

# Understanding Technology Diffusion: The Role of Trade, FDI, and Migration

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# The Problem

- ▶ Technological progress is a critical mechanism for explaining sustainable growth and productivity differences across countries
- ▶ Foreign sources of technology account for about 90 percent of domestic productivity growth in most countries (Keller, 2004)
- ▶ Large part of U.S. innovations are made by immigrant scientists and engineers (Global Economic Prospects 2008)
- ▶ Brain Drain vs Development Potential of Migration

# Research Question

- ▶ What are the long-run effects of migration, together with other channels, on technology diffusion
- ▶ Are there different channels of technology diffusion between developed and developing countries

# Contribution

## Migration

Traditionally, channels of diffusion include:

- Trade: Coe and Helpman (1995), Eaton and Kortum (2001)
- FDI: Harrison and Aitken (1999), Keller and Yeaple (2009)
- Student Flows: Park (2004), Le (2009)

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## Developed vs Developing

Separate focus on developed & developing countries:

- OECD countries: Coe and Helpman (1995), Kao (1999)
- Non-OECD countries: Coe and Helpman (1997)
- Single Country Studies: Harrison and Aitken (1999)

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## CHAT Data

Traditionally, technology diffusion measures include:

- TFP Data: Captures variation in capacity utilization, labor hoarding, and ignores innovations that increase product variety
- Patent Citation Data: Measured along the extensive margin, Patent Fraud

# Diffusion Measure

- ▶ Cross-country Historical Adoption of Technology Data: Comin et al. (2008)
  - ▶ Usage Intensities for 115 technologies in 150 countries since 1800
    - ▶ **Sample Selection**: 23 Technologies in 25 developed and 46 developing countries between 1971 & 2001
    - ▶ Each technology represents a capital good that is used to produce a final good or service (Example: Computer - Number of computers designed for use by one person)
    - ▶ Extensive Margin: A potential producer decides whether to incur a fixed cost of adopting the new production method
    - ▶ Intensive Margin: Number of units of capital goods used in production (determined by productivity)

$$Diff_{j,t} = \frac{1}{I} \sum_{i=0}^I Diff_{i,j,t} = \frac{A_{ijt}}{\max\{A_i\}}$$

# Estimating Equation

$$Diff_{jt} = \beta \mathbf{x}_{jt-1} + \sum_{s=-q1}^{q2} c \Delta \mathbf{x}_{jt-1+s} + \alpha_j + \theta_t + \varepsilon_{jt} \quad (1)$$

- ▶ Estimate (1) as suggested by Mark and Sul (2003)

Diff: Technology Diffusion

$\alpha$ : Country Fixed Effects

$\theta$ : Time Fixed Effects

X:  $\begin{bmatrix} \textit{Trade} \\ \textit{FDI} \\ \textit{Migration} \\ \textit{Education} \\ \textit{Private Investment} \end{bmatrix}$  Variables

Cointegration Test



Table: DOLS Estimation Results

Dep Var: Rel. Usage Int.	DOLS with Migration		IV-DOLS		IV-DOLS (Interaction)	
	Developed Countries	Developing Countries	Developed Countries	Developing Countries	Developed Countries	Developing Countries
FDI	0.018*** (0.00)	-0.043*** (0.01)	-0.049 (0.04)	0.377*** (0.09)	-0.035 (0.04)	0.388*** (0.08)
Trade	0.019 (0.10)	0.309*** (0.08)	1.323*** (0.40)	-3.803*** (0.63)	1.265** (0.59)	-4.004*** (0.65)
Education	1.013*** (0.17)	0.310 (0.19)	1.682*** (0.31)	0.163 (0.13)	3.767*** (0.70)	0.284 (0.27)
Private Inv.	0.232** (0.09)	0.028 (0.06)	-0.050 (0.07)	0.042 (0.10)	0.064 (0.06)	0.042 (0.10)
Emigration	0.183*** (0.05)	0.254*** (0.08)	0.234 (0.30)	1.444** (0.53)	3.461*** (0.93)	1.580** (0.69)
Emigr × Educ	- (-)	- (-)	- (-)	- (-)	-2.779*** (0.65)	-0.061 (0.43)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	630	684	630	684	630	684

