E\left[Y^T | T = 1\right] - E\left[Y^A | T = 0\right],$$

where $T \in \{0, 1\}$ denotes whether or not a country is open to free trade.

But for $\hat{\gamma}$ to be an unbiased estimate of γ, the following must be true:

$$\begin{aligned} E\left[Y^T | T = 1\right] &= E\left[Y^T | T = 0\right], \\ E\left[Y^A | T = 1\right] &= E\left[Y^A | T = 0\right]. \end{aligned}$$

That is, the Autarkic economies would have the same income per capita as the trading countries if they opened to trade, and vice-versa for the trading countries if they became Autarkic. (A good shorthand term for this assumption is *exchangeability*, if the experimenter had exchanged the treatment and control groups prior to performing the experimenter, she would have have obtained the same causal effect estimate.)

Are these assumptions plausible? Probably not. The extent to which a country trades is an endogenous outcome that is very likely to be correlated with other factors that directly affect income per capita.

- Countries that are rich for other reasons might trade more because they can afford to import more goods from overseas.
- Countries that pursue sound economic policies (i.e., that raise income) may also choose to pursue trade (another sound economic policy).
- Countries that are rich in natural resources may trade because there is high world demand for their goods. But it may be their rich endowments that account for their wealth, not trade *per se*.

One should therefore be very skeptical of any "causal inference" that stems from a naive comparison of the incomes of trading and non-trading countries. In point of fact, countries that trade more are on average wealthier, but this correlation need not be causal.

1 Using the method of Instrumental Variables (IV) to measure causal effects

1.1 Looking for experiments in strange places

What we need is an "experiment" that exogenously raises or lowers trade in some group of countries. In past class examples, we've used both natural or quasi-experiments (the

NJ minimum wage change, the rollout of cell phones in Kerala, India) and randomized experiments (the Food Stamps cash-out, the Jensen-Miller rice subsidy) to isolate exogenous variation in the treatment variable of interest.

In the case of free trade, such experiments are difficult to find. Even policy changes that open or close a country to trade (for example, war, natural disaster, revolutionary overthrow) are potentially suspect: they are quite likely to induce *other* economic and policy shocks *in addition to trade* that also directly raise or lower real income.

This dilemma—the inability to find a convincing experiment—motivates a subtle and powerful approach to identify causal effects. This method is Instrumental Variables (IV), frequently referred to by the name of the statistical procedure conventionally used to implement it, Two Stage Least Squares (2SLS).

Here's the idea: we are interested in measuring the effect of trade on income. Since trade is endogenous, we are reluctant to draw any causal inferences from the observed correlation between trade and income.

- Assume now that there is some third, exogenously assigned variable, $Z \in \{0, 1\}$ that affects the extent to which countries trade.
- Assume further that we have reason to believe that Z has no effect on national income *except*, potentially, through its effect on trade.
- Under these assumptions, Z may serve as an "instrument" that exogenously manipulates trade, allowing us to study trade's effect on income. Economists would say that Z is a valid "instrumental variable" for analyzing the causal effect of trade on income.

James Feyrer's 2019 paper, "Trade and Income—Exploiting Time Series in Geography," proposes an ingenious IV approach for analyzing the causal effect of trade on national per capita income. His insight is as follows: historically, most trade between non-contiguous countries occurred by sea. As the cost of air freight fell over the last four decades, a substantially larger share of trade was transported by airplane rather than ship. The impact of this cost reduction is not uniform across different pairs of trading partners. For country pairs connected by a direct sea route (e.g., Spain and Brazil), the declining cost of air freight is not particularly important; it reduces transport time but not necessarily transport cost. For country pairs that are connected by a highly indirect sea route however (e.g., Japan and the Western Europe), the reduction in the cost of air freight means that traded goods will potentially have to travel a much shorter distance by air than sea. This makes trade much cheaper for these country pairs.

This insight underlies Feyrer's empirical approach: As air freight gets cheaper, countries that have a high value of their "Air-Sea Distance Difference" ($ASDD$)—that is, the air distance to their trading partners relative to their sea distance to their trading partners—will experience a large increase in trade volumes. By contrast, trade flows among countries that have small or zero $ASDDs$ will not be greatly affected.

