What should countries do to catch up? The challenge of technology diffusion

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Harvard Kennedy School
&
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INQUIRY
INTO THE
NATURE AND CAUSES
OF THE
WEALTH OF NATIONS.

By ADAM SMITH, LL.D. F.R.S.

WITH
A LIFE OF THE AUTHOR.

ALSO,

A VIEW OF THE DOCTRINE OF SMITH, COMPARED WITH THAT OF THE
FRENCH ECONOMISTS; WITH A METHOD OF FACILITATING THE
STUDY OF HIS WORKS; FROM THE FRENCH OF M. GARNIER.

IN THREE VOLUMES.

VOL. I.

LONDON:
PRINTED FOR J. MARRYARD, PANTON STREET, HAY-
MARKET; AND F. ZINKE, 448, STRAND.

1811.
Malawi

$226 per capita
Haiti

$819 per capita
Morocco $3,108 per capita
Poland

$13,431 per capita
Singapore $55,182 per capita
The Great Acceleration
The Great Divergence
The two Nogales
Guerrero

$5,281 per capita
Sinaloa

$10,945 per capita
Guanajuato $20,827 per capita
Nuevo Leon $42,281 per capita
A productivity gap that is consistent with...

- ...same legal framework
- ...same federal judicial system
- ...same political representation system
- ...same exchange rate
- ...same interest rate
- ....same macroeconomic setup
- ....same financial architecture
My main claim: technology does not diffuse because of the nature of technology itself.
But what is technology?
Lift (force)

From Wikipedia, the free encyclopedia

For other uses, see Lift (disambiguation).

A fluid flowing past the surface of a body exerts a force on it. Lift is the component of this force that is perpendicular to the oncoming flow direction.[1] It contrasts with the drag force, which is the component of the surface force parallel to the flow direction. If the fluid is air, the force is called an aerodynamic force. In water, it is called a hydrodynamic force.

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1 Overview
2 Simplified physical explanations of lift on an airfoil
   2.1 Flow deflection and Newton's laws
   2.1.1 Limitations of deflection/turning
   2.2 Increased flow speed and Bernoulli's principle
      2.2.1 Conservation of mass
      2.2.2 Limitations of explanations based on Bernoulli's principle
3 Basic attributes of lift
   3.1 Pressure differences
   3.2 Angle of attack
   3.3 Airfoil shape
   3.4 Air speed and density
   3.5 Lift coefficient
   3.6 Pressure integration
4 A more comprehensive physical explanation
   4.1 Lift involves action and reaction at the airfoil surface and is felt as a pressure difference
   4.2 The airfoil affects the flow over a wide area around it
   4.3 The pressure differences and the changes in flow speed and direction support each other in a mutual interaction
5 The understanding of lift as a physical phenomenon
6 Mathematical theories of lift
   6.1 Navier-Stokes (NS) equations
   6.2 Reynolds-Averaged Navier-Stokes (RANS) equations
   6.3 Inviscid-flow equations (Euler or potential)
   6.4 Linearized potential flow
   6.5 Circulation and the Kutta-Joukowski theorem
   6.6 Momentum balance in lifting flows
7 Lift of three-dimensional wings
8 Viscous effects: Profile drag and stalling
What do you do when your tooth hurts?

Search the web and fix it yourself?  ...or look for a dentist
Knowhow needs to be in brains
Collective knowhow
Who has more knowhow?
Products differ in the amount of collective knowhow they require
Different family businesses

Butcher

Baker

Candlestick maker
THE COMPANIES

U.S.  CANADA  AUSTRALIA  JAPAN  KOREA  EUROPE
- Boeing  - Boeing  - Boeing  - Kawasaki  - KAL-ASD  - Messier-Dowty
- Spirit  - Messier-Dowty  - Mitsubishi  - Fuji  - Rolls-Royce  - Latecoere
- Vought  - Fuji  - Saab  - GE  - Latecoere  - Alenia
- GE  - Fuji  - Saab  - Goodrich  - Rolls-Royce  - Alenia

WING TIPS
- Korea

MOVABLE TRAILING EDGE
- Australia

TAIL FIN
- Fredrickson, Washington

HORIZONTAL STABILIZER
- Foggia, Italy

AFT FUSELAGE
- Charleston, S.C.