Table: Extreme Bound Analysis

Z-Variables	Avg $\beta$	Avg s.e.	t-value	Min $\beta$	Min s.e.	Max $\beta$	Max s.e.	Leamer	Sala-I-Martin
<b>Developed</b>									
FDI	-0.05	0.03	-1.27	-0.10	0.04	0.02	0.02	Robust	Robust
Trade	0.70	0.57	1.19	-0.00	0.46	1.54	0.66	Fragile	Fragile
Education	3.81	0.65	5.91	2.67	0.69	5.0	0.65	Robust	Robust
Private Invest	0.12	0.05	2.48	0.06	0.06	0.19	0.05	Robust	Robust
Emigration	3.27	0.77	4.31	2.42	0.71	4.12	0.74	Robust	Robust
Emigr $\times$ Educ	-2.58	0.55	-4.71	-3.43	0.52	-1.80	0.51	Robust	Robust
<b>Developing</b>									
FDI	0.34	0.05	6.33	0.25	0.05	0.41	0.05	Robust	Robust
Trade	-2.73	0.61	-4.48	-4.14	0.60	-1.54	0.57	Robust	Robust
Education	0.54	0.26	1.63	-0.97	0.24	2.07	0.26	Robust	Robust
Private Invest	0.05	0.08	0.70	0.01	0.09	0.10	0.07	Robust	Robust
Emigration	1.82	0.67	2.71	-0.42	0.66	3.96	0.62	Fragile	Robust
Emigr $\times$ Educ	-0.16	0.38	-0.30	-1.54	0.37	1.20	0.35	Robust	Robust

FDI (IV), Trade (IV), Education, Private Investment, Emigration (IV) and the Interaction Term are sequentially included in the y-vector, with the other variables being included in the z-vector to check each of those variables for robustness. Additionally, a combination of the variables credit-to-GDP, real GDP, life expectancy, and public investment are added to carry out the EBA

# Conclusion

- ▶ Technology diffuses idiosyncratically to developed and developing countries
- ▶ Migration is a significant channel of technology diffusion
- ▶ Results are mostly robust to various model specifications
- ▶ Things to do:
  - ▶ Develop a better strategy to address endogeneity issues
  - ▶ Disentangle the negative effect of trade in developing countries
  - ▶ How does migration enhance technology diffusion?

Thank you!

## Sample Selection

- ▶ Exclude countries that have less than 50% of observations for more than half of the technologies relative to the average (91 countries)
- ▶ Exclude technologies which differ from the mean number of observation by more than 1.5 standard deviations (23 technologies) [List of Technologies](#)
- ▶ Estimation period of 1971 - 2001
- ▶ Average the relative usage intensities across technologies to obtain the measure:
 
$$Diff_{j,t} = \frac{1}{I} \sum_{i=1}^I Diff_{i,j,t}$$
- ▶ Exclusion of countries that have less than 5 observations over the 31 year sample period (71 countries) [List of Countries](#)
- ▶ Production technologies are scaled by either population or GDP
- ▶ Control for obsolete technologies to ensure changes in diffusion are not due to an outdated technology

[Summary Stats](#)

Category	Technology	Definition
Agriculture	Harvester	Number of self-propelled machines that reap and thresh in one operation (per unit of real GDP)
	Irrigated area	Irrigated area as a share of cultivated land
	Tractor	Number of wheel and crawler tractors used in agriculture (per unit of real GDP)
	Pesticides	Metric tons of active ingredients in pesticides used in or sold to the agricultural sector (per unit of real GDP)
	Fertilizer	Metric tons of fertilizer consumed (per unit of real GDP)
Transportation	Aviation I	Civil aviation passenger-KM traveled on scheduled services (per capita)
	Aviation II	Civil aviation ton-KM of cargo carried on scheduled services (per unit of real GDP)
	Rail I	Thousands of passenger journeys by railway (per capita)
	Rail II	Ton-KM of freight carried on railways (excluding livestock and passenger baggage, per unit of real GDP)
	Rail III	Geographical/route lengths of line open at the end of the year (per unit of real GDP)
	Rail IV	Metric tons of freight carried on railways(per unit of real GDP)
	Vehicle I	Number of passenger cars in use (per capita)
	Vehicle II	Number of commercial vehicles, typically including buses and taxis, in use (per unit of real GDP)
Telecommunication	Cellphone	Number of users of portable cell phones (per capita)
	Newspaper	Number of newspaper copies circulated daily (per capita)
	Radio	Number of radios (per capita)
	Telephone	Number of mainline telephone lines (per capita)
	Mail	Number of items mailed/received (per capita)
	Telegram	Number of telegrams sent (per capita)
	TV	Number of television sets in use (per capita)
General Purpose	Internet	Number of people with access to the worldwide network (per capita)
	Computer	Number of self-contained computers designed for use by one person (per capita)
	Electricity	Gross output of electric energy in Kwhr (per unit of real GDP)