Here's how $ASDD$ is defined. Let D^S_{jk} be the sea distance between countries j and k and D^A_{jk} be the air distance. Let $ASDD_{jk} = D^S_{jk} - D^A_{jk}$. If country j and k have nothing between them but water, then their sea and air distances will be the same ($ASDD_{jk} = 0$). If they are separated by land masses that a cargo ship must circumnavigate, then $ASDD_{jk} > 0$.

Now, define for each country j its average $ASSD$ as the trade-volume weighted $ASDD_{jk}$ for all of its trading partners k. Specifically

$$\overline{ASDD}_j = \frac{\sum_k \left(D^S_{jk} - D^A_{jk}\right) \times T_{jk}}{\sum_k T_{jk}},$$

where T_{jk} is the trade volume between j and k (in dollars, for example) in 1960.

If Feyrer's hypothesis is correct, then trade flows will rise differentially between countries with relatively high $ASDD$ as air freight gets cheaper, and if $ASDD$ only affects a country's economy via its effect on trade, then cross-country variation in $ASDD$ provides a kind of natural experiment for studying the causal effect of trade on income: as the cost of air freight falls, countries with high $ASDD$ should begin to trade more than countries with low $ASDD$, which will in turn allow us to study the effect of trade on national incomes.

You object: $ASDD$ is not the *only* determinant of changing trading patterns. The U.S. began trading extensively with China in the 1990s but was trading extensively with Japan decades earlier. Clearly, the gap between the US-China and US-Japan $ASDD$ is trivial, so the falling cost of air freight cannot be the cause of rising China trade. That's correct! But that's not a problem for the IV approach. $ASDD$ need not be the *only* determinant of trade. What we need is:

1. $ASDD$ has a measurable, direct causal effect on trade. This is called the *first stage.*

2. $ASDD$ does not plausibly affect national income through any other channel but trade. This is called the *exclusion restriction.* It's the second assumption—the exclusion restriction—that we'll want to scrutinize in our discussion of this paper.

1.2 Making this work

Figure 1 of Feyrer shows that air freight came to encompass a substantial share of U.S. trade between 1965 and 2005, while Figure 3 documents that countries' trading volumes became substantially more sensitive to air distance between 1960 and 1995 and, simultaneously, substantially *less* sensitive to sea distance.

Figure 1. Air Freight Share of US Trade Value (Excluding North America)

Source: Hummels (2007, 133)

