

Trade and Growth

Introduction I

- In the models thus far each country is treated as an “island”; its technology is generated within its boundaries
- A framework in which frontier technologies are produced in advanced economies and then copied or adopted by “follower” countries provides a better approximation
- Thus, should not only focus on differential rates of endogenous technology generation but on technology adoption
- Exogenous growth models have this feature, but technology is exogenous
- Technology adoption involves many challenging features:
 - Even within a single country, we observe considerable differences in the technologies used by different firms
 - It is difficult to explain how in the globalized world some countries may fail to import and use technologies

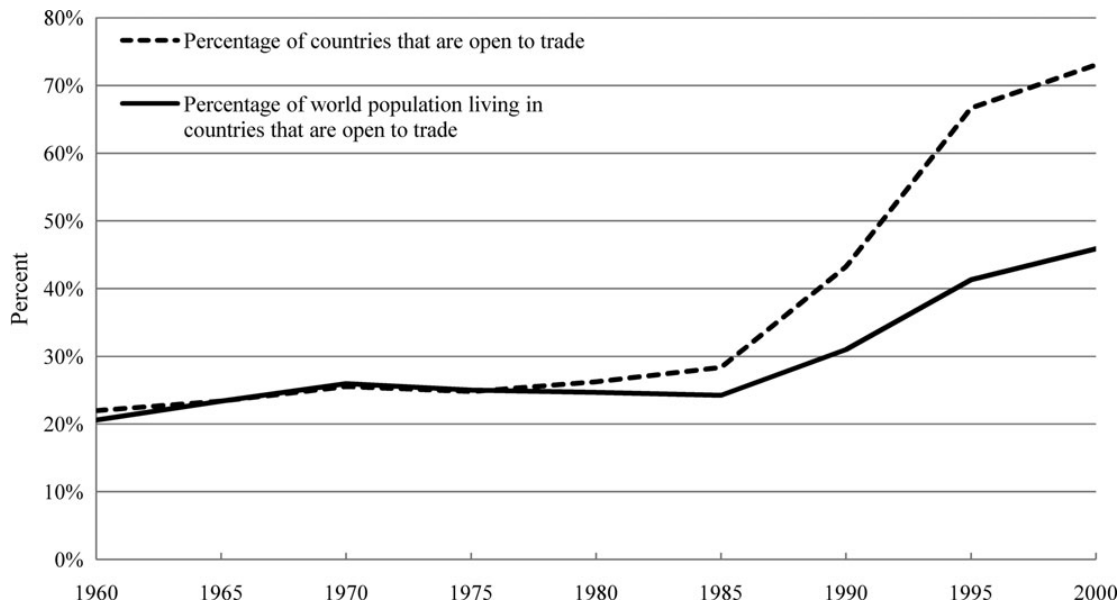
Productivity Differences within Narrow Sectors

- Micro-data studies: even within a narrow sector there are significant and persistent productivity differences across plants
- Little consensus on the causes
 - Correlation between plant productivity and plant size, various measures of technology, capital intensity
 - A key determinant seems to be the skill level of the workforce
 - Although these correlations cannot be taken to be causal
- Productivity differences appear to be related to the entry of new and more productive firms and the exit of less productive ones (recall Schumpeterian models)
- But entry and exit account for only about 25% of average TFP growth, with the remaining accounted for by continuing firms
- Thus models in which firms continually invest in technology are important for understanding differences across firms and countries

Technology Diffusion

- Despite technology and productivity differences among firms, cross-sectional distributions of productivity are not stationary
- New and more productive technologies diffuse over time
- Griliches's (1957) study of the adoption of hybrid corn in the US (findings confirmed by others):
 - Slow diffusion affected by local economic conditions
 - Likelihood of adoption in an area related to the market size and the skill level
- Important lessons:
 - Differences are not only present across countries, but also within countries
 - Even within countries better technologies do not immediately get adopted by all firms
- But causes of within-country and cross-country productivity and technology differences might be different: ability?

FIGURE 1. Openness to Trade, 1960–2000 *Note:* Openness is defined according to the Sachs and Warner (1995) criteria. Sample includes 141 countries.