FIXED TRAILING EDGE
- Nagoya, Japan

WING
- Nagoya, Japan

ENGINE NACELLES
- Chula Vista, CA

CENTER FUSELAGE
- Grottaglie, Italy

FORWARD FUSELAGE
- Nagoya, Japan

CARGO / ACCESS DOORS
- Sweden

WING/BODY FAIRING
- Winnipeg, Canada

MAIN LANDING GEAR
- Wheel Well
- Nagoya, Japan

LANDING GEAR
- Gloucester, UK

CENTER WING BOX
- Nagoya, Japan

FORWARD FUSELAGE
- Wichita, Kansas

FIXED AND MOVABLE LEADING EDGE
- Tulsa, Oklahoma

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The SCRABBLE Theory of Economic Development
With 1 letter,

A

You can make 1 word, of 1 letter
With 3 letters,

A C T

a
at

You can make 4 words, of up to 3 letters
With 4 letters,

You can make 9 words, of up to 4 letters
With 10 letters,

You can make **595** words, of up to 10 letters
What explains these differences in productivity?
Some technologies diffuse quickly
From Scrabble to the world
**INTUITION**

- Countries that have more letters will be able to make more products. They would be more diversified.

- Products that require more letters will be made by fewer countries. Products will be less ubiquitous.

- Countries that have more letters will be able to make products that require more letters.

- Products that are less ubiquitous will be made by countries that are more diversified.

- Countries that have more letters should be more diversified and able to make less ubiquitous products.
Diversification vs. Ubiquity (2009)
This pattern also holds subnationally: Municipalities in Chile

Diversification vs. Ubiquity

FOR CHILE 2008
Cities in Turkey

Diversification vs. Ubiquity

[Graph showing the relationship between diversification and ubiquity for cities in Turkey, with specific cities labeled.]
States in Mexico

Diversification vs. Ubiquity
Departments in Colombia

Diversification vs. Ubiquity

2012 - Total Wages

Country Diversity

av_ubq Fitted values
And Districts in Sri Lanka

Diversification vs. Ubiquity
How to get new letters?
The infection problem
Example 1: DETROIT

All successful car firms in Detroit came out of Olds Motor Works
Silicon Valley consists almost exclusively of Fairchild Semiconductor renegades.
II. Diffusion of knowhow between firms across countries

Example 3: The garment exports of Bangladesh (Klepper and Mostafa, 2011)
Bangladesh

What did Bangladesh export between 1962 and 2010?

http://www.atlas.cid.harvard.edu/
Diffusion of Knowhow across Countries via Migrants
Erik Hornung (AER, 2014)

Immigration and the diffusion technology: The Huguenot diaspora in Prussia

Louis XIV of France

Revocation of the Edict of Nantes

**EDIT DU ROY, PORTANT SUPPRESSION**

Des Edits de Nantes et de Nismes;

Revocation generale de tous les Privileges cy-devant accordez a ceux de la Religion pretendue reformee;

Et qui ordonne la Demolition de tous les Temples, & l'Interdiction de l'exercice de ladite Religion dans tout le Royaume, Pais & Terres de l'Obedissance de Sa Majeste.

