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14.03/003 Microeconomic Theory and Public Policy, Fall 2025

Lecture slides 15. Does trade raise national incomes? Measuring the gains from trade using the method of instrumental variables

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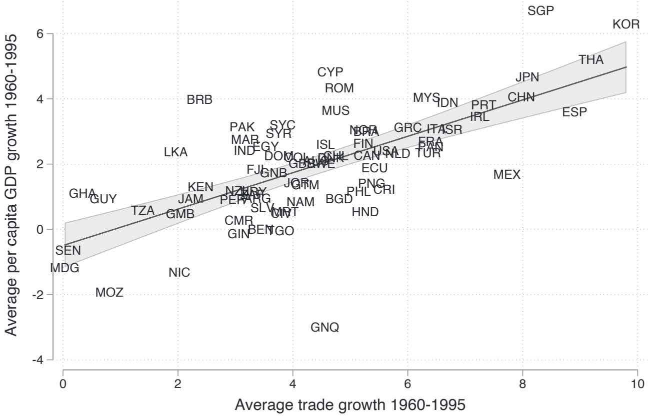
Does trade raise national income?

Trade and national income

- Theory clearly predicts that trade increases national income—that is, the bundle of goods and services a country can purchase
- Is the theory right?
- **Hard to conduct an experiment**: cannot readily manipulate the trade flows of various countries to study effect on national incomes

Trade and national income growth: What does this figure tell about the effect of rising trade on income per capita?

Figure 5: Average Per Capita GDP Growth versus Trade Growth 1960-1995



source: Penn World Tables 6.2, IMF Direction of Trade database.

Trade and national income

Cross country comparisons

What does this figure tell us about the causal effect of trade on national income? Probably not much

- The extent to which a country trades is endogenous
- 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*.

Trade and growth

Back to causal inference

- 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 income per capita, γ_j is the causal effect of trade on Y in country j (γ stands for Gains from trade), and the superscripts A and T signify Autarky and Trade

- **Fundamental Problem of Causal Inference** says that we cannot observe income per capita for country j both under both Autarky and free trade *simultaneously*

- Can readily calculate

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

  where $T \in \{0, 1\}$ indicates whether a country is open to free trade

- But $\hat{\gamma}$ is probably not a good estimate of γ^*

Trade and growth

What can we do instead?

We need an **“experiment”** that exogenously raises or lowers trade in some group of countries

- In the case of free trade, such experiments are difficult to find
- What about unexpected events that suddenly open or close a country to trade (for example, war, natural disaster, revolutionary overthrow)?
- Are these good quasi-experiments for this causal question?
- Problem: they are likely to cause *other* economic and policy shocks *in addition to trade* that also directly raise or lower real income

Instrumental Variables (IV) —

The big idea

Instrumental variables

- The difficulty of running an RCT or quasi-experiment motivates a subtle and powerful approach to identify causal effects: the **method of Instrumental Variables (IV)**
- **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
  1. Imagine hypothetically that there is some third variable $Z \in \{0, 1\}$ that affects the extent to which countries trade
  2. And this variable is *as good as randomly assigned* to countries. That is, 'treated' and 'untreated' countries are comparable/ exchangeable
  3. Finally, we suspect that Z affects national income—if it affects it at all—*only* through its effect on trade
- Under these assumptions, Z can serve as an "instrument" that exogenously manipulates trade, allowing us to study **trade's** causal effect on income

Instrumental variables: Core idea

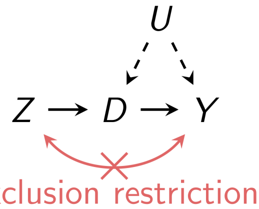
The world has randomized **something** —

but it's **not exactly the thing you want**

Under an exclusion restriction, you may be able to "exploit"

that available randomness and get (approximately) what you want anyway

IV: Core idea



- D is the treatment, Y is the outcome of interest, U is the unmeasured confounder (the source of endogeneity), and Z is the 'instrument'
- We would like to know the causal effect of D on Y. But U makes this a hard problem
- The instrumental variable setup is as follows
  1. We have a first-stage relationship: Z causally affects D
  2. We need an exclusion restriction: There is no effect of Z on Y that does *not* run through D
  3. Measure the reduced form relationship: the causal effect of Z on Y
  4. Estimate the causal effect of D on Y by comparing the causal effects of Z on D and Z on Y