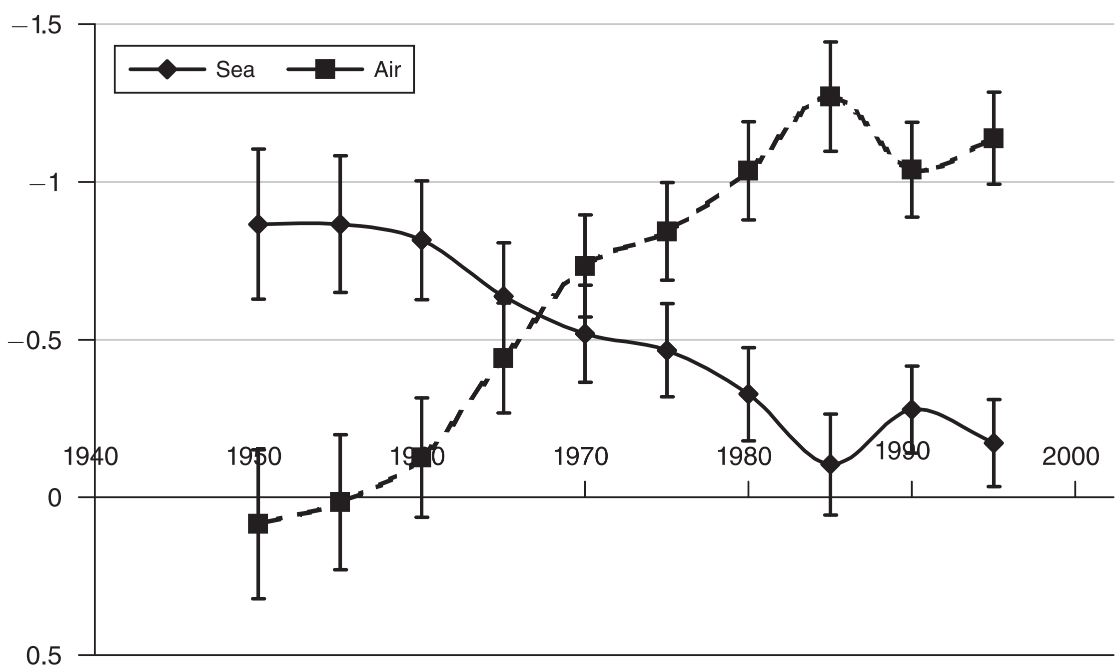


Figure 3. The Change in Elasticity of Trade with Respect to Sea and Air Distance over Time from a Gravity Regression with Country-Fixed Effects

How can we use this information about the changing relationship between $ASDD$ and trade volumes to find the causal effect of trade on income? That's where the subtlety comes in.

The validity of our approach will rest on three pillars:

1. Balance of treatment and control groups
2. First stage relationship: Is there a causal effect of the instrumental variable on the endogenous variable?
3. Exclusion restriction: Is it plausible that the instrumental variable affects the outcome variable *only* through its effect on the endogenous variable?

Now, imagine that we have a set of potentially comparable countries that differ according to whether they have High $ASSD$ ($A = 1$) or Low $ASDD$ ($A = 0$). In our example, the endogenous variable of interest is a country's trading volume, the instrumental variable is the country's $ASDD$, and the outcome variable is the country's GDP.

1.2.1 Condition 1: Balance of treatment and control groups

As with our previous examples of causal inference, our treatment and control groups be comparable—that is, they must have have balanced counterfactual outcomes.

- Let Y_{jt} equal the GDP of country j in time t.
- Imagine that there are two time periods, $t = \{0, 1\}$, and that in the early period t_0, traded goods travel exclusively by sea, whereas in the latter, they can travel by air or sea.
- Let ΔY_j equal the change in GDP in country j between $t = 0$ and $t = 1$.
- For each country, imagine two potential outcomes

  $$\Delta Y_j \in \left\{\Delta Y_j^1, \Delta Y_j^0\right\},$$

  where ΔY_j^1 is the change in GDP in j if $A = 1$ and ΔY_j^0 is the change in GDP in j if $A = 0$.
- Of course, each country j is either one type or the other ($ASDD$ is either High or Low, $A = 1$ or $A = 0$). So, we will never observe both ΔY_j^1 and ΔY_j^0 (i.e., the fundamental problem of causal inference, FPCI). Thus ΔY_j^1 and ΔY_j^0 are counterfactuals of one another.

- Balance of the treatment and control groups implies exchangeability:

$$\begin{aligned} E\left[\Delta Y_j^1 | A=1\right] &= E\left[\Delta Y_j^1 | A=0\right] \\ E\left[\Delta Y_j^0 | A=1\right] &= E\left[\Delta Y_j^0 | A=0\right]. \end{aligned}$$

  If the countries with high $ASDD$ were somehow assigned low $ASDD$, their GDP growth would be the same as the the countries that actually have low $ASDD$, and vice versa if the low $ASDD$ countries were somehow assigned to have high $ASDD$.

1.2.2 Condition 2: Is there a causal effect of the instrumental variable on the endogenous variable?

For our proposed Instrumental Variables approach to be valid, it must be the case that $ASDD$ has a causal effect on the amount that countries trade. This is called the "first stage" relationship by econometricians. This existence of a first stage relationship is verifiable as a statistical matter. (Though as always, correlation does not imply causality. More on this below.)

- Write T_{jt} as the trade volume (in dollar terms, for example) of country j in year t.
- Again, imagine two counterfactual states for each country j, one in which it has Low $ASDD$ ($A = 0$) and the other if it has High $ASDD$ ($A = 1$).
- We know that between 1965 and 1995, air transport got considerably less expensive overall and simultaneously the air volume of U.S. trade increased considerably (Figure 1).
- Define the counterfactual change in trade volume between 1965 and 2005 in each country under $ASDD \in \{0, 1\}$ as

$$\Delta T_j \in \left\{\Delta T_j^1, \Delta T_j^0\right\}$$

- We require the following:

$$\Delta T_j^1 \geq \Delta T_j^0 \ \forall \ j,$$

  In words, country $j's$ trade volume must increase by more between time 0 and 1 if $ASDD$ is High than if $ASDD$ is low.

