Collective Knowhow

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& Santa Fe Institute
March 2014

Differences in productivity

Why are countries poor (or rich?)

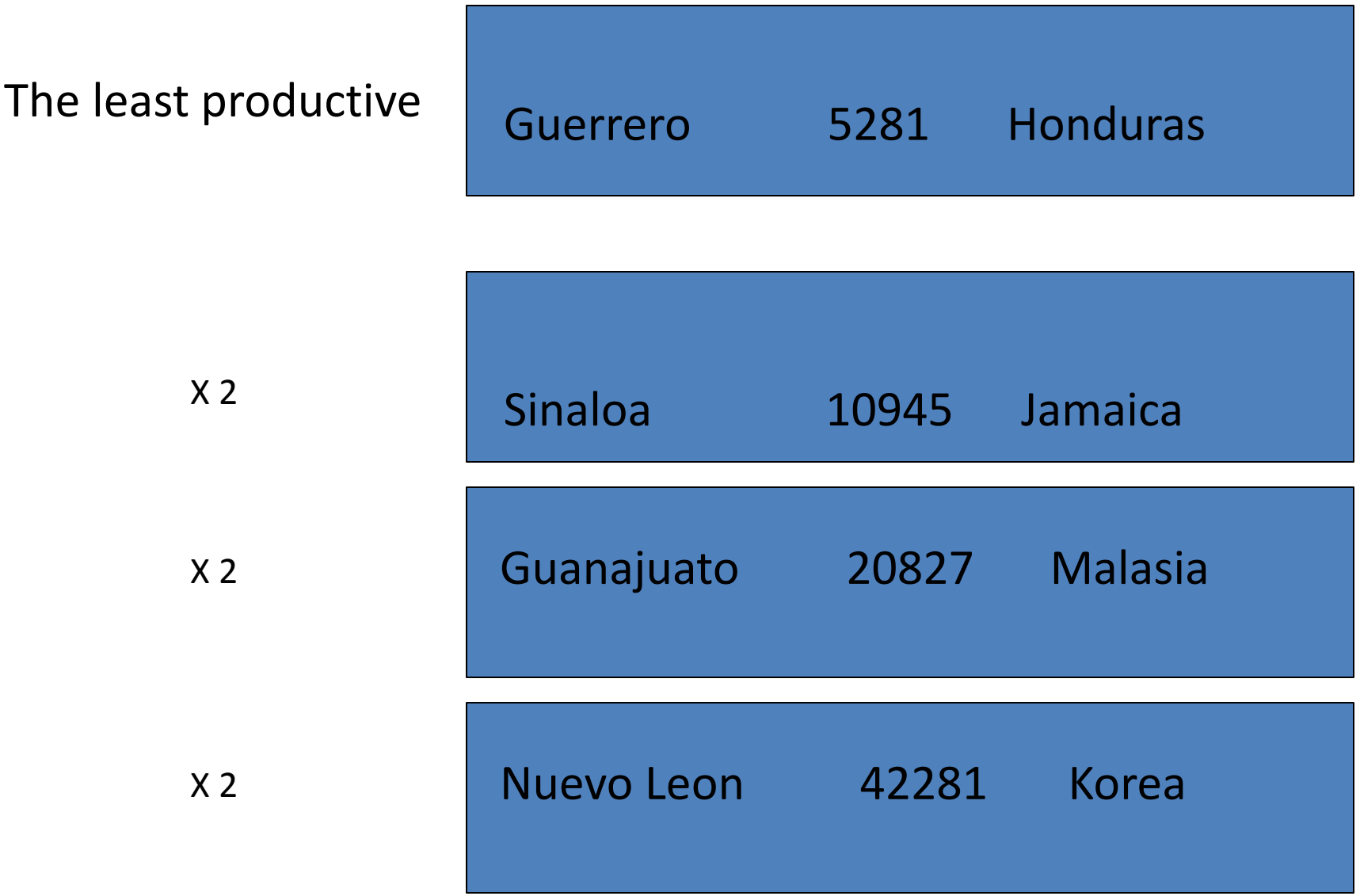
- When Adam Smith published his book in 1776, the richest country in the world was 4 times richer than the poorest country
- According to the World Development Indicators (2011) published by the World Bank, the poorest countries in the world in the world in 2008 were:

		US$ per capita	
		At market prices	PPP
Poorest	Congo, Dem. Rep.	99	297
	Burundi	111	354
	Guinea-Bissau	128	497
	Eritrea	147	584
X 4	Haiti	410	1088
	Guinea	417	1113
	Bangladesh	462	1233
	Kenya	464	1470
X 4	Cape Verde	1632	3239
	Turkmenistan	1705	6138
	Ecuador	1746	7402
	Morocco	1770	4056
X 4	Chile	6229	13370
	Mexico	6591	13407
	Croatia	6796	17219
	Czech Republic	7632	23341

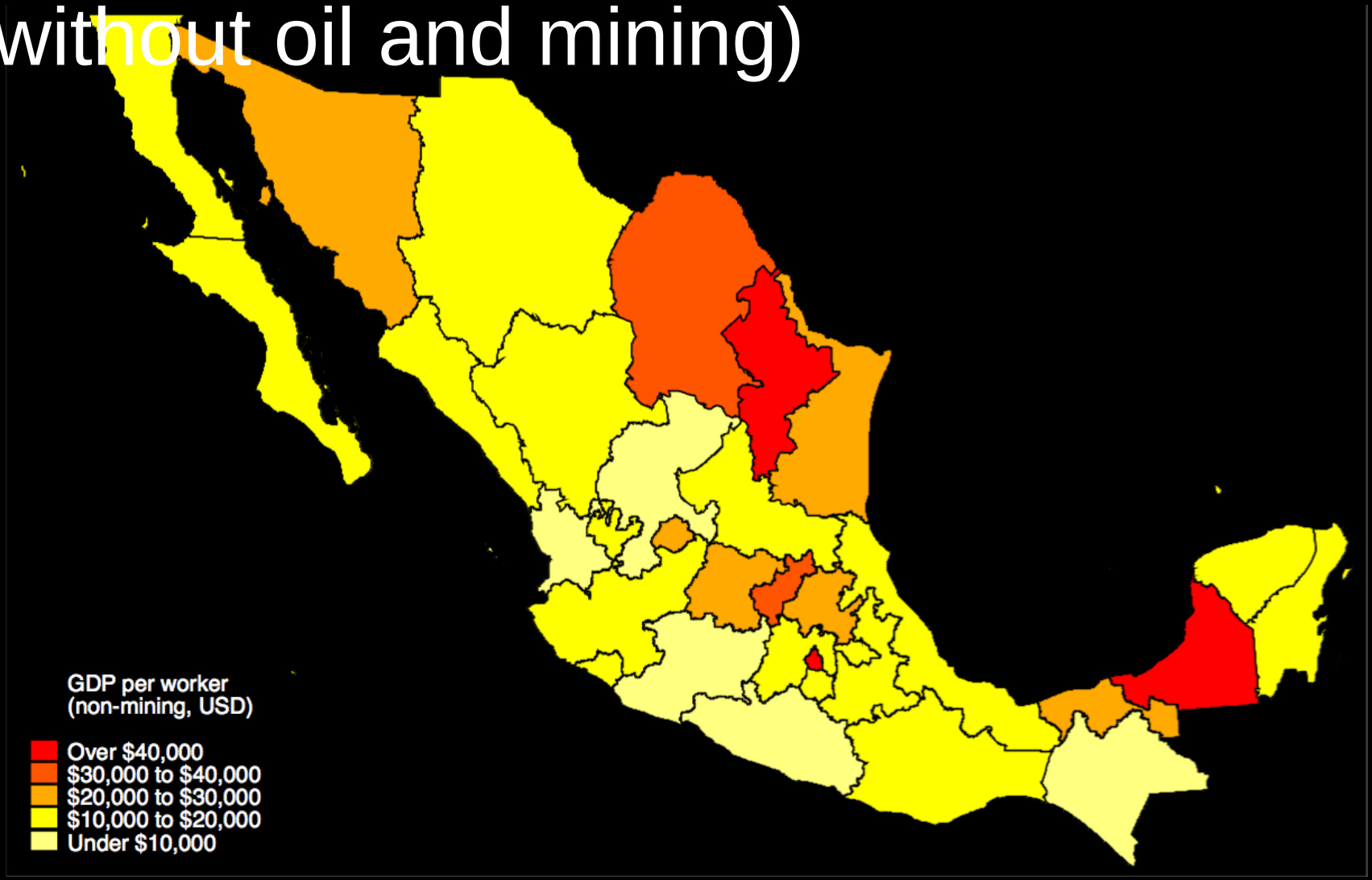
		US$ per capita	
		At market prices	PPP
X 4	Australia	24401	33369
	Belgium	25055	33520
	Germany	25420	33665
	Canada	26143	36039
The richest	Hong Kong, China	34587	40599
	Switzerland	37789	37780
	United States	38206	43179
	Japan	40481	31484
	Norway	42684	49711