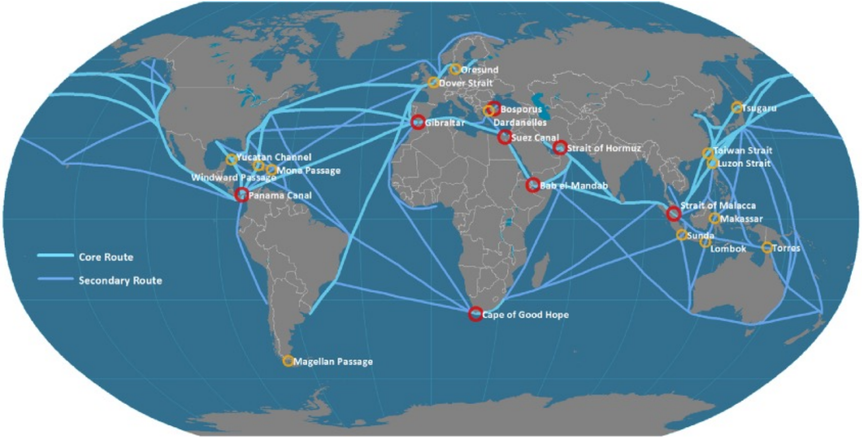
Feyer 2019 — An Instrumental Variables Approach to Measuring the Causal Effect of Trade on National Income

Feyrer 2019

An Instrument for trade

- James Feyrer's 2019 paper, "Trade and Income—Exploiting Time Series in Geography"
- Proposes an ingenious **Instrumental Variables (AKA, IV or 2SLS) approach** for analyzing the causal effect of trade on national per capita income
- **Insight**: Historically, most trade between non-contiguous countries occurred by sea
- As the cost of air freight fell over the last four decades, countries began shipping (some) goods by airplane rather than ship
- This cost decline differentially reduced the cost of trade for countries whose trading routes involved circumnavigating large land masses (i.e., continents)

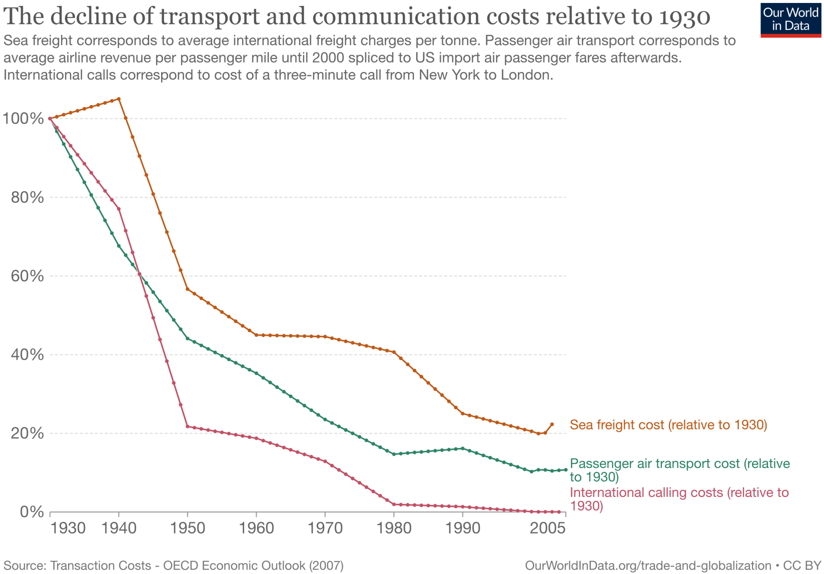
Major world shipping routes



Distance from Shenzen, China to Boston, U.S.

By sea: 11,321 nautical miles
By air: 7,943 nautical miles

Transport costs have plummeted: sea freight, air travel, telecoms



U.S. air freight volumes as a share of U.S. trade value, 1965 – 2005

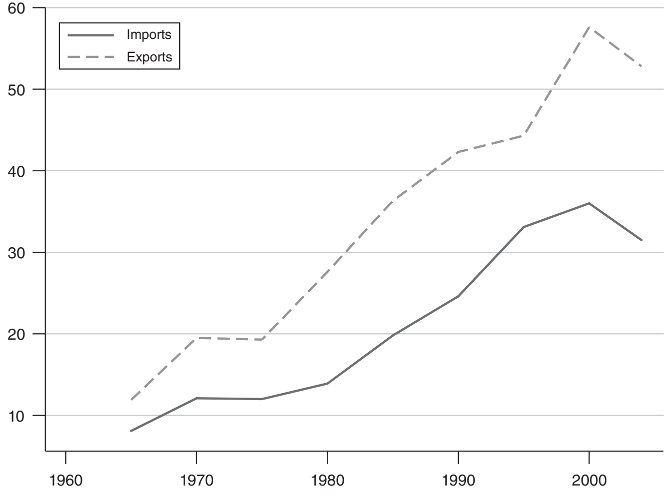


FIGURE 1. AIR FREIGHT SHARE OF US TRADE VALUE (EXCLUDING NORTH AMERICA)