Verifie en Parlement le 22. Octobre 1685.
Huguenots on the run

http://www.huguenotsociety.org.uk/history.html
Huguenots in Prussia – 1685-1795

New technologies introduced by Huguenots in Prussia
- New ways of dyeing fabrics
- Cotton printing
- Hosiery knitting loom
- Silk spinning

100 years after:
- Textile factories in towns with an influx of Huguenots in 1700 are significantly more productive
- And use more advanced technology (more looms)

Closer to today

Moser, Voena & Waldinger, 2014: Jewish scientists leaving Germany

Peri, Shih & Sparber, 2014: H-1B visas

AnnaLee Saxenian, 2006: Silicon Valley off-shoots
The percentage of immigrants varies enormously across the world.
The developing world is very closed to immigration

Singapore  1 in 2.4
Panama  1 in 24
Mexico  1 in 240
Colombia  1 in 400
But is it push or pull?
Quotas on foreign skilled workers are very common

• Ireland: maximum 50% non-EU citizens
• Kazakhstan: maximum 30% foreign
• Egypt, Guatemala, Panama: maximum 10% foreign
• Cambodia: maximum 6% foreign
• Dem. Rep. Congo: maximum 4% foreign
• Ghana, Mozambique, Nigeria, Thailand: 1 or 2 per firm
How to get more letters?
The chicken and egg problem
The Product Space
Community characteristics: Complexity, Connectedness and Market Size
Where are the monkeys?
Venezuela 2015

$33.3B USD
Mexico 2015

$382B USD
How do monkeys jump?
A tale of two countries

GHANA

THAILAND
1962: Roughly equal income

<table>
<thead>
<tr>
<th>Country</th>
<th>GDP per capita (constant 2000 US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>$295</td>
</tr>
<tr>
<td>Thailand</td>
<td>$363</td>
</tr>
</tbody>
</table>
Human capital story:

Years of schooling of Thailand and Ghana as a function of time.
GHANA
Ghana’s exports in 1962

Raw & roasted cocoa beans: 65%

Manganese: 1%

Sawlogs & veneer logs of non-coniferous: 8%

Worked wood of non-coniferous: 7%

Other exports: 3%
Thailand’s exports in 1962
Thailand vs. Ghana in the Product Space

1965

Thailand

Total Value: $615,728,000

Ghana

Total Value: $294,604,000
1990

Total Value: $21,914,013,991

Total Value: $1,086,328,204

Thailand

Ghana
1995

Total Value: $50,644,730,628

Thailand

Total Value: $1,294,057,269

Ghana
2005

Total Value: $1,111,099,204,052

Thailand

Total Value: $1,871,625,725

Ghana
2010

Total Value: $186,564,165,927

Thailand

Total Value: $4,052,850,523

Ghana
Ghana’s exports in 1962

Raw & roasted cocoa beans: 65%

Manganese:
- Sawlogs & veneer logs of non-coniferous: 8%
- Worked wood of non-coniferous: 7%
- Aluminium ore: 8%
Ghana’s exports in 2010

Raw & roasted cocoa beans

- 43% Cocoa butter & paste
- 12%

Gold, non-monetary

Manganese

Fresh or dried fruit N.E.S.
Fresh or dried banana & plantains
Edible nuts
Fish N.E.S.
Ghana’s exports per capita at constant 2005 prices
Thailand’s exports in 1962
Thailand’s exports in 2010
Thailand’s exports per capita at constant 2005 prices
Divergence, big time

Evolution of the GDP per capita of Thailand and Ghana as a function of time.
Explaining growth
Economic Complexity controlling for NR Exports

Income Per Capita controlling for NR Exports
How many letters you have?

How close are you to other good products?

Few letters
Hard to add more

More letters
Easy to add more

Many letters
Hard to add more by just copying others
The Strategic Setting

Ease to acquire more letters

<table>
<thead>
<tr>
<th>Complexity Outlook Index</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Relative endowment of letters

- **Stairway to heaven**
  - Parsimonious industrial policy
  - Help jump short distances to other products

- **Bridge over troubled waters**
  - Strategic bets
  - Little space to improve quality and few nearby trees

- **Let it be**
  - It ain't broke
  - Ample space to move in all directions

- **Hey Jude: make it better**
  - Competitiveness policy
  - Improve the conditions of the sectors that already exist
The Strategic Setting: intensive vs. extensive

- **Stairway to heaven**
  - Parsimonious industrial policy
  - Help jump short distances to other products

- **Bridge over troubled waters**
  - Strategic bets
  - Little space to improve quality and few nearby trees

- **Let it be**
  - It ain't broke
  - Ample space to move in all directions

- **Hey Jude: make it better**
  - Competitiveness policy
  - Improve the conditions of the sectors that already exist
Why is growth not more inclusive?
Why is growth not more inclusive?