The US is 387 times richer (or 145 at PPP) than the DR Congo

Productivity per worker in US$



Productivity per worker, 2009 (without oil and mining)



note

Source: Employment by industry and federal entity, 2009 Economic Census

The explosion of growth in income per capita

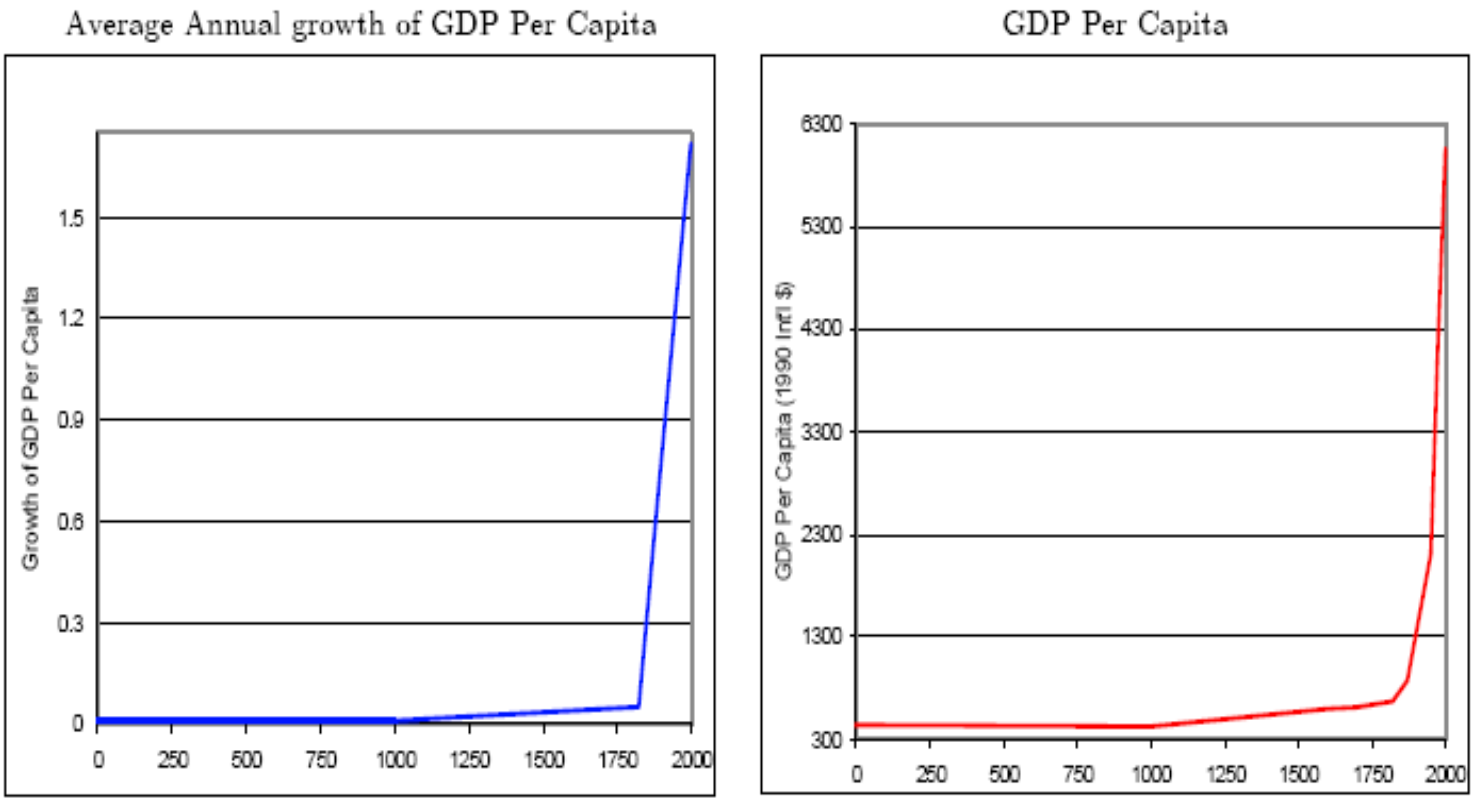
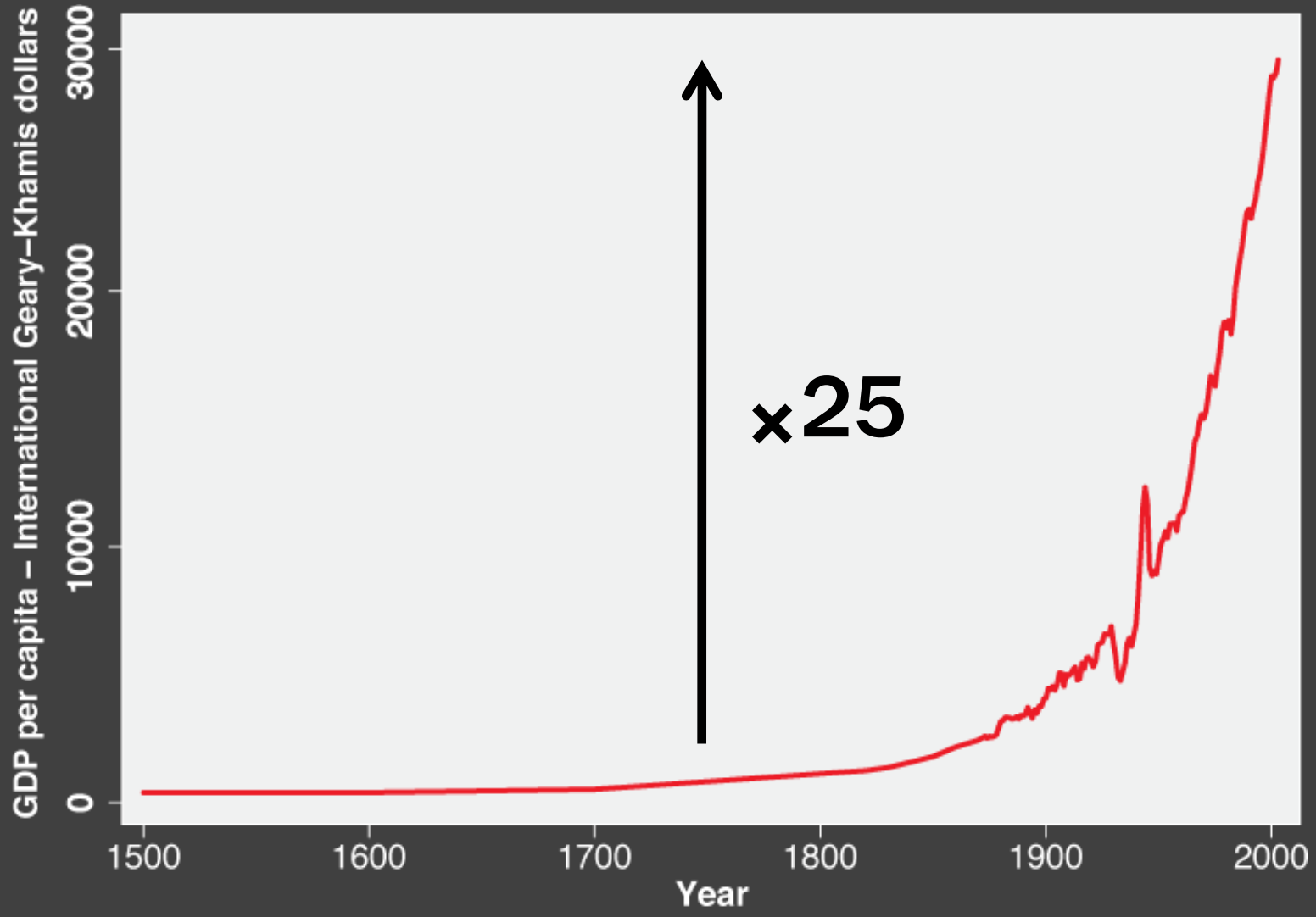