Source: Authors' analysis based on data described in the text.

Technology Transfers and Cross-Country Convergence

World average technology level

$$A_{\tau}^* = e^{g\tau}$$

Let A_t denote the economy's productivity, and assume

$$A_{t+1} = F(A_t, A_{\tau}^*)$$

where

- F is increasing in both arguments
- $\gamma_{i,t+1} = A_{t+1}/A_t = F(A_t, A_{\tau}^*)$ is the size of an innovation in country i
- $F(A, A) = \gamma \cdot A$, where $\gamma > 1$

A country with $A_t < A_\tau^*$ achieves innovations of size greater than average

$$\frac{F(A_t, A_\tau^*)}{A_t} > \gamma$$

since $F(A_t, A_\tau^*) > F(A_t, A_t) = \gamma A_t$

A country with $A_t > A_\tau^*$ makes innovations of size less than γ

$$\frac{F(A_t, A_\tau^*)}{A_t} < \gamma$$

since $F(A_t, A_\tau^*) < F(A_t, A_t) = \gamma A_t$

Thus the further below its steady-state path A_τ^* a country is, the faster it will grow

Problem: There is no evidence of technological catch-up for all countries!

Technology Transfers versus Trade in Goods

Devereux and Lapham (1994)

Recall Romer (1990)

$$Y = H_1^\alpha L^\beta \int_0^A x_i^{1-\alpha-\beta} di = AH_1^\alpha L^\beta x^{1-\alpha-\beta}$$

$$\dot{A} = zH_2A \quad \text{and} \quad H = H_1 + H_2$$

Then

$$x_i = x \quad \Rightarrow \quad g = \frac{\dot{A}}{A} = zH_2$$

$$P_A = \frac{\pi}{r}$$

Labour market clearing

$$w_1 = \alpha x^{1-\alpha-\beta} L^\beta H_1^{\alpha-1} A = w_2 = zAP_A$$

and in equilibrium

$$g^{\text{autarky}} = z(H - H_1) = zH - \theta r$$

Flows of ideas

Two identical countries except for varieties, with $A = A^*$

The set of ideas used in research increases

$$\dot{A} = \dot{A}^* = zH_2(A + A^*) = 2zH_2A$$

The productivity of researchers doubles, while that in manufacturing is unaffected

Hence

$$H_1 = \frac{\theta r}{2z}$$

and

$$g^{trade} = 2zH - \theta r > g^{autarky} = zH - \theta r$$

Trade in Goods

Labour market equilibrium conditions

$$\alpha H_1^{\alpha-1} L^\beta \left(\int_0^A x_i^{1-\alpha-\beta} di + \int_0^{A^*} x_j^{1-\alpha-\beta} dj \right) = z A P_A$$
$$\alpha H_1^{*\alpha-1} L^\beta \left(\int_0^A x_i^{*1-\alpha-\beta} di + \int_0^{A^*} x_j^{*1-\alpha-\beta} dj \right) = z A^* P_A^*$$

We can show that prices for intermediaries are the same in both countries, and that the amount of each intermediary produced is

$$x_i = x_j = x = X(H_1)$$
$$x_i^* = x_j^* = x^* = X(H_1^*)$$

Patent royalties are

$$P_A = P_A^* = \frac{\pi + \pi^*}{r}$$

The labour market conditions can be written as

$$\alpha H_1^{\alpha-1} L^\beta x^{1-\alpha-\beta} \frac{A + A^*}{A} = z P_A$$

$$\alpha (H_1^*)^{\alpha-1} L^\beta (x^*)^{1-\alpha-\beta} \frac{A + A^*}{A^*} = z P_A$$