- Due to FPCI, this assumption is also not testable. We only see countries in one state—$ASDD$ is High or Low—or another.

- However, we can test one *necessary but not sufficient* condition for the validity of this relationship, which is:

$$E\left[\Delta T_j | A = 1\right] > E\left[\Delta T_j | A = 0\right].$$

  That is, the average growth in trade in the $A = 1$ countries must be greater than in the $A = 0$ countries.

- We can check this empirically by verifying that:

$$\frac{1}{n_{A=1}} \times \sum_{j,A=1} \Delta T_j > \frac{1}{n_{A=0}} \times \sum_{j,A=0} \Delta T_j,$$

  where $n_{A=1}$ is the number of countries with $A = 1$ and similarly for $n_{A=0}$

- Figure 3 of Feyrer suggests that this relationship holds in the data.

1.2.3 Exclusion restriction

- A valid instrumental variable must also satisfy an "Exclusion Restriction." The exclusion restriction says that the instrumental variable (here $ASDD$) must *only* affect the outcome variable of interest (here GDP) *indirectly* through its effect on the intermediating endogenous variable of interest (here, Trade).

- If we do *not* find it plausible that $ASDD$ *only* affects national income through its impact on trade, we cannot interpret any measured relationship between distance and income as the causal effect of trade on income.

- Conversely, if we find it plausible that $ASDD$ *only* affects national income through its impact on trade, we *can* interpret the measured relationship between distance and income as reflecting (though not identical to) the causal effect of trade on income.

- The exclusion restriction can be expressed formally as follows:

$$E\left[\Delta Y_j | \Delta T_j = k, A = 1\right] = E\left[\Delta Y_j | \Delta T_j = k, A = 0\right],$$

  where k is some constant.

- This equation says that if were were to hold trade in country j constant at a given level k, $ASDD$ would have no effect on GDP—since its entire effect operates through influencing trade. If, counterfactually, country j traded the same amount (k) with either $ASDD = 1$ or $ASDD = 0$, its GDP would be the same.

- This postulate is also *untestable*. We cannot manipulate *ASDD* for a given country, and moreover, if we could, this would also affect T_j (under our hypothesis above). Nevertheless, the exclusion restriction must be plausible or the IV strategy is a non-starter. So, if we believe that *ASDD* affects GDP through some other mechanism (e.g., *ASDD* increases a country's air traffic, and the smell of burning jet fuel makes citizens happier and more productive, raising GDP), then *ASDD* will not allow us to isolate the causal effect of trade on GDP.

1.3 Implementation

If we accept the conditions above, the empirical analysis proceeds as follows:

1. First we check for 'balance' of treated and untreated groups. We cannot compare balance of counterfactuals (due to FPCI), but we can confirm that there is no systematic cross-country relationship in 1960 (prior to 'treatment') between air freight usage and GDP per capita.