Table: List of countries

Developed Countries			Developing Countries			
Australia	Germany	New Zealand	Argentina	Egypt	Malaysia	Russia
Austria	Greece	Norway	Bolivia	El Salvador	Mali	Saudi Arabia
Belgium	Ireland	Portugal	Brazil	Ghana	Mexico	South Africa
Canada	Israel	Singapore	Bulgaria	Guatemala	Morocco	Sri Lanka
Czech Republic	Italy	Spain	Cameroon	Honduras	Mozambique	Syria
Denmark	Japan	Sweden	Chile	Hungary	Pakistan	Tanzania
Finland	Korea, Rep	Switzerland	China	India	Panama	Thailand
France	Netherlands	United Kingdom	Colombia	Indonesia	Paraguay	Togo
		United States	Congo, Dem	Iran	Peru	Turkey
			Ivory Coast	Kenya	Philippines	Uruguay
			Ecuador	Malawi	Poland	Venezuela
					Romania	Zimbabwe

Sample includes 25 developed countries and 46 developing countries between the period 1973 and 1999 for which at least 5 observations were available. Gaps were filled using linear interpolation.

Table: Summary Statistics

	Total	Developed Countries	Developing Countries
Relative Technology Usage	0.18 (0.11)	0.26 (0.10)	0.11 (0.06)
FDI	2.65 (5.14)	3.45 (6.55)	1.74 (3.08)
Trade	62.72 (48.07)	72.09 (59.21)	52.65 (28.55)
Emigration	5.108 (5.47)	7.95 (6.49)	2.77 (3.02)
Private Investment	22.84 (8.09)	24.66 (6.54)	21.24 (8.88)
Education	2.35 (0.55)	2.73 (0.39)	2.02 (0.45)
<i>N</i>	1314	630	684



Table: Summary Statistics

	Total	Developed Countries	Developing Countries
Relative Technology Usage	0.18 (0.11)	0.26 (0.10)	0.11 (0.06)
Agriculture	0.20 (0.13)	0.24 (0.13)	0.16 (0.11)
General Purpose	0.15 (0.13)	0.22 (0.14)	0.09 (0.07)
Telecommunication	0.16 (0.14)	0.23 (0.15)	0.10 (0.09)
Transportation	0.21 (0.17)	0.34 (0.14)	0.09 (0.08)
FDI	2.65 (5.14)	3.45 (6.55)	1.74 (3.08)
Trade	62.72 (48.07)	72.09 (59.21)	52.65 (28.55)
Emigration	5.108 (5.47)	7.95 (6.49)	2.77 (3.02)
Private Investment	22.84	24.66	21.24

Name	Definition	Source
Relative Usage Intensity	Usage intensity of country $j$ at time $t$ relative to technology frontier	CHAT: Author's calculation
FDI	Sum of net FDI Inflow and net FDI Outflow	World Bank
FDI Outflow	Net outflows (new investment outflows less disinvestment) of investment from the reporting economy to the rest of the world, as share of GDP.	World Bank
FDI Inflow	Net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors, as share of GDP	World Bank
Trade	Sum of exports and imports of goods and services measured as a share of GDP	World Bank
Credit	Credit to the private sector as a share of GDP	World Bank
Life Expectancy	Indicates the average number of years a newborn infant would live.	World Bank
Migration	Migration stock of country $j$ , reported by selected destination countries, relative to country $j$ 's population*	UN Migration Database
Education	Human Capital per person (index), based on years of schooling (Barro and Lee 2012) and returns to education (Psacharopoulos, 1994)	Penn World Table
GDP per capita	PPP Converted GDP Per Capita (Laspeyres), derived from growth rates of $c, g, i$ , at 2005 constant prices	Penn World Table
Public Investment	Public investment as a share of GDP	Penn World Table
Private Investment	Private investment as a share of GDP	Penn World Table