Figure 2.2. The Evolution of the World Income Per Capita over the Years 1-2001
Source: Maddison (2001, 2003)

Income per capita in the US



The Great Divergence

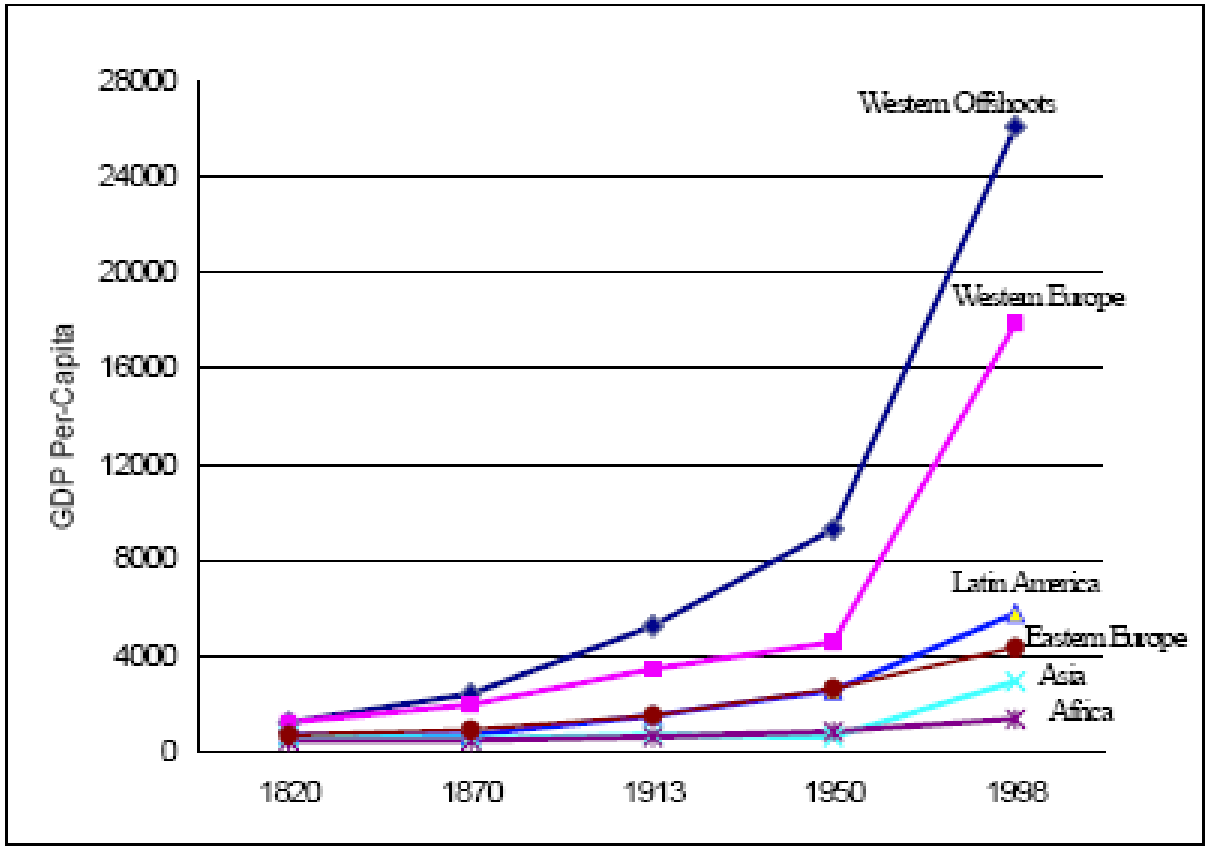
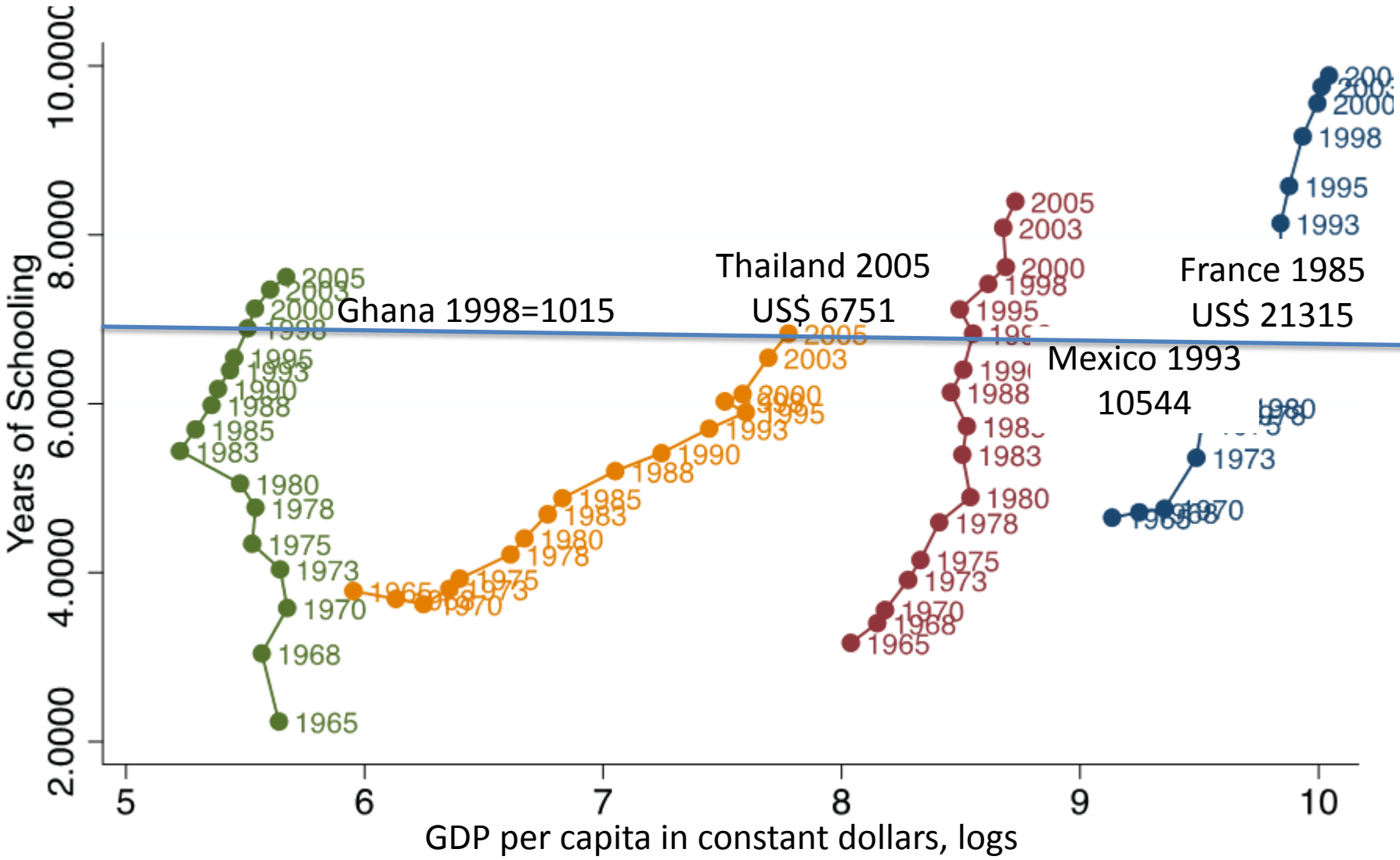