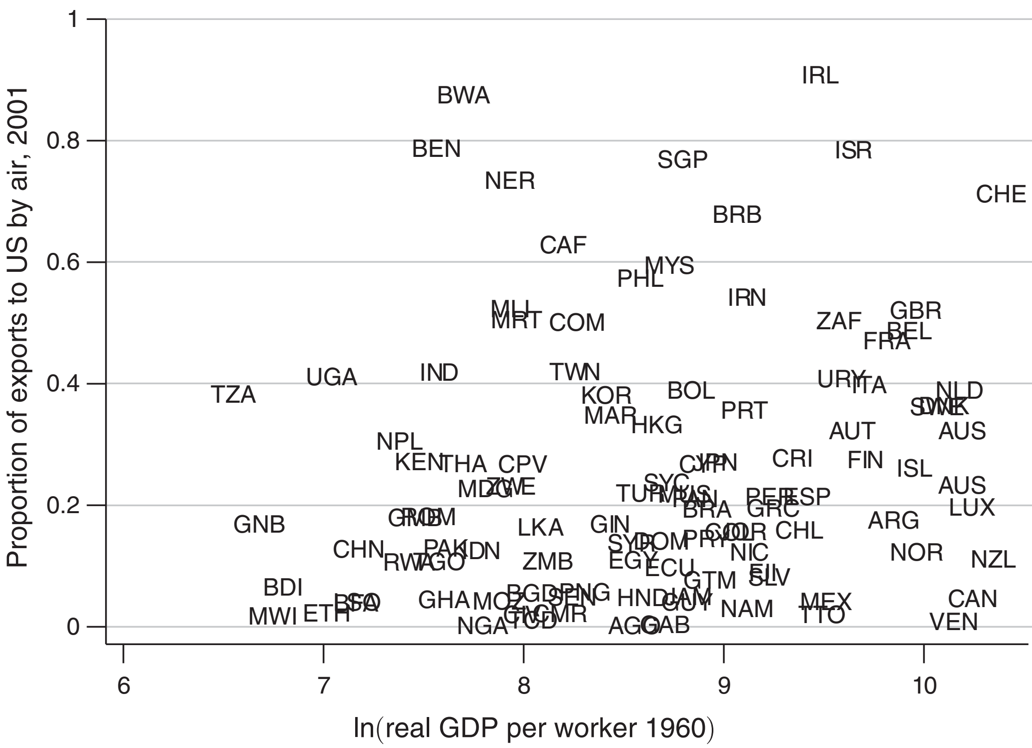


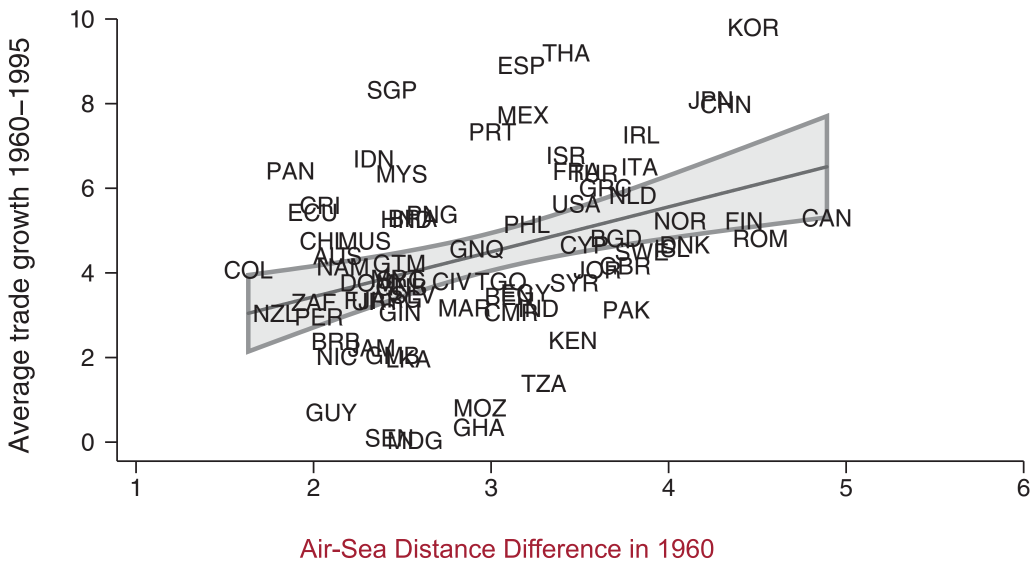
FIGURE 2. 2001 AIR IMPORTS TO THE UNITED STATES VERSUS 1960 GDP PER CAPITA

2. Second, we check that trade grows by more in $ASDD = 1$ than $ASDD = 0$ countries between times $t = 0$ and $t = 1$:

$$E[\Delta T_j | A = 1] > E[\Delta T_j | A = 0]$$

$$\text{or } \frac{1}{n_{A=1}} \times \sum_{j,A=1} \Delta T_j > \frac{1}{n_{A=0}} \times \sum_{j,A=0} \Delta T_j$$