Source: Hummels (2007, 133)

What gets shipped by air: Top 20 commodities

TABLE 1—TOP 20 HS2 TRADE CATEGORIES BY AIR

HS code	Description	Air import value (billion dollars)	Percent by air
85	Electrical machinery and equip. and parts, telecommunications equip., sound recorders, television recorders	64.97	42.0%
84	Machinery and mechanical appliances, including parts	64.26	39.8%
71	Pearls, stones, prec. metals, imitation jewelry, coins	23.03	88.1%
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and accessories	20.63	59.2%
29	Organic chemicals	20.28	63.9%
98	Agric., construction, trans., electric/gas/sanitary, eng. and mgmt. and envir. quality services	18.23	51.5%
30	Pharmaceutical products	12.37	77.6%
62	Articles of apparel, accessories, not knit or crochet	5.32	16.8%
97	Works of art, collectors pieces, and antiques	4.45	81.7%
61	Articles of apparel, accessories, knit or crochet	3.75	13.9%
88	Aircraft, spacecraft, and parts thereof	3.45	16.3%
95	Toys, games, and sports equip., parts & acces.	2.22	11.0%
91	Clocks and watches and parts thereof	2.07	68.0%
64	Footwear, gaiters and the like, parts thereof	1.61	10.6%
38	Miscellaneous chemical products	1.53	33.5%
42	Articles of leather, animal gut, harness, travel good	1.48	20.7%
87	Vechicles other than railway, parts and accessories	1.29	0.8%
39	Plastics and articles thereof	1.20	6.3%
82	Tools, implements, cutlery, spoons, and forks, of base metal and parts	1.11	25.8%
3	Fish, crustaceans, mollusks, aquatic invertebrates	0.93	11.8%

Source: US Census Bureau—US Imports of Merchandise (2001)

Trade flows have become increasingly sensitive to cost of air freight

They ***used to be*** *very sensitive to cost of sea freight.* ***Why is this relevant****?*

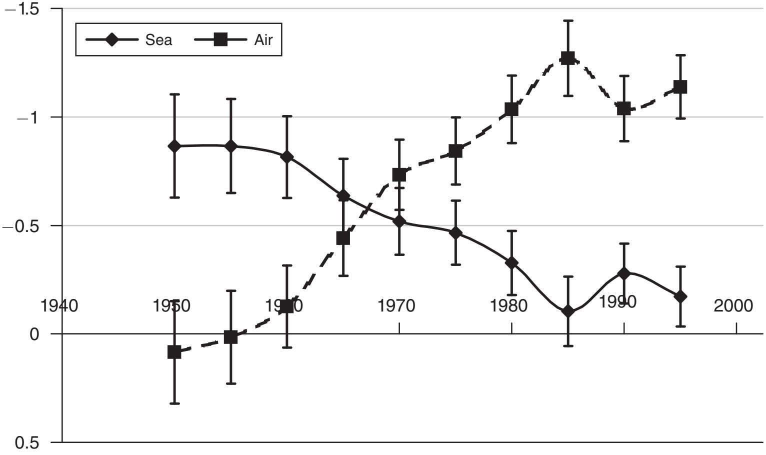


Figure 3. The Change in Elasticity of Trade with Respect to Sea and Air Distance over Time from a Gravity Regression with Country-Fixed Effects

Key measure: The Air-Sea Distance Difference (ASDD)

- Air-Sea Distance Difference $\boldsymbol{ASDD}$: difference between the distance of a country to its trading partners by air versus by sea
  - Let D_{jk}^S be the *sea distance* between countries j and k
  - Let D_{jk}^A be their *air distance*
  - Let $ASDD_{jk} = D_{jk}^S - D_{jk}^A$
  - If country j and k have nothing between them but water, then $ASDD_{jk} = 0$
  - If separated by land masses that a cargo ship must circumnavigate, then $ASDD_{jk} > 0$
  - Let T_{jk} is the trade volume between j and k in dollars in 1960
- Then

$$\overline{ASDD}_j = \left[\sum_k \left(D_{jk}^S - D_{jk}^A\right) \times T_{jk}\right] / \sum_k T_{jk}$$