Figure 2.32. The Great Divergence
Source: Maddison (2001)

LAND
LABOR
NO
CAPITAL
HUMAN CAPITAL

Years of schooling and income per capita



Our answer

Collective productive knowhow

It is because the US and others learned about new ways of making new products

Knowhow

= *the competence to perform a task*

Knowhow ≠ Comprehension

Collective Knowhow

= *the competence to do things that no individual can do*

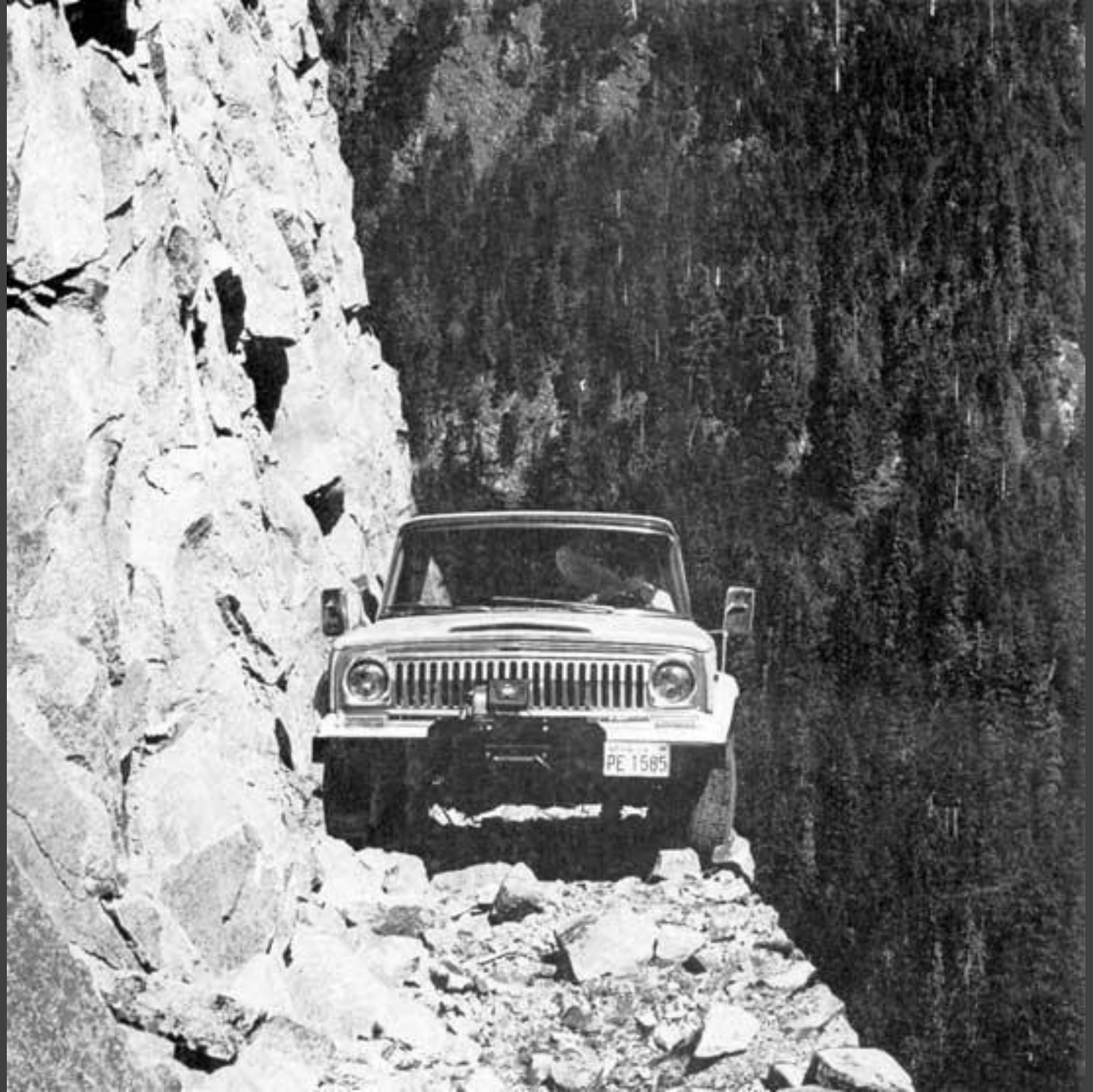
First
© PA

Where is technology?

- It comes in three ontologies
- Embedded
  - Lipid salts
- Codified
  - Blueprints, recipes
- Tacit
  - Speaking a language, playing a sport or an instrument, diagnosing a problem
  - Learned by doing, hard to transfer
  - How can you learn what you don’t do?

Tacit knowledge and diffusion

- Goods and blueprints can easily be moved around
  - There is cel phone service in Somalia
- Tacit knowledge moves through much narrower channels
- Technology changes its composition
  - Translator vs. Google Translate
  - Employee vs. kiosk


PE 1585

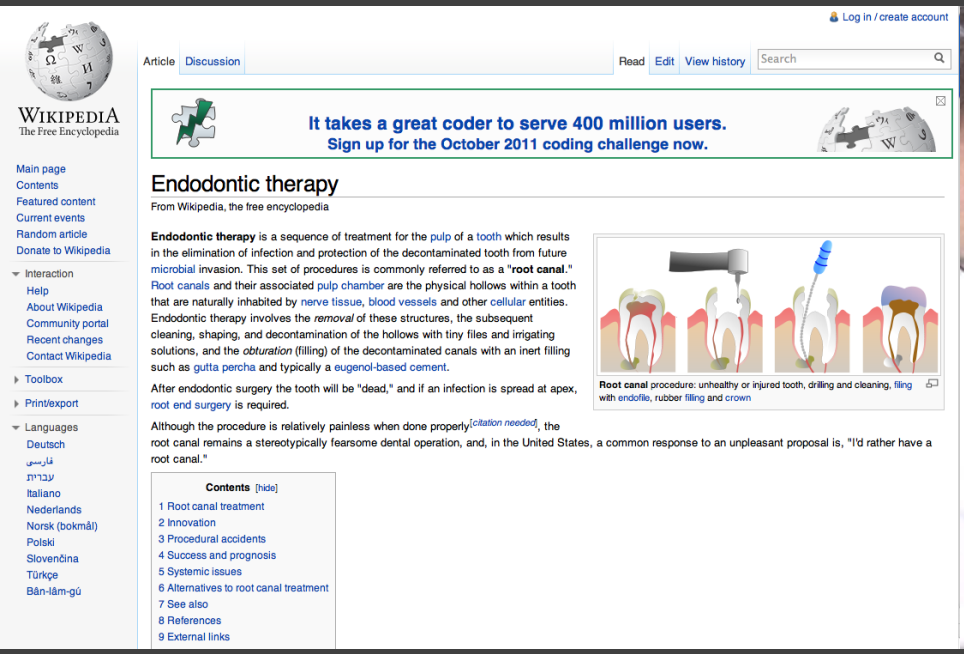
Who has more productive knowledge?

An Inuit?

...or Modern Man?

Tacit knowledge needs to be in brains

What do you do when a tooth hurts?



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The Free Encyclopedia

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Polski
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Türkçe
Bân-lâm-gú

It takes a great coder to serve 400 million users.
Sign up for the October 2011 coding challenge now.