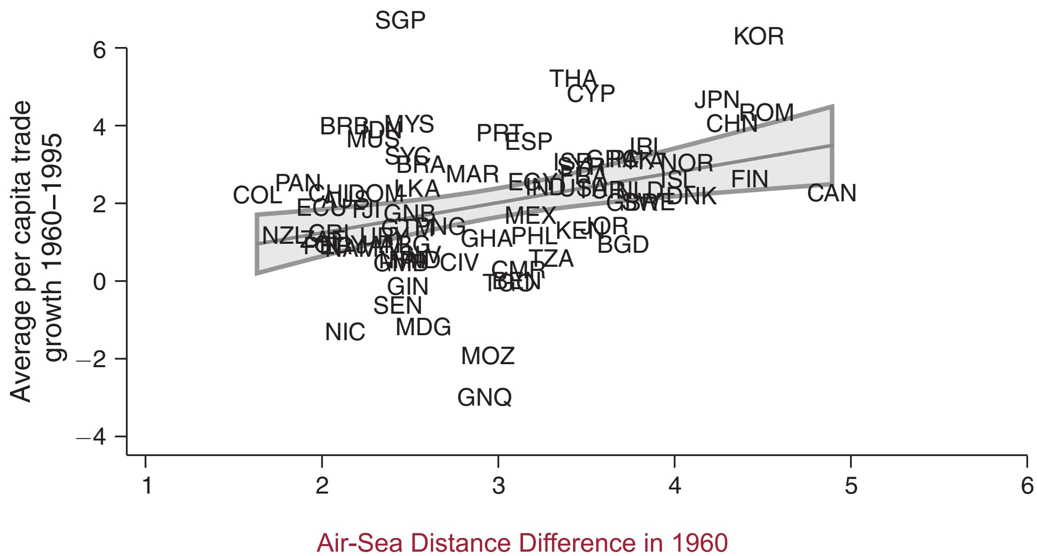
If this inequality is satisfied, then A is a candidate instrument for T. If this inequality is not satisfied, then our assumption that $[\Delta T_j | A = 1] > [\Delta T_j | A = 0] \;\; \forall \; j$ is false. Verifying the inequality above does not prove that the assumption is correct. But rejecting it would demonstrate that the assumption is false.



3. Next, we can test whether GDP rises by more over time (between $t = 0$ and $t = 1$) in $ASDD = 1$ versus $ASDD = 0$ countries. The hypothesis that trade raises income implies that

$$E\left[\Delta Y_j | A = 1\right] > E\left[\Delta Y_j | A = 0\right].$$

That is, having verified above that trade rises by more in $A = 1$ than $A = 0$ countries, GDP should also rise by more in $A = 1$ than $A = 0$ countries if trade raises GDP (and not if it does not). This is called the 'reduced form' estimate.



Let's say that these three relationships (balance, first stage, reduced form) are verified in the data. We might be correct to conclude that trade has a positive causal effect on national income. But we would not *yet* have an estimate of the *causal effect of trade on income*. Instead, we'd have estimates of the causal effect of $ASDD$ on trade and on income. We need to take one more step.

2 Estimating a causal relationship using the method of Instrumental Variables

- We want to estimate the causal effect of trade volumes on GDP. Let's write this as:

$$E\left[\Delta Y|\Delta T\right] = \alpha + \gamma \Delta T, \tag{1}$$

  where γ denotes the causal effect of trade on GDP. This is the parameter we'd like to estimate.

- We found that $ASDD$ is correlated with the change between 1960 and 1995 in the extent that a country trades, and given our assumptions above, we view this correlation as causal:

$$\pi_1 = E\left[\Delta T|A = 1\right] - E\left[\Delta T|A = 0\right] > 0$$

- We compare the change in the incomes of $ASDD$ High and Low countries.

$$\pi_2 = E\left[\Delta Y | A = 1\right] - E\left[\Delta Y | A = 0\right].$$

Here, π_2 is the causal effect of $ASDD$ (not trade) on GDP.