Fraction of Capabilities Available

Fraction of Products that is Possible

$k_{c,0}^a / N_a$

$k_{c,0}^p / N_p$

NAICS $R^*=1$

NAICS $R^*=0.5$

SITC-4 $R^*=0.5$

SITC-4 $R^*=1$

HS-6 $R^*=0.5$

HS-6 $R^*=1$
Economic complexity at the municipal level in Mexico
Economic Complexity helps explain why Chiapas is poor: Oaxaca-Blinder decomposition
Put some letters everywhere or put all letters somewhere?
Some letters everywhere or all letters somewhere?

Some roads

Economic zone
Economic activity tends to be concentrated in space
How do you mix your letter with other letters?
Yinsk
Raza
Agent Coulson
General Gabriel
Abu Bakaar
Jarvis
Hogan
William Ginter Riva
Major Allen
Award Ceremony Narrator
Guards
Tom Morello
Marco Khan
Daston Kalili
Ido Ezra
Jimmy Pratt
Ramirez
Ahmed
Omar
Howard Stark
Viper 1
Viper 2
Amira Ahmed
Colonel Craig
Dealer at Craps Table
Women at Craps Table

Shaun Toub
Faran Tahir
Clark Gregg
Bill Smitrovich
Sayed Badreya
Paul Bettany
Jon Favreau
Peter Billingsley
Tim Guinee
Will Lyman
TOM MORELLO
MARCO KHAN
DASTON KALILI
Ido Ezra
KEVIN FOSTER
Garrett Noel
Eileen Weisinger
Ahmed Ahmed
FAHIM FAZLI
Gerard Sanders
Tim Rigby
Russell Richardson
Nazanin Boniadi
Thomas Craig Plume
Robert Berkman
Stacy Stas