Endodontic therapy

From Wikipedia, the free encyclopedia

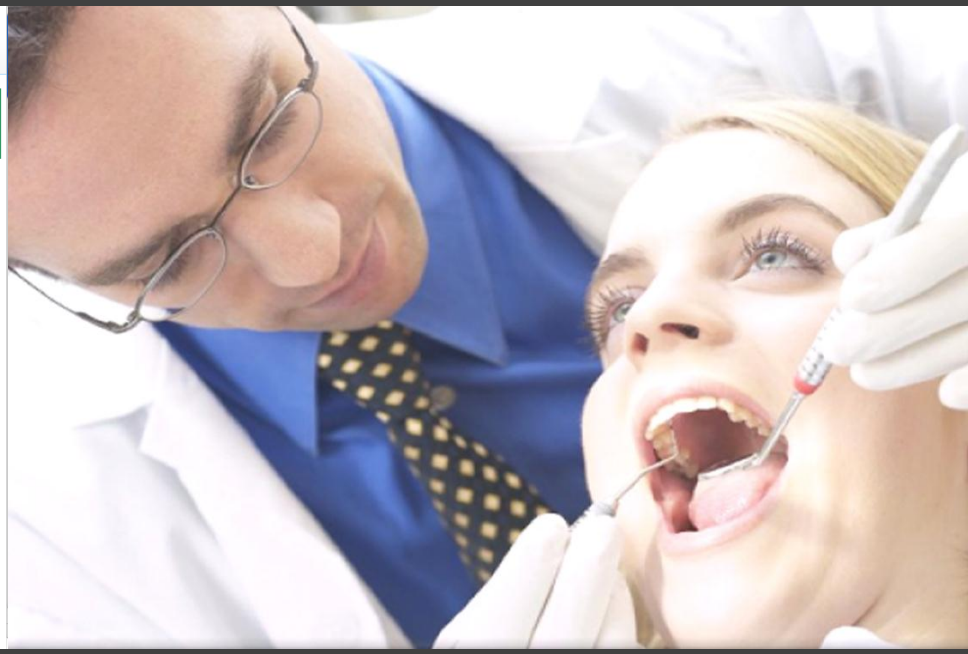
Endodontic therapy is a sequence of treatment for the pulp of a tooth which results in the elimination of infection and protection of the decontaminated tooth from future microbial invasion. This set of procedures is commonly referred to as a "**root canal**." Root canals and their associated pulp chamber are the physical hollows within a tooth that are naturally inhabited by nerve tissue, blood vessels and other cellular entities. Endodontic therapy involves the *removal* of these structures, the subsequent cleaning, shaping, and decontamination of the hollows with tiny files and irrigating solutions, and the *obturation* (filling) of the decontaminated canals with an inert filling such as gutta percha and typically a eugenol-based cement.

After endodontic surgery the tooth will be "dead," and if an infection is spread at apex, root end surgery is required.

Although the procedure is relatively painless when done properly[*citation needed*], the root canal remains a stereotypically fearsome dental operation, and, in the United States, a common response to an unpleasant proposal is, "I'd rather have a root canal."

Root canal procedure: unhealthy or injured tooth, drilling and cleaning, filing with endofile, rubber filling and crown

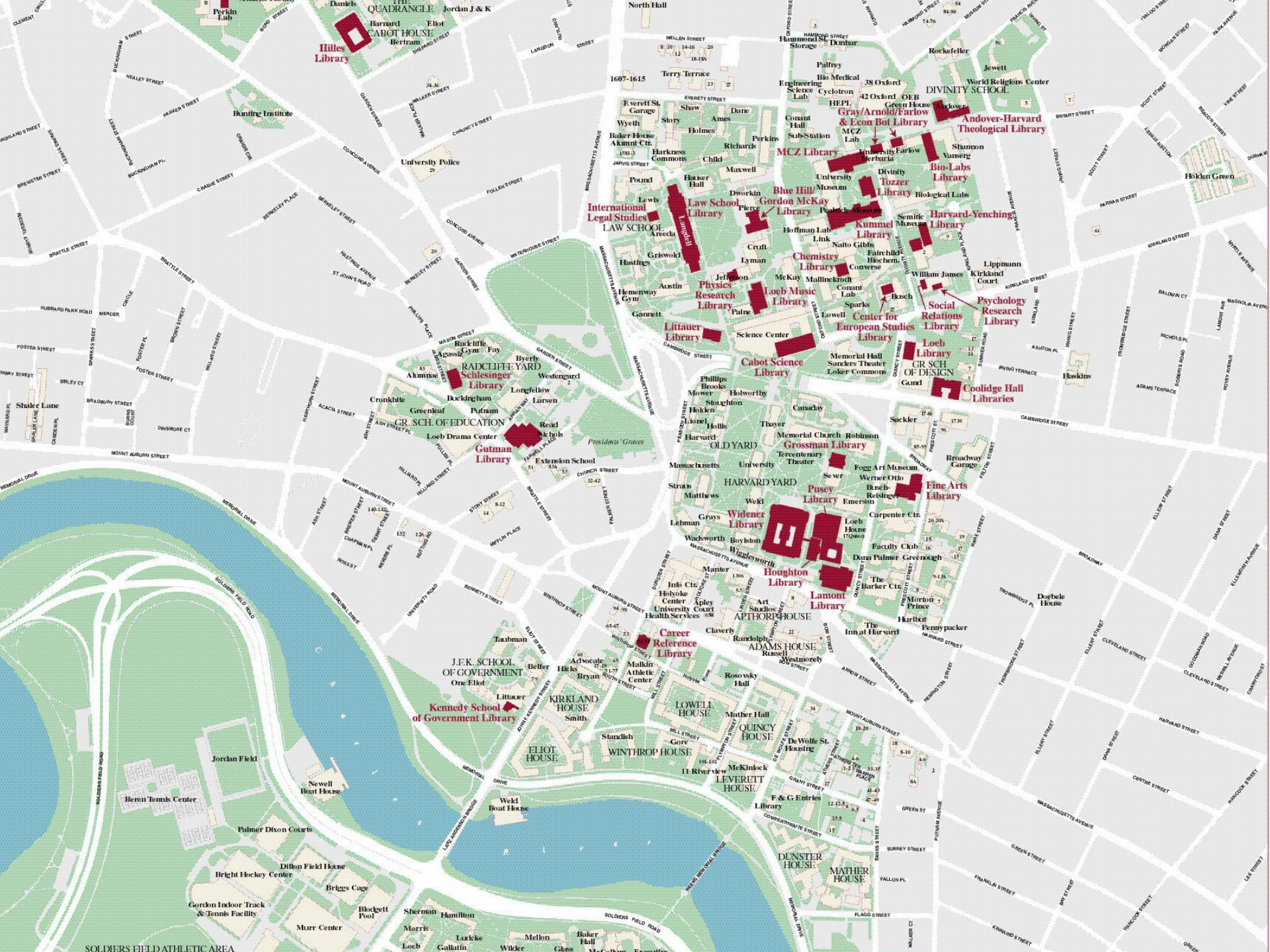
Contents [hide]
1 Root canal treatment
2 Innovation
3 Procedural accidents
4 Success and prognosis
5 Systemic issues
6 Alternatives to root canal treatment
7 See also
8 References
9 External links



Search the web and fix it yourself?

...or look for a dentist

If knowledge increases, where do you store it?


Hilles Library
Gray/Arnold/Farlow & Econ Bot Library
Andover-Harvard Theological Library
MCZ Library
Bio-Labs Library
Tozzer Library
Law School Library
Blue Hill/Gordon McKay Library
International Legal Studies
Harvard-Yenching Library
Kummel Library
Chemistry Library
Physics Research Library
Loeb Music Library
Social Relations Library
Psychology Research Library
Center for European Studies Library
Littauer Library
Cabot Science Library
Loeb Library
Coolidge Hall Libraries
Schlesinger Library
Gutman Library
Grossman Library
Fine Arts Library
Pusey Library
Widener Library
Houghton Library
Lamont Library
Career Reference Library
Kennedy School of Government Library
Memorial Church
Science Center
Memorial Hall
Sanders Theater
Loker Commons
Gund
Sackler
Fogg Art Museum
Werner Otto
Busch-Reisinger
Carpenter Ctr.
Loeb House
Faculty Club
Dana Palmer
Greenough
Barker Ctr.
Morton
Prince
Hurlbut
Pennypacker
The Inn at Harvard
Dunster House
Mather House
Lowell House
Quincy House
Eliot House
Winthrop House
Leverett House
Kirkland House
Adams House
Apthorp House
Currier House
Radcliffe Yard
Gr. Sch. of Education
Gr. Sch. of Design
Old Yard
Harvard Yard
Holden Green
Divinity School
Peabody Museum
Semitic Museum
Fairchild Biochem.
Lippmann
Kirkland Court
William James
Busch
Sparks
Lowell
Conant Lab
Mallinckrodt
McKay
Jefferson
Lyman
Cruft
Griswold
Hastings
Austin
Hemenway Gym
Gannett
Paine
Pierce
Lewis
Dworkin
Pound
Hauser
Maxwell
Child
Harkness Commons
Richards
Perkins
Sub-Station
Conant Hall
MCZ Lab
Farlow Herbaria
Vanserg
Shannon
Biological Labs
University Museum
Divinity
Andover
Green House
OEB
42 Oxford
38 Oxford
Engineering Science Lab
Cyclotron
Bio Medical
Jewett
Rockefeller
Palfrey
Dumbar
Hammond St. Storage
North Hall
Terry Terrace
1607-1615
Everett St. Garage
Shaw
Dane
Ames
Story
Wyeth
Holmes
Baker House Alumni Ctr.
Harvard Law School
Langdell
Law School
Areeda
Griswold
Hastings
Lyman
Cruft
Jefferson