- That's a start, but we have not yet estimated γ, *the causal effect of trade on GDP*. If we had exogenous (as good as randomly assigned) variation in the change in trade that countries experienced, we could simply estimate equation (1) above, and $\hat{\gamma}$ would be our causal effect estimate.

- We cannot do that because the variation in trade that we observe is endogenous. Naively regressing ΔGDP on ΔT will tell us about the correlation between trade and GDP, but it will not provide an unbiased estimate of γ.

- It turns out that we *can* infer this causal relationship using the observed *causal* relationships between (1) $ASDD$ and ΔT, and (2) $ASDD$ and ΔY.

2.1 Instrumental variables algebra

Putting the pieces together:

- Causal effect of $ASDD$ on Trade:

$$\begin{aligned} E\left[\Delta T | A = 1\right] &= \alpha_1 + \pi_1 \\ E\left[\Delta T | A = 0\right] &= \alpha_1 \\ E\left[\Delta T | A = 1\right] - E\left[\Delta T | A = 0\right] &= \pi_1 \end{aligned} \tag{2}$$

- Causal effect of $ASDD$ on GDP growth:

$$\begin{aligned} E\left[\Delta Y | A = 1\right] &= \alpha_2 + \pi_2 \\ E\left[\Delta Y | A = 0\right] &= \alpha_2 \\ E\left[\Delta Y | A = 1\right] - E\left[\Delta Y | A = 0\right] &= \pi_2 \end{aligned} \tag{3}$$

- Substituting (2) and (3) into (1) gives us the expression for the causal effect of $ASDD$ on GDP growth:

$$\begin{aligned} E\left[\Delta Y|A=1\right]-E\left[\Delta Y|A=0\right] &= \pi_2 \\ &= \gamma\left(E\left[\Delta T|A=1\right]-E\left[\Delta T|A=0\right]\right) \\ &= \gamma\times\pi_1 \end{aligned}$$

  By implication

$$\pi_2=\gamma\times\pi_1.$$

- Thus, our estimate of π_2 is closely related to the causal effect of trade on GDP (γ) in equation (1) above. They only differ by a scalar: $\pi_2=\gamma\times\pi_1$.

- Combining our two causal effects estimates, π_1 and π_2, we can estimate the causal effect of trade on income:

$$\frac{E\left[\Delta Y|A=1\right]-E\left[\Delta Y|A=0\right]}{E\left[\Delta T|A=1\right]-E\left[\Delta T|A=0\right]}=\frac{\pi_2}{\pi_1}=\frac{\pi_1\times\gamma}{\pi_1}=\hat{\gamma}$$

- We thus estimate the causal effect of trade on income by taking the ratio of the two causal effects: the causal effect of $ASDD$ on GDP growth and the causal effect of $ASDD$ on trade growth. This ratio gives us $\hat{\gamma}$, our Instrumental Variables (IV) estimate of the causal effect of trade on GDP.

- Intuitively, we are comparing incomes among potentially similar countries that have different $ASDD$'s. This comparison gives us the causal effect of $ASDD$ on income growth ($\hat{\pi}_2=\gamma\times\pi_1$). We convert this number into an estimate of the causal effect of trade on income by re-scaling the GDP growth difference between high and low $ASDD$ countries by the causal effect of $ASDD$ on trade growth.

- [A bit of history: The IV method was developed in 1928 by the economist, P.G. Wright, who wanted to measure the causal effect of supply changes on the price of flaxseed. He used weather shocks as an exogenous source of variation in supply of flaxseed. Instrumental Variables has become central to causal empirical analysis in economics within the last two decades.]