Substituting for x and x^* , the labour market conditions become

$$H_1 = B \left(\frac{1}{\mu} \right)^{(\alpha+\beta)/\beta}$$

$$H_1^* = B \left(\frac{1}{1-\mu} \right)^{(\alpha+\beta)/\beta}$$

where $\mu \equiv A/(A + A^*)$ and B a constant

Symmetric equilibrium

Suppose $A^* = A$, then $\mu = 1/2$

Since

$$H_1 = B \left(\frac{1}{\mu} \right)^{(\alpha+\beta)/\beta} \quad \text{and} \quad H_1^* = B \left(\frac{1}{1-\mu} \right)^{(\alpha+\beta)/\beta}$$

so

$$H_1^* = H_1$$

Return to labour in both sectors doubles

$$\begin{aligned} 2A\alpha H_1^{\alpha-1} L^\beta x^{1-\alpha-\beta} &= Az \frac{2\pi}{r} \\ 2A^*\alpha (H_1^*)^{\alpha-1} L^\beta (x^*)^{1-\alpha-\beta} &= A^* z \frac{2\pi^*}{r} \end{aligned}$$

Thus $\Rightarrow H_2$ and g are not affected

Asymmetric equilibrium

Now suppose that $A^* > A$. Then

$$\mu < \frac{1}{2} \Rightarrow H_1^* < H_1$$

What is the long-run equilibrium?

Since A^* grows faster than A , over time, $\eta \rightarrow 0$. Hence

$$H_1 = H$$

$$(H_1^*)^{\beta/(\alpha+\beta)} \left(H^{\alpha/(\alpha+\beta)} + (H_1^*)^{\alpha/(\alpha+\beta)} \right) = \frac{\theta r}{z}$$

where

$$H_1^* < \frac{\theta r}{z}$$

Then

$$g^{trade} = z(H^* - H_1^*) > g^{autarky} = zH - \theta r$$

Implications

- Main effect captured is a version of market size effect, leading to the innovation gains from trade
 - with fixed research costs, larger market \rightarrow higher profits and hence greater incentives to innovate
 - reasonably robust to other specifications
- Caveats:
 - If the R&D sector competes with production, there will be powerful offsetting effects, because trade will also increase the demand for production workers
 - If the full scale effect is removed and we focus on an economy with semi-endogenous growth, trade opening will increase innovation temporarily, but not in the long run

Imitation and Product Cycles

Krugman (JPE 1979) and Grossman and Helpman (Innovation and Growth in the Global Economy, MIT Press 1991, chapter 11)

- Product cycle: new products are invented in the North (and initially produced there) and then imitated by the South (and production shifts to this area)
- North has higher wages than South
- Innovation and imitation take the form of increasing product variety
- Can have one or many countries within each group
- Free international trade: no trading costs
- These are models about the international division of labour

Product Cycles I (Krugman)

North

The only input in the production of final goods are tradeable intermediate goods,

$$Y^N = \int_0^{A^N} x_j^\alpha dj,$$

where A^N is the number of varieties produced in the North

To produce one unit of the intermediate good, one unit of labour is required, which receives a wage w^N

New varieties are discovered according to

$$\dot{A} = zA,$$

where A is total number of varieties already discovered

South

Same production functions for final and intermediate goods, and it produces A^S varieties

Then

$$Y^S = \int_0^{A^S} x_j^\alpha dj$$

It does not innovate

Instead, it can imitate some of the goods already discovered in the North, according to the following function

$$\dot{A}^S = mA^N$$

where $m \equiv \dot{A}^S / A^N$ is the rate of imitation

The wage cost in the South is $w^S < w^N$

Consumers

They have the same utility function in the North and the South

$$U = \int_0^{\infty} \log c_t \cdot e^{-\rho t} dt$$

The supplies of labour in each country are given and are L^N and L^S , respectively

Trade

The price of the final good is one in both countries

Intermediate goods are traded

Output

We have $Y^N = A^N x^\alpha$ and $Y^S = A^S x^\alpha$

The steady state

In a steady state, the number of varieties manufactured by the two countries grow at the same rate, g

Denote the share of each country in the total number of products as

$$\mu^i \equiv \frac{A^i}{A}, \quad i = N, S$$

Let

$$g = \frac{\dot{A}}{A} \quad \text{and} \quad g^i = \frac{\dot{A}^i}{A^i}$$

Since $A = A^S + A^N$, we have

$$g = \mu^S g^S + \mu^N g^N$$

It follows that

$$g = g^S = g^N = z$$

Now

$$\mu^S A = A^S$$

Differentiating with respect to time

$$\dot{\mu}^S A + \mu^S (\dot{A}^N + \dot{A}^S) = \dot{A}^S$$

In steady state

$$\dot{\mu}^S = 0$$

thus

$$\mu^S = \frac{\dot{A}^S / A^N}{\dot{A}^S / A^N + \dot{A}^N / A^N} = \frac{m}{m + z}$$