Major areas of concentration at Harvard

50

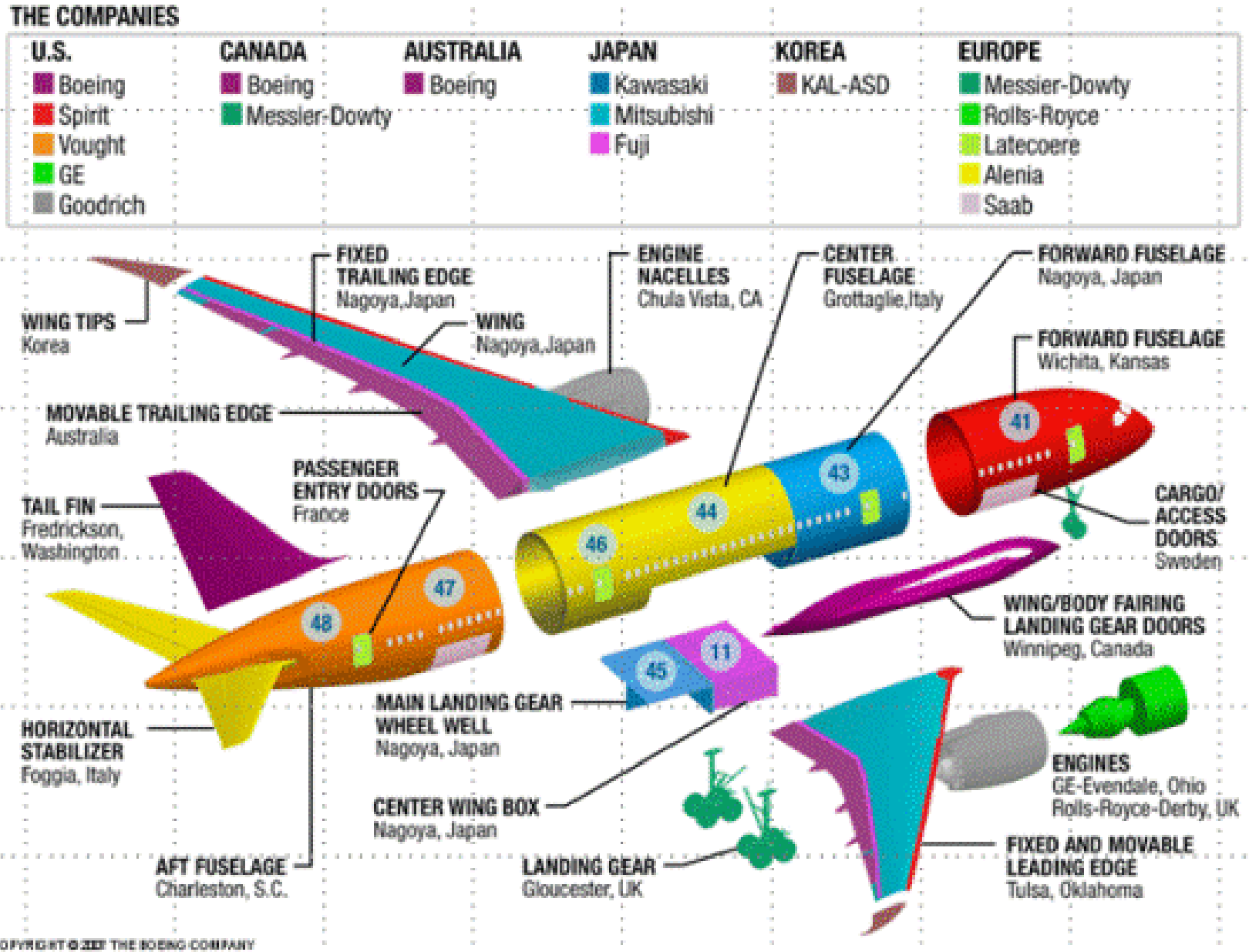
Standard Fields of Study

- African and African American Studies
- Anthropology
- Applied Mathematics
- Astrophysics
- Biomedical Engineering
- Chemical and Physical Biology
- Chemistry
- Chemistry and Physics
- Classics
- Computer Science
- Earth and Planetary Sciences
- East Asian Studies
- Economics
- Engineering Sciences
- English
- Environmental Science and Public Policy
- Folklore and Mythology
- Germanic Languages and Literatures
- Government
- History
- History and Literature
- History and Science
- History of Art and Architecture
- Human Developmental Biology
- Human Evolutionary Biology
- Linguistics
- Literature
- Mathematics
- Molecular and Cellular Biology
- Music
- Near Eastern Languages and Civilizations
- Neurobiology
- Organismic and Evolutionary Biology
- Philosophy
- Physics
- Psychology
- Comparative Study of Religion
- Romance Languages and Literatures
- Slavic Languages and Literatures
- Social Studies
- Sociology
- South Asian Studies
- Special Concentrations
- Statistics
- Visual and Environmental Studies
- Studies of Women, Gender, and Sexuality

How do we use productive knowledge

- Products differ in the number of personbytes they require
- To create products with more than 1 personbyte, you need to aggregate personbytes
- This is done in networks of individuals we call firms
  - Firms can do things individuals cannot
- ...and in networks of firms
  - Firms cannot make all they need

Nikon
D200
感謝キャン
プレゼ
Nikon
Nikon
D70s
D70S
Yodobashi-Camera



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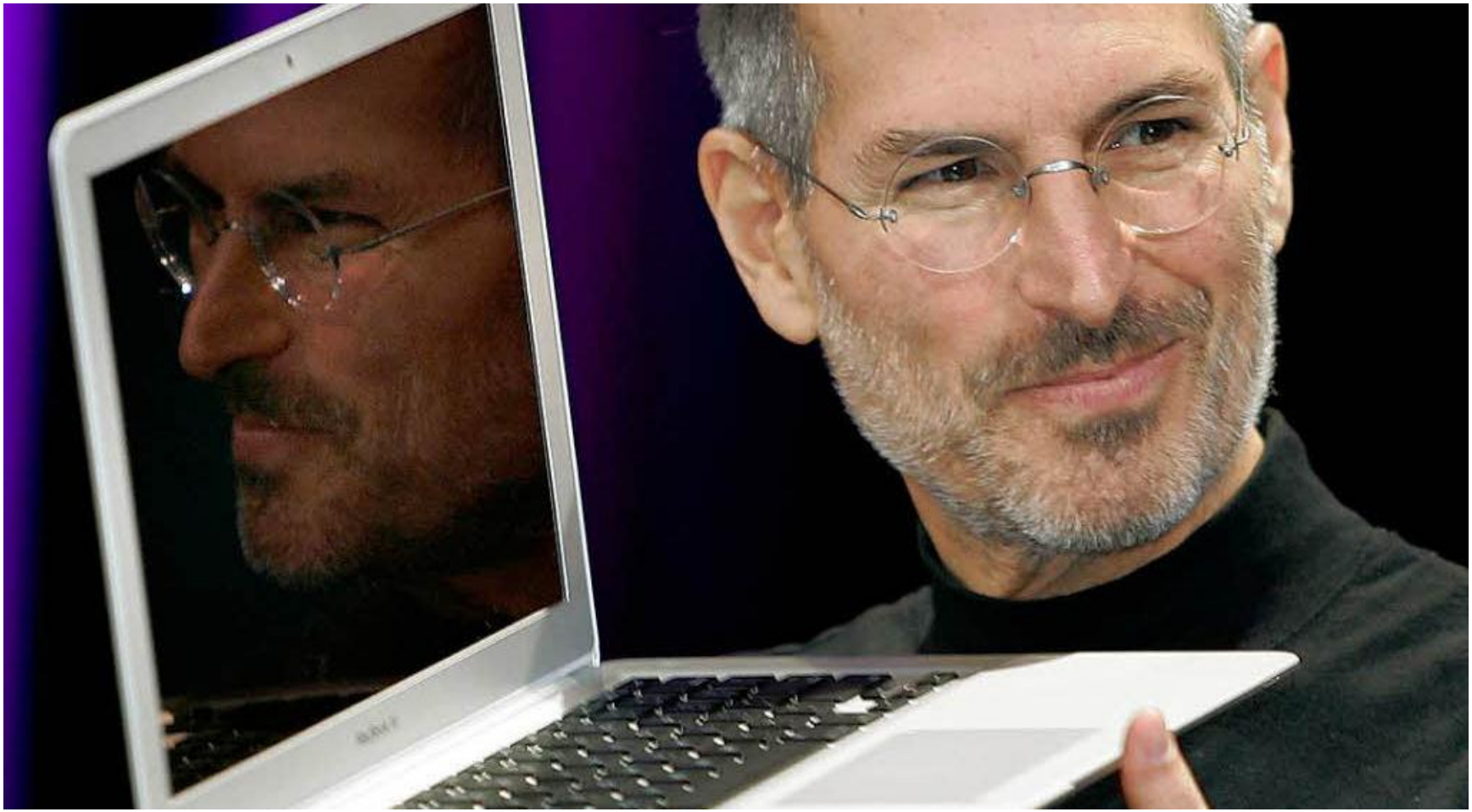
FACTOID
(from Klenow and Hsieh, 2011)