- It's easiest to think of this as binary variable: $ASDD_j \in \{0, 1\}$, where $ASDD_j = 1$ implies country j has a large differential difference and $ASDD_j = 0$ implies the opposite

Key instrumental variables construct: The exclusion restriction

The exclusion restriction says

- Instrument $ASDD$ affects the outcome variable of interest *only* through its effect on the intermediating endogenous variable, ΔT
- This implies that conditional on ΔT_j, the value of A_j is irrelevant
- Can be expressed formally as follows, where c is some constant:

$$E\left[\Delta Y_j | \Delta T_j = c, A_j = 1\right] = E\left[\Delta Y_j | \Delta T_j = c, A_j = 0\right],$$

This postulate is <u>untestable</u>

- Cannot manipulate $ASDD$ for a given country, and moreover, if we could, this would also affect T_j (under our hypothesis above)
- The exclusion restriction must be plausible or the IV strategy is a non-starter

The exclusion restriction might be <u>falsifiable</u>

The ASDD idea — do we trust it?

Potential concerns

- $ASDD$ is not the *only* determinant of changing trading patterns
- U.S. began trading extensively with China in the 1990s but was trading extensively with Japan decades earlier
- That cannot be explained by air freight costs!

Is that a problem? *Not necessarily*. We require that:

1. $ASDD$ has a direct, measurable *causal* effect on trade
2. $ASDD$ does not plausibly affect national income through any other channel but trade

Putting IV to work — four steps

Putting IV to work: Four steps

1. Balance of treatment and control groups
2. First stage: Causal effect of the instrument ($ASDD$) on the endogenous variable (ΔT)
3. Reduced form: Causal effect of the instrument on the outcome variable ΔY
4. IV estimate: Causal effect of ΔT on ΔY

Step 1: Balance of treatment and control groups

Treatment and control groups must be comparable—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, two potential outcomes

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

where ΔY_j^1 is change in GDP in j if $A_j = 1$, ΔY_j^0 is change in GDP in j if $A_j = 0$.

We now face our standard exchangeability challenge

Step 1: Balance of treatment and control groups

- **Fundamental Problem of Causal Inference**
  - Each country j is one type or the other ($ASDD$ either High or Low, $A = 1$ or $A = 0$)
  - Cannot observe both ΔY_j^1 and ΔY_j^0
- **Nevertheless, this condition must be plausible — or it's a no-go**

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

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

No systematic relationship btwn air shipments ↔ GDP/worker in 1960

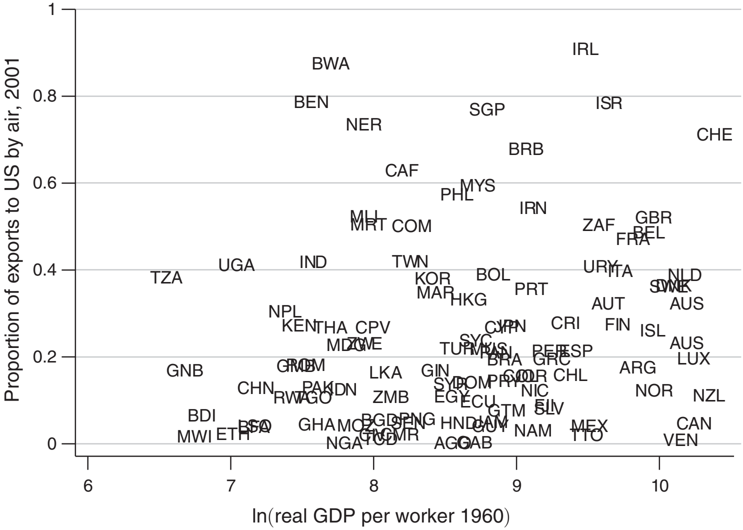


FIGURE 2. 2001 AIR IMPORTS TO THE UNITED STATES VERSUS 1960 GDP PER CAPITA

Step 2: Causal effect of instrument on endogenous variable

$ASDD$ must have a causal effect on a country's trade growth between 1960 and 1995

- Write T_{jt} as trade volume (in dollar terms, for example) of country j in year t
- Imagine two counterfactual states for each country j, one in which it has Low $ASDD$ ($A = 0$) and the other if it has High $ASDD$ ($A = 1$)
- 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:

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

- **This is *partially* testable**

Step 2: Causal effect of instrument on endogenous variable

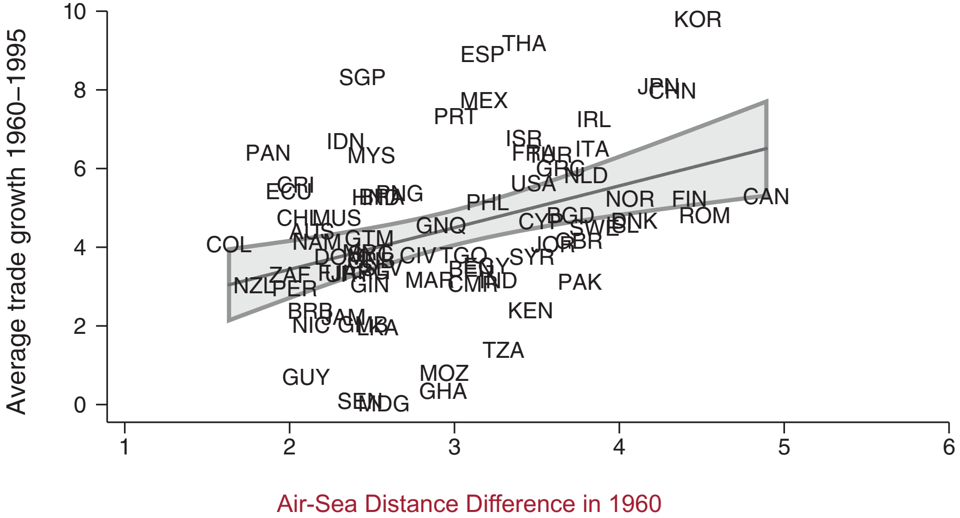
Country $j's$ trade must increase by more if $ASDD_j = 1$ than if $ASDD_j = 0$

- Due to the Fundamental Problem of Causal Inference, this assumption is not directly testable
- We see countries in only one state: $ASDD \in \{0, 1\})$
- We can test one *necessary but not sufficient* condition:

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

- Average growth in trade in the $A = 1$ countries must be greater than in the $A = 0$ countries

First Stage: $\Delta TRADE$ 1960–1995 vs. Air-Sea Distance Difference 1960



Step 2: Estimating the causal effect of trade on GDP

1. Let's write the causal effect of ΔT on ΔY as

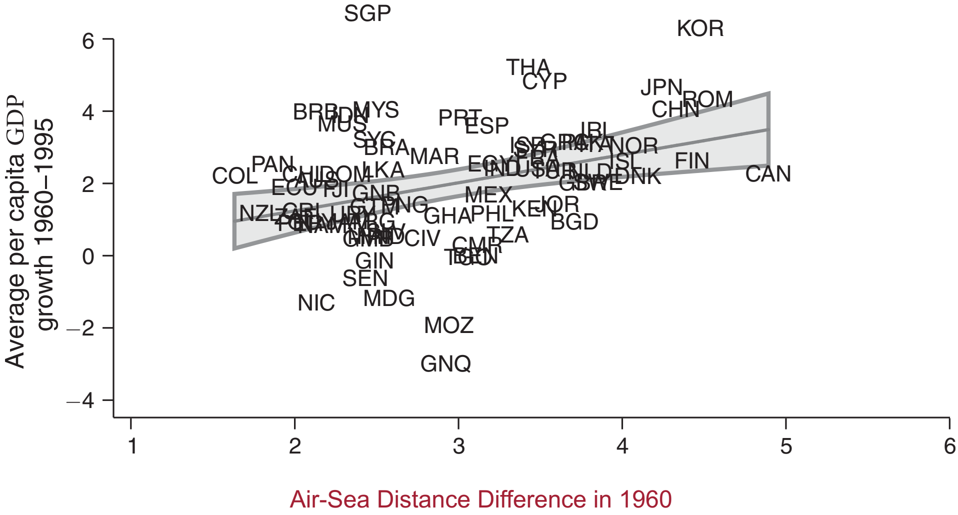
$$E\left[\Delta Y_j | \Delta T_j\right] = \alpha + \gamma \Delta T_j$$

2. We estimated the causal effect of $ASDD$ on ΔT between 1960 and 1995 (first stage)

$$\pi_1 = E\left[\Delta T_j | A_j = 1\right] - E\left[\Delta T_j | A_j = 0\right] > 0$$