Implications

- What does this steady state look like?
 - The rate of growth is constant and exogenous and the share of goods produced by each country is constant
 - The structure of trade remains unchanged: North always exports new products and imports old products
 - But the actual goods involved continually change: Each good is first produced in and exported by North; then the industry moves to the lower wage country
- The greater the rate of imitation is, the larger the share (and the relative income) of the South
- The growth rate is unaffected by imitation
- Krugman's analysis has limited policy implications because both the rate of innovation and of imitation are exogenous
- The new growth theories can be used in this framework to examine what determines them

Product Cycles II (Grossman and Helpman)

North

As before but growth is endogenous

Let L_1^N denote the level of employment in the Northern intermediate goods sector

New varieties are discovered according to

$$\dot{A} = zL_2^N A$$

South

The South can imitate according to

$$\dot{A}^S = \eta L_2^S A^N$$

The wage cost in the South is w^S

Solving the model

Can solve the model like Romer's model

Crucial equations: arbitrage and asset equations

In the South

$$V^S = \frac{w^S}{\eta A^N} \quad \text{and} \quad V^S = \frac{\pi^S}{r^S}$$

In the North

$$V^N = \frac{w^N}{zA} \quad \text{and} \quad V^N = \frac{\pi^N}{r^N + \dot{A}^S/A^N}$$

The steady state

In a steady state, the number of varieties manufactured by the two countries grow at the same rate, g

As before

$$\mu^S = \frac{\dot{A}^S/A^N}{\dot{A}^S/A^N + \dot{A}^N/A^N} = \frac{m}{m + g}$$

But g and m are now endogenous

We obtain

$$g = (1 - \alpha)\eta L^S - \alpha\rho$$

and

$$m = g \frac{(1 - \alpha)(\eta L^S - zL^N)}{\alpha\rho - (1 - \alpha)(\eta L^S - zL^N)}$$

Remarks

- The growth rate is determined by parameters in the South, not by those in the country that innovates
- The greater the capacity to imitate in the South (as determined by the parameter η and the labour supply), the faster technological change is, as Northern firms have to keep inventing new products in order not to be driven out of the market by the lower-cost Southern firms
- The rate of imitation itself depends on labour supplies and the productivity of researchers in both economies
- Conclusion 1: imitation increases growth!
- Conclusion 2: intellectual property right (IPR) protection
 - Consider η an inverse measure of IPR
 - Stronger IPR increases income gap between North and South
 - But it also reduces growth
 - Overall welfare effect on the North ambiguous

Learning by Doing and Comparative Advantage

Young (1991)

- Popular argument, used to justify infant industry protection:
 - Static gains come at the cost of dynamic losses
 - International trade induces some countries to specialize in industries with relatively low growth potential
 - The mechanism for potential dynamic losses is learning-by-doing externalities in some sectors
- Model of **bounded** learning by doing
- Ricardian model: trade is driven by differences in technology rather than in endowments
- Two countries, North and South
- Assume all countries are “almost identical”
- Thought experiment: move from autarky to full international trade

Production

- Two economies, A and B .
- Single factor: skilled labor
- CRS technology and perfect competition
- Both economies may produce any one of an infinite number of goods $s \in [0, \infty)$
- s denotes increasing technological sophistication
- Technologies differ in the unit labour requirements
 - more sophisticated goods have lower *potential* unit labour requirement
 - but higher *actual* unit labour requirement when first introduced

Potential unit labour requirements

$$\bar{a}(s) = \bar{a}.e^{-s}$$

Actual unit labour requirements

$$a(s, t) = \begin{cases} \bar{a}.e^{-s} & \text{for all } s \leq S(t) \\ \bar{a}.e^{s-2S(t)} & \text{for all } s > S(t) \end{cases} ,$$