- In the US the average employee works in an organization with 100 workers
- India has 4 times the population of the US
- 100 * 4 = 400?
- In India, the number is 4
- How many personbytes can you embed in a product in a firm of 4 people?
- What does it say about the productivity of micro-enterprises and the informal sector?

Steve Jobs did not know how to make a computer



The Oscars

- Actor in a Leading Role
- Actor in a Supporting Role
- Actress in a Leading Role
- Actress in a Supporting Role:
- Animated Feature:
- Animated Short Film:
- Cinematography
- Costume Design
- Director
- Documentary Feature:
- Documentary Short
- Film Editing
- Foreign Language Film
- Live Action Short Film
- Makeup and Hairstyling:
- Original Score

- Original Song
- Picture
- Production Design
- Sound Editing
- Sound Mixing
- Visual Effects:
- Adapted Screenplay
- Original Screenplay
- Original Musical

Proposed Categories

- Casting
- Stunt Coordination
- Title Design

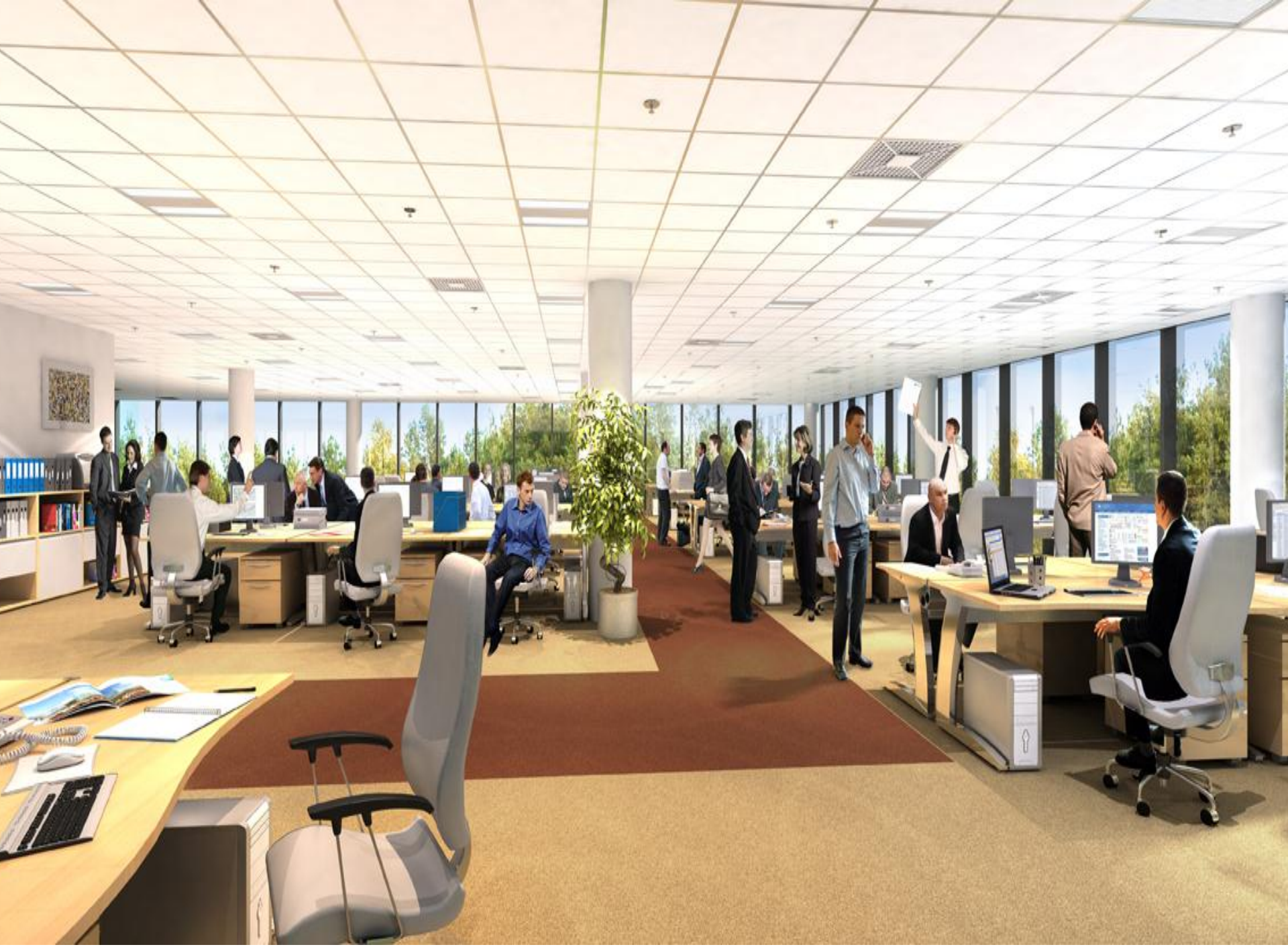
THE DIVISION OF KNOWLEDGE VS. THE DIVISION OF LABOR