Step 3: The reduced form relationship between $ASDD$ and ΔY

Reduced form: ΔGDP 1960–1995 v. Air-Sea Distance Difference 1960



Step 3: Estimating the causal effect of trade on GDP

1. Let's write the causal effect of ΔT on ΔY as

$$E\left[\Delta Y_j | \Delta T_j\right] = \alpha + \gamma \Delta T_j$$

2. We estimated the causal effect of $ASDD$ on between 1960 and 1995 (first stage)

$$\pi_1 = E\left[\Delta T_j | A_j = 1\right] - E\left[\Delta T_j | A_j = 0\right] > 0$$

3. We compared change in incomes of $ASDD$ High and Low countries (second stage)

$$\pi_2 = E\left[\Delta Y_j | A_j = 1\right] - E\left[\Delta Y_j | A_j = 0\right].$$

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

Step 4: The causal effect of trade on GDP — Instrumental Variables estimates

Step 4: Estimating the causal effect of trade on GDP

We have estimated the causal effect of ΔT on ΔY

- We've estimated the causal effect of $ASDD$ on ΔY – not quite what we are after
- We believe that causal effect operates through $ASDD's$ causal effect on ΔT
- We therefore need one more step to get that causal relationship

Step 4: Estimating the causal effect of trade on GDP

1. Let's write the causal effect of ΔT on ΔY as

$$E\left[\Delta Y_j | \Delta T_j\right] = \alpha + \gamma \Delta T_j$$

2. We estimated the causal effect of $ASDD$ on between 1960 and 1995 (first stage)

$$\pi_1 = E\left[\Delta T_j | A_j = 1\right] - E\left[\Delta T_j | A_j = 0\right] > 0$$

3. We compared change in incomes of $ASDD$ High and Low countries (second stage)

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

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

Step 4: Estimating the causal effect of trade on GDP

We have one more step left...

1. We estimated the causal effect of $ASDD$ on between 1960 and 1995 (first stage)

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

2. We compared change in incomes of $ASDD$ High and Low countries (second stage)

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

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

3. Now, **estimate** $\hat{\gamma}$ using the estimated *causal* relationships between (1) $ASDD$ and ΔT, and (2) $ASDD$ and ΔY

Step 4 Estimating the causal effect of trade on GDP: IV method

1. Causal effect of $ASDD$ on Trade

$$\begin{aligned}
E\left[\Delta T_j | A_j = 1\right] &= \alpha_1 + \pi_1 \\
E\left[\Delta T_j | A_j = 0\right] &= \alpha_1 \\
E\left[\Delta T_j | A_j = 1\right] - E\left[\Delta T_j | A_j = 0\right] &= \pi_1
\end{aligned}$$

2. Causal effect of $ASDD$ on GDP growth

$$\begin{aligned}
E\left[\Delta Y_j | A_j = 1\right] &= \alpha_2 + \pi_2 \\
E\left[\Delta Y_j | A_j = 0\right] &= \alpha_2 \\
E\left[\Delta Y_j | A_j = 1\right] - E\left[\Delta Y_j | A_j = 0\right] &= \pi_2
\end{aligned}$$

3. Substituting gives us expression for the causal effect of $ASDD$ on GDP

$$\begin{aligned}
E\left[\Delta Y_j | A_j = 1\right] - E\left[\Delta Y_j | A_j = 0\right] &= \pi_2 \\
&= \gamma \left(E\left[\Delta T_j | A_j = 1\right] - E\left[\Delta T_j | A_j = 0\right]\right) \\
&= \gamma \times \pi_1 \\
\boldsymbol{\pi_2} = &\ \boldsymbol{\gamma \times \pi_1 \longrightarrow \gamma = \pi_2 / \pi_1}
\end{aligned}$$

IV Algebra: Closing the loop

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

$$\frac{E\left[\Delta Y_j | A_j = 1\right] - E\left[\Delta Y_j | A_j = 0\right]}{E\left[\Delta T_j | A_j = 1\right] - E\left[\Delta T_j | A_j = 0\right]} = \frac{\pi_2}{\pi_1} = \frac{\pi_1 \times \gamma}{\pi_1} = \hat{\gamma}$$

- We thus estimate the causal effect of trade on income by **taking the ratio of the two causal effects**

Instrumental Variables Estimates

The causal effect of trade on income: Key results

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.