$S(t)$ - the most sophisticated good for which all l.b.d has been exhausted

Equivalent to the stock of knowledge

Externality: Knowledge acquired through l.b.d spillovers across all goods

$$\frac{dS(t)}{dt} = \int_{S(t)}^{\infty} L(s, t) ds$$

Consumption

$$U_t = \int_t^{\infty} e^{-\rho(\tau-t)} \cdot u_{\tau} \cdot d\tau$$

where

$$u_{\tau} = \int_0^{\infty} \log [c(s, \tau) + 1] ds,$$

- Perfect competition

$$p(s, t) = a(s, t) \cdot w(t)$$

- Consume only a limited range of goods
- Goods are symmetrically located around $S(t)$, since $p(S(t), t)$ is the lowest price at t
- Goods consumed go from $M(t) \leq S(t)$ to $N(t) \geq S(t)$

The closed economy

Growth is given by cost reduction and we can show that

$$g = \text{average} \left\{ -\frac{da(s, t) / dt}{a(s, t)} \right\} = \frac{1}{2} \cdot 2\dot{S}(t) = \frac{L}{2}$$

Trade in goods

- International trade *without* spillovers of ideas
- Two economies, identical except for \bar{L} and the stock of technological knowledge $S(t)$
- Let $S^A - S^B > 0$
- Let the relative wage be $\omega = w^A/w^B > 1$
- Good s is produced in the LDC only if

$$a^B(s) < \omega \cdot a^A(s)$$

Structure of trade

For an intermediate wage gap between the two countries we have

- Prices
 - For $s \geq S^A(t)$ lower cost in A than in B
 - Other goods are cheaper in country B
- Production
 - Goods $s < S^A(t)$ are produced in country B
 - Goods $s \geq S^A(t)$ are produced in A
- So A is only producing goods in which there is learning potential while B is producing both goods with and goods without learning potential

General results emerge

- Developed economy always produces a more sophisticated set of goods than less developed country
- Growth rates
 - For the developed economy the free-trade growth rate is always as great or greater than that under autarky
 - For the developing economy the free-trade growth rate is never greater than that under autarky and may be lower
- There are winners and losers!
- International trade can harm when there are learning-by-doing externalities

Summing up so far

- Effect of trade on growth is empirical issue
- The benefits of greater market size for firms involved in innovation must be present according to any model of endogenous technological change
- But the effect of trade integration on the rate of endogenous technological progress may be limited because of 'incorrect specialization'
- Caveats
 - Learning-by-doing externalities are much more important in some sectors than in others
 - In most situations specialization is not perfect, thus some amount of learning-by-doing takes place in all economies
 - Flows of information imply productivity gains in countries that were not initially specializing in those sectors (e.g., Korea was an importer of cars, and now a net exporter)

Empirical evidence I

- Most believe trade promotes growth
- Dollar (1992) and Sachs and Warner (1995): positive correlation between openness and growth
- Skeptics:
 - Rodrik (1997) and Rodriguez and Rodrik (1999): empirical evidence that trade promotes growth is weak
 - Young (1993): models in which international trade can slow down growth in some countries
 - Standard measure is endogenous
 - Sachs-Warner's measure is binary and thus too crude!

Empirical evidence II

- Openness was initially measured as

$$Open = \frac{\text{exports+imports}}{GDP}$$

- This measure performed badly in regressions
- Problem of endogeneity
- The Sachs-Warner Criteria: we should measure policy variables not outputs
 - Dummy variable for openness based on five individual dummy variables for trade-related policies
 - A country was classified as closed or as open

Empirical evidence III

- Sachs-Warner Criteria: A country was classified as closed if it displayed at least one of the following characteristics:
 1. Average tariff rates of 40 percent or more (TAR)
 2. Nontariff barriers covering 40 percent or more of trade (NTB)
 3. A black market exchange rate at least 20 percent lower than the official exchange rate (BMP)
 4. A state monopoly on major exports (XMB)
 5. A socialist economic system (SOC)
- But evidence was weak
- Policy measure not well correlated with outcome measures (OPEN)