3 Feyrer IV results (all in one table)

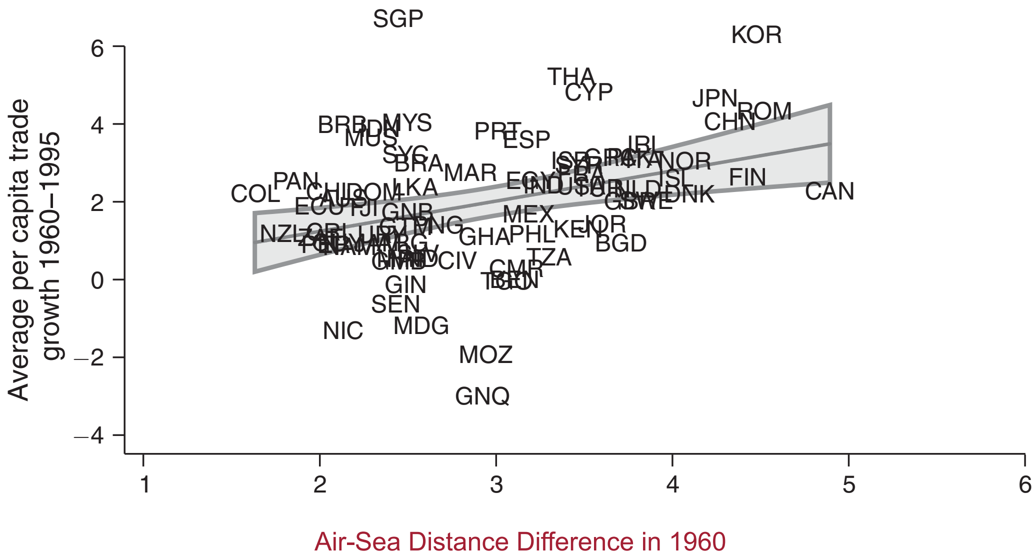


TABLE 4—PANEL ESTIMATES OF TRADE ON PER CAPITA GDP

	ln(real GDP per capita)		
	OLS (1)	Trade weight (2)	Pop weight (3)
ln(trade)	0.446	0.578	0.611
	(0.041)	(0.082)	(0.131)
R^2	0.965		
		ln(trade)	
First stage			
ln(predicted trade)		0.993	0.731
		(0.144)	(0.187)
Instrument F-statistic		47.22	15.29
First-stage R^2		0.975	0.972
Instrument-partial R^2		0.170	0.067
		ln(real GDP per capita)	
Reduced form			
ln(predicted trade)		0.573	0.446
		(0.116)	(0.130)
Reduced-form R^2		0.947	0.943
Instrument-partial R^2		0.118	0.052
Observations	774	774	774
Countries	101	101	101
Years	10	10	10

Notes: Standard errors are clustered by country. Regressions are on data at 5-year intervals from 1950 to 1995. Regressions include country and time dummies.

- The first column shows the Ordinary Least Squares (OLS) relationship between the change in GDP and the change in trade at the country level during 1960 - 1995 for 76 countries:

  $$\text{Column (1)}: \Delta \ln GDP_{j,60-95} = \alpha + \beta_1 \Delta \ln Trade_{j,60-95} + e_j.$$

  The point estimate of 0.446 implies that a 1% rise in trade is *associated with* a 0.45% rise in GDP (an elasticity of 0.45). You should not view this relationship as causal.

- The second and third column show the relationship between $ASDD$ and trade growth (middle panel), GDP growth (bottom panel), and the 2SLS estimate (top panel)

  $$\text{Column (2)}: \Delta \ln Trade_{j,60-95} = \alpha' + \pi_1 ASDD_j + e'_j,$$

  where Feyrer estimates that $\hat{\pi}_1 = 0.993$

- And

$$\text{Column (3)}: \; \Delta \ln GDP_{j,60-95} = \alpha'' + \pi_2 ASDD_j + e''_j,$$

where $\hat{\pi}_2 = 0.582$.

- Recall that $\hat{\pi}_2 = \gamma \times \pi_1$. Hence, we can calculate the causal effect of trade on GDP as:

$$\hat{\gamma} = \frac{\pi_1 \times \gamma}{\pi_1} = \frac{\hat{\pi}_2}{\hat{\pi}_1} = \frac{0.753}{0.993} = 0.582$$

- This is within rounding error of what Feyrer obtains in the top panel, where where $\hat{\gamma} = 0.573$. I've denoted the change in trade in this equation with an asterisk (ΔT^*_j) because this is *not* the endogenous trade variable available in the data. Rather, it is the exogenous component due to $ASDD$, which is found in column 2 of the Feyrer table.

- Thus, our causal estimate of the effect of trade on GDP is that a one percent rise in trade raises GDP per capita by six-tenths of a percentage point.