▶ Panel Unit Root Tests:

- ▶ Im-Pesaran- Shin (IPS) test and Fisher-type tests (Augmented Dickey-Fuller and Phillips-Perron)
- ▶ Individual intercept and trend with the optimal lag length being selected by the Akaike Information Criterion (AIC) Unit Root

▶ Cointegration Tests:

- ▶ Kao and Chiang (1999) and Pedroni (1999) tests
- ▶ Lag length being selected by the Akaike Information Criterion (AIC)

Table: Cointegration Test

Pedroni:	Panel PP-Statistic:	-6.47	(0.00)
	Panel ADF-Statistic:	-6.96	(0.00)
	Group PP-Statistic:	-15.08	(0.00)
	Group ADF-Statistic:	-6.92	(0.00)
Kao:	ADF	2.19	(0.01)

Table: Unit Root Tests

Panel A: Variables in Levels						
	Diffusion Lag	FDI	Trade	Emigr	Educ	Private Inv.
IPS-test	18.25 (1.00)	-12.96 (0.00)	-6.73 (0.00)	9.2 (1.00)	2.91 (0.99)	-5.4 (0.00)
ADF-test	95.15 (1.00)	689.3 (0.00)	293.9 (0.00)	174.23 (0.28)	213.4 (0.01)	277.29 (0.00)
PP-test	67.1 (1.00)	424.74 (0.00)	226 (0.00)	130.15 (0.97)	125.9 (0.99)	198.7 (0.03)
Panel B: Variables in First Differences						
	Diffusion Lag	FDI	Trade	Emigr	Educ	Private Inv.
IPS-test	-9.84 (0.00)	-24.11 (0.00)	-23.54 (0.00)	-4.2 (0.00)	-1.81 (0.03)	-25.25 (0.00)
ADF-test	588.88 (0.00)	895.17 (0.00)	801.43 (0.00)	300.79 (0.00)	217 (0.00)	1084 (0.00)
PP-test	1301 (0.00)	3801 (0.00)	1727 (0.00)	217.58 (0.00)	123.65 (0.99)	2473 (0.00)

The table reports test statistics for IPS and Fisher-type panel unit root tests. p-values are in parenthesis. The  $H_0$  for both tests is that all series are nonstationary. Lags are chosen according to the Akaike Information Criterion. All tests include an individual intercept and trend.

▶ FDI:

$$FDI - DI_i = (\text{Inverse of Bilateral Distance}_{i,US}) * FDI_{US}$$

$$FDI - RE_i = Religion_{iUS} * FDI_{US}$$

$$FDI - LA_i = Language_{iUS} * FDI_{US}$$

$$FDI - MO_i = (\text{Domestic Movement}_i) * FDI_{US}$$

- ▶ Trade and Migration similarly
- ▶ Education: 10 year lag average years of schooling of the population being 40 years and over to represent parent's education (Barro & Lee, 2013)

Table: Summary results for first-stage regressions

	Emigration	FDI	Trade	Education
<u>Individual endogenous regressors:</u>				
Angrist-Pischke $\chi^2$ - tests of underidentification:	81.54	103.38	218.56	234.34
	(0.00)	(0.00)	(0.00)	(0.00)
F- statistics:	70.64	42.66	42.11	206.35
	(0.00)	(0.00)	(0.00)	(0.00)
Underidentification test: Kleibergen-Paap rk LM Statistic:	14.9		(0.09)	
Hansen J statistic:	9.94		(0.27)	
<u>Weak instrument-robust inference:</u>				
Anderson-Rubin Wald test (F-stat):	68.82		(0.00)	
Anderson-Rubin Wald test ( $\chi^2$ ):	904.02		(0.00)	
Stock-Wright LM S statistic:	297.38		(0.00)	

\* p-values in parenthesis