Empirical evidence IV

- Recent micro evidence supports an effect of trade
- Exporting firms
 - Bernard and Jensen (1997), Bernard, Eaton, Jensen and Kortum (2004)
 - Firms that engage in exporting are typically more productive
 - Might be “learning by exporting” but could be selection (Melitz, 2003)
- Importing firms
 - Firms in developing countries that import machinery from advanced economies more productive
 - Goldberg and Pavnik, 2007

Empirical evidence V

- New evidence from Wacziarg and Welch (World Bank Ec. Review 2008)
- Create a policy measure from a variety of dummies that is continuous
- Is it well correlated with openness?
- Consider both direct and indirect effects
 - Impact on growth controlling for investment
 - Impact on investment

TABLE 3. Replication of Sachs-Warner Cross-sectional Regressions

Variable	(1) Growth 1970–89	(2) Growth 1989–98	(3) Growth 1970–80	(4) Growth 1980–89	(5) Growth 1989–98
Real GDP per capita (t)	-1.5929 (4.89)	-1.150 (1.95)	-1.292 (2.83)	-1.397 (3.84)	-1.261 (2.13)
Sachs-Warner openness dummy variable(1970–89 or 1990–98 periods)	1.9845 (3.87)	0.136 (0.21)			
Openness status based on liberalization dates (t)			1.387 (1.86)	2.574 (4.17)	0.521 (0.84)
Secondary-school enrollment rate (t)	0.8059 (0.68)	4.689 (2.43)	0.169 (0.10)	1.822 (1.40)	4.872 (2.52)
Primary-school enrollment rate (t)	1.4003 (1.65)	1.381 (0.86)	2.455 (2.01)	-0.139 (0.11)	1.616 (0.99)
Government Consumption to GDP ratio ($t, t + X$)	-0.0844 (3.02)	-0.063 (1.32)	-0.005 (0.19)	-0.065 (2.51)	-0.059 (1.26)
Number of revolutions per year ($t, t + X$)	-0.4359 (0.58)	-0.986 (1.08)	-1.238 (1.12)	-0.211 (0.21)	-1.030 (1.13)
Number of assassinations per capita per year ($t, t + X$)	0.0296 (0.13)	0.483 (1.56)	0.276 (0.94)	0.188 (0.54)	0.473 (1.54)
Deviation of the price level of investment (t), as in Sachs-Warner	-0.1709 (0.53)	-0.734 (1.24)	-0.476 (0.99)	0.350 (0.87)	-0.721 (1.23)
Gross domestic investment/ real GDP ($t, t + X$)	0.0757 (2.64)	0.051 (1.01)	0.076 (2.02)	0.103 (2.30)	0.040 (0.76)
Extreme political repression (from Sachs-Warner)	-0.6974 (1.66)	0.165 (0.28)	-0.907 (1.47)	-0.780 (1.51)	0.224 (0.38)
Population density ($t - 10$)	0.0006 (0.90)	0.0009 (1.40)	0.001 (0.60)	0.001 (0.87)	0.001 (1.49)
Intercept	12.2482 (4.87)	7.752 (1.81)	9.334 (2.84)	10.635 (3.86)	8.288 (1.92)
Adjusted R^2	0.546	0.211	0.35	0.53	0.32
Number of observations	91	89	99	97	89

Note: Numbers in parentheses are t -statistics. The beginning date of each period (1970 in columns 1 and 3, 1980 in column 4, and 1989 in columns 2 and 5) is denoted by t . ($t, t + X$) denotes the average computed between dates t and $t + X$ ($X = 20$ in column 1 and 10 in columns 2–5). The dependent variable is defined as the real annual per capita growth rate of GDP in the relevant period.

Source: Authors' analysis based on data described in the text. Growth, income, and investment data are from Heston, Summers and Aten (2002).