Gulmira Kid
Gulmira Mom
Reporters
Flight Attendants
Himself
Air Force Lieutenant
Herself
Stan’s Girls
CAOC Analysts
Summer Kylie Remington
Ava Rose Williams
Vladimir Kubr
Callie Marie Crouchwell
Javan Tahir
Sahar Bibiy
Patrick O’Connell
Adam Harrington
Meera Simhan
Ben Newmark
Ricki Noel Lander
Jeannine Kaspar
Sarah Cahill
Stan Lee
Justin Rex
Zorianna Kit
Lana Kinnear
Nicole Lindeblad
Masha Lund
Gabrielle Tuite
Joshua Haro
Micah Hauptman
James Bethea
<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Lead</td>
<td>Mora Godley</td>
</tr>
<tr>
<td>Technical Advisor</td>
<td>Phung Champlin</td>
</tr>
<tr>
<td>Software Analyst</td>
<td>Emanuel Stjohn</td>
</tr>
<tr>
<td>Software Engineer</td>
<td>Nakita Hathcock</td>
</tr>
<tr>
<td>Tech Financial Advisor</td>
<td>Bea Windham</td>
</tr>
<tr>
<td>Lead Tech Expert</td>
<td>Lizette Gries</td>
</tr>
<tr>
<td>Lead Film Editor</td>
<td>Don Lizotte</td>
</tr>
<tr>
<td>Visual Effects Producer</td>
<td>Brent Greenwald</td>
</tr>
<tr>
<td>Visual Effects Creative Dir</td>
<td>Jong Tandy</td>
</tr>
<tr>
<td>Visual Effects Supervisor</td>
<td>Krista Koppes</td>
</tr>
<tr>
<td>Visual Effects Editor</td>
<td>Suzi Messing</td>
</tr>
<tr>
<td>Compositor</td>
<td>Joseph Lamark</td>
</tr>
<tr>
<td>Rotoscope Artist</td>
<td>Nichole Mehler</td>
</tr>
<tr>
<td>Paint Artist</td>
<td>Breanne Hardeman</td>
</tr>
<tr>
<td>Matte Painter</td>
<td>Elvia Loveless</td>
</tr>
<tr>
<td>Sound Designer</td>
<td>Eulah Ouzts</td>
</tr>
<tr>
<td>Dialogue Editor</td>
<td>Lynsey Armbruster</td>
</tr>
<tr>
<td>Sound Editor</td>
<td>Le Loman</td>
</tr>
<tr>
<td>Re-recording Mixer</td>
<td>Lynne Hier</td>
</tr>
<tr>
<td>Music Supervisor</td>
<td>Irish Alter</td>
</tr>
<tr>
<td>Composer</td>
<td>Leone Lammert</td>
</tr>
<tr>
<td>Foley Artist</td>
<td>Leon Pullins</td>
</tr>
<tr>
<td>Construction Coordinator</td>
<td>Terence Gathright</td>
</tr>
<tr>
<td>Construction Manager</td>
<td>Erick Stimpson</td>
</tr>
<tr>
<td>Head Carpenter</td>
<td>Lucinda Mullarkey</td>
</tr>
<tr>
<td>Key Scenic</td>
<td>Chadwick Regnier</td>
</tr>
<tr>
<td>Cinematography</td>
<td>Nelle Spafford</td>
</tr>
</tbody>
</table>
Going to work is a pain
Even when there is good infrastructure
But letters want to combine (even with frictions)
Transport can make an 8 hour shift last 12 hours long, that, with costs, leaves only 6 hours pay, or an effective tax rates of 50% for low-income formal workers.
Fixed Costs

• Connecting to any of these networks requires fixed costs:
  • for a KWH of electricity, liter of water, a bus ride, etc.
  • Commuting to work, opening and maintaining a bank account

• If your income is low, it does not pay to connect you to the network
  • Fixed costs will not be recouped

• But if you are not connected you will be unproductive and hence poor
Kenya:
• 81 mobiles/100 people

• 23% access to electricity
The Exclusion Trap

• If you are poor, it is not profitable to connect you
• If you are not connected, you are unproductive and hence poor.
• Tradeoff of inclusion: how to pay fixed costs
Solutions?

Inclusive growth has to connect people to the inputs that would make them productive, by either:

1) **Lowering the fixed cost**
   - Adopting technology
     - Cell phones vs. fixed line telephones in Kenya
     - Micro-lending
     - Solar-based electricity

2) **Sharing the fixed costs**
   - Collective investments that connect people to networks
     - U.S. Post Office
We the People...
One year earlier, in 1775, the Continental Congress....
Created the Postal Service
1775
What kind of inequality should we care about?
Policy ideas in three areas

• Maximize infection points
• Solve chicken and egg problems
• Maximize inclusion
Maximize infection points

• Adopt more open immigration (and labor) policies
• Adopt a diaspora strategy
• Tolerate (integrate) diasporas in your midst
• Encourage study- and work-abroad programs
• Facilitate foreign direct investment in new areas
Solve chicken-and-egg problems

• Develop organizations capable of scanning the space of possibilities, identifying obstacles and removing them
  • Investment promotion 2.0
  • Development funds 2.0
• Adopt place-based policies to coordinate the move of capabilities to backward regions
  • Special economic zones
• Help locations (cities, regions, countries) identify new “export” activities
  • Huge multiplier effects
Maximize inclusion

• Connect people to networks by exploiting technologies that lower fixed costs
• ...and develop mechanisms to share the costs
• Invest in urban infrastructure
  • Connect people to the networks that they need to be productive
• But charge for it
  • Or it will not be sustainable