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Number of countries	94	94	94	94	94

TABLE 5. Fixed-Effects Regressions of Growth, Investment, and Openness on Liberalization Status, 1950–98

Item	(1) 1950–98	(2) 1950–70	(3) 1970–90	(4) 1990–98
<i>Dependent variable: Growth</i>				
Liberalization	1.417 (5.05)	0.611 (1.29)	1.787 (3.11)	2.547 (2.39)
Number of observations	4,936	1,728	2,312	1,116
Number of countries	133	108	112	133
Adjusted R ²	0.05	0.03	0.04	0.04
<i>Dependent variable: Investment rate</i>				
Liberalization	1.937 (9.06)	2.545 (7.57)	1.237 (2.91)	0.762 (2.16)
Number of observations	5,078	1,844	2,321	1,140
Number of countries	136	110	117	136
Adjusted R ²	0.04	0.10	0.11	0.02
<i>Dependent variable: Openness</i>				
Liberalization	5.531 (7.42)	2.302 (1.89)	4.097 (3.74)	-1.803 (0.83)
Number of observations	5,078	1,844	2,321	1,140
Number of countries	136	110	117	136
Adjusted R ²	0.22	0.02	0.14	0.08

Note: Numbers in parentheses are robust *t*-statistics. Regressions are based on the specifications in equations (1)–(3). All regressions include time and country fixed-effects (estimates not reported).

Source: Authors' analysis based on data described in the text.

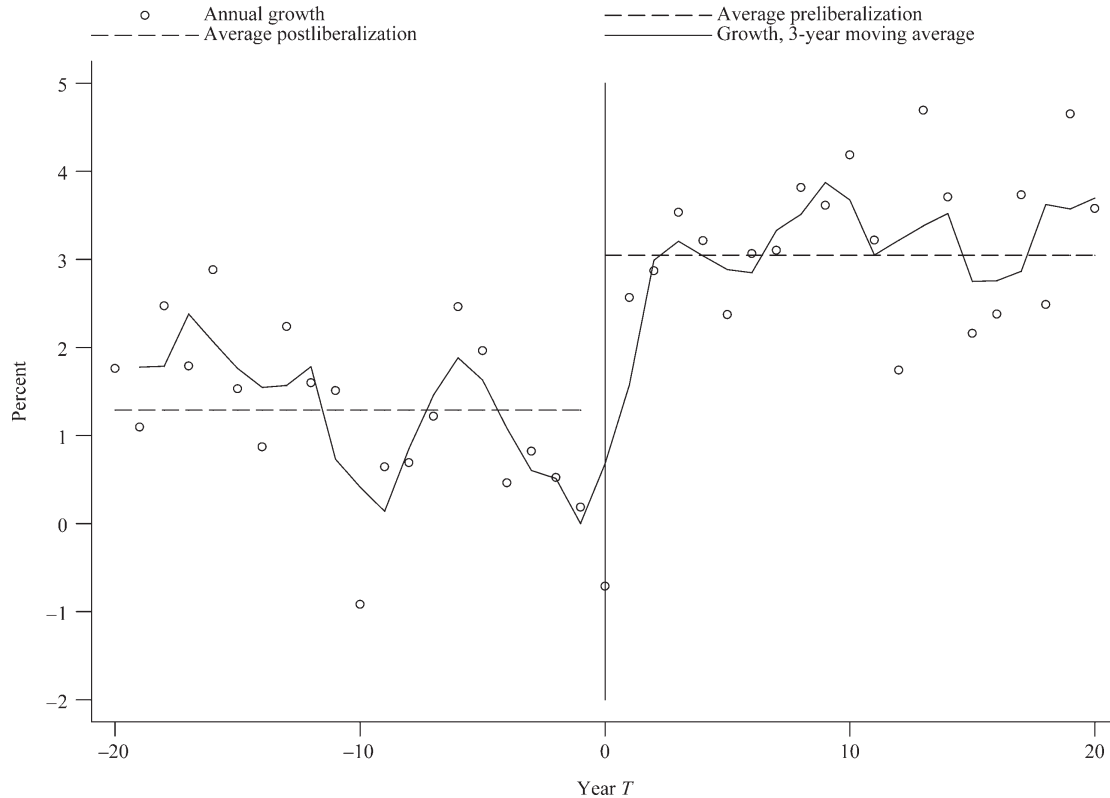
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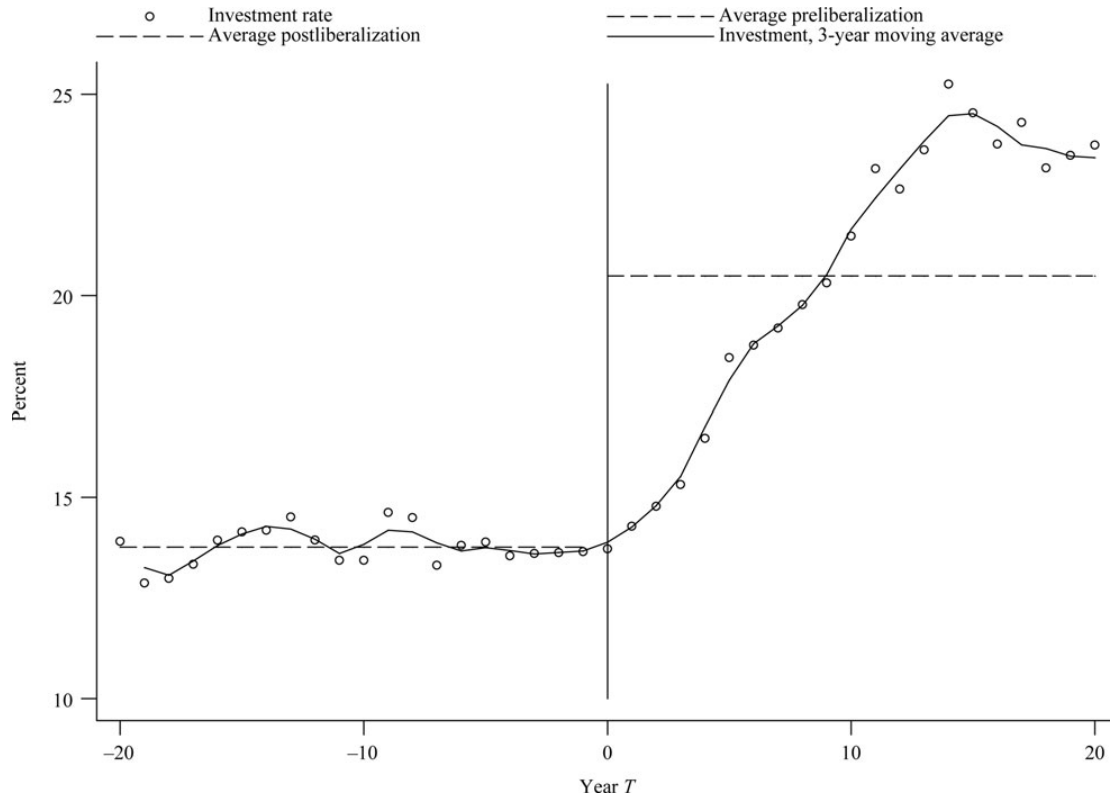
Source: Authors' analysis based on data described in the text.

FIGURE 2. Sample Means for Growth before and after Liberalization



Source: Authors' analysis based on data described in the text.

FIGURE 3. Sample Means for Investment before and after Liberalization



Source: Authors' analysis based on data described in the text.

Conclusions I

- Effect of trade on growth is empirical issue
- International trade in knowledge and in commodities change both the dynamics and potentially long-run implications of the closed-economy neoclassical growth models
- Nature of international trade interacts with the process of economic growth
- Theoretical analysis highlighted important mechanisms and suggested negative effects of trade on growth could be important
- But impact of international trade on growth ultimately an empirical question
 - Early evidence was rather unsatisfactory
 - Recent one indicates positive and large impact both direct and through investment
 - Trade liberalization increases annual growth (direct) by 1.5 points and investment by 1.5-2 percentage points

Conclusions II

- Still effect of openness is not large
- Many countries are not using best available technologies
- Need to understand better what are the *barriers* to adoption
 - Education of the labour force
 - Financial development that prevents investments in imitation
 - Lack of infrastructure that would not allow firms to sell enough and recoup fixed costs
 - Poor institutions such as insecure property rights