Division of knowledge then

BUTCHER

BAKER

CANDLESTICK MAKER

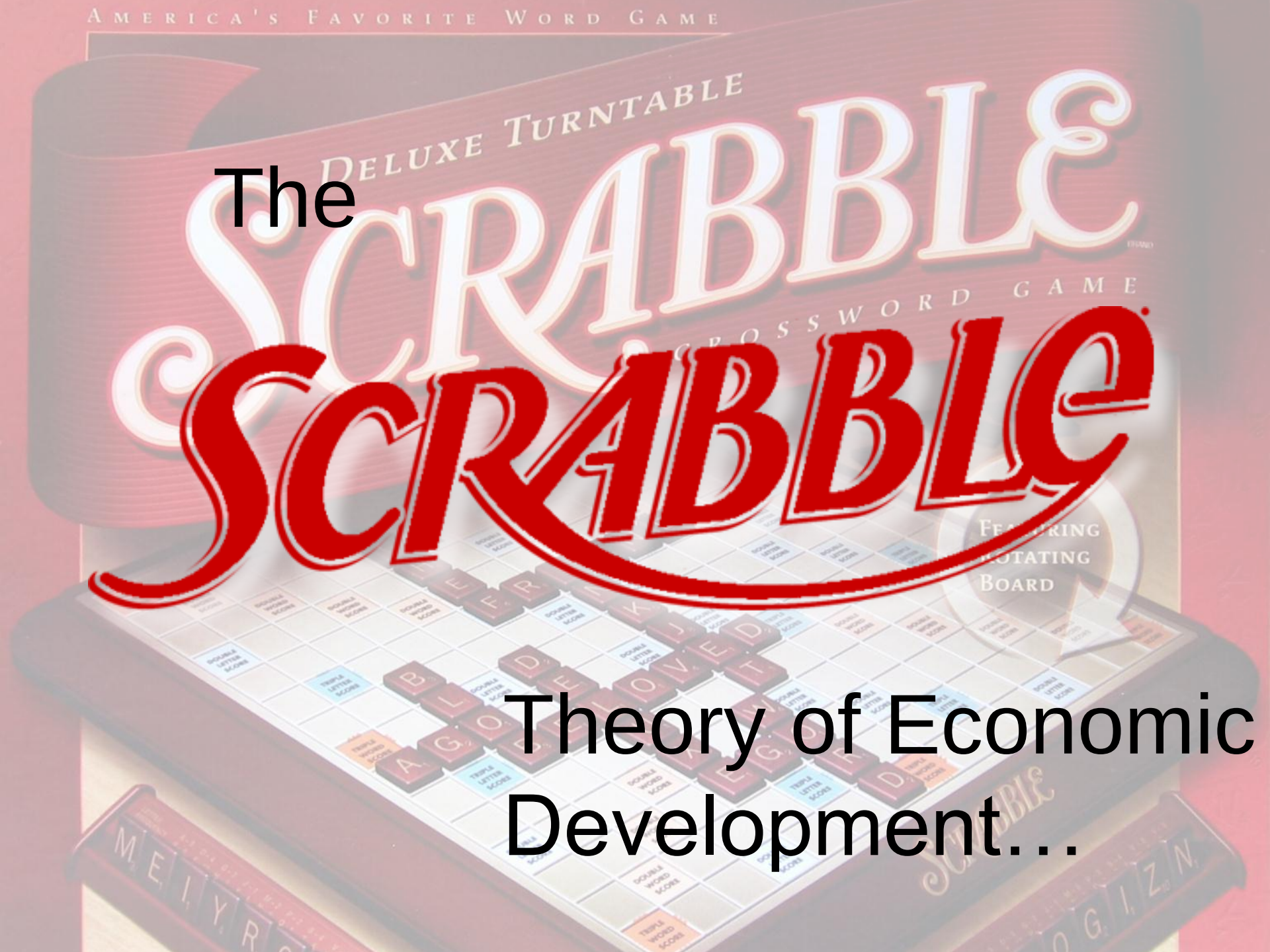


Division of knowledge now

The differences: the number of personbytes

In sum,

- We are not richer because we individually hold more knowledge
- …but because more knowledge is held at the social level
- We are limited in the amount of knowledge we can individually hold
  - Call that 1 personbyte
- …so the only way we can have more knowledge at the social level is through the division of knowledge (and hence of labor)
- Why do we know more than the Inuits?
  - Because they each individually hold all the PK and we hold only a small fraction
- Most of modern production requires many personbytes
- These are put together in networks of people we call firms
- …and in networks of firms
- Why, in this setting, does technology not diffuse across countries?



The

Theory of Economic Development…

If you have only one letter…

… there aren’t many words to write.

If you have three letters…

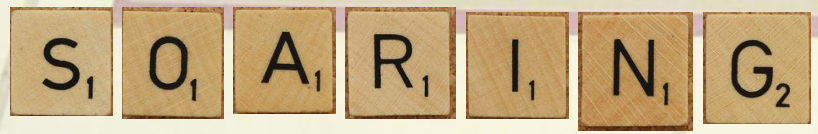
You can write 4 words:

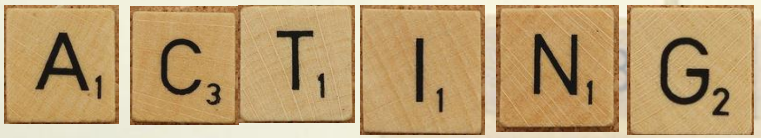
Now you have four letters…

You can write 8 words:

Think about all the words you could write with:

You could write 595 words such as:





INTUITION

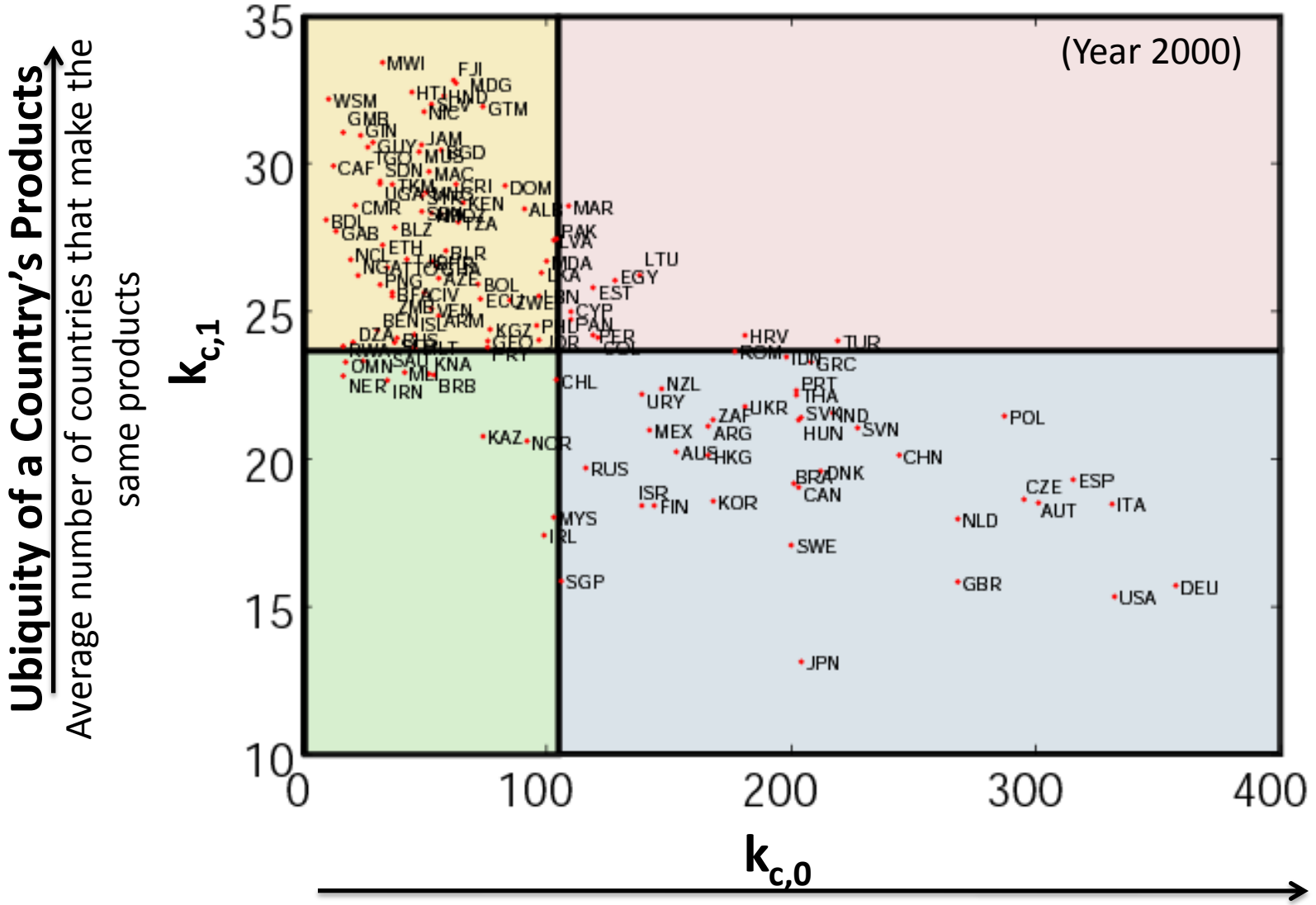
- Countries that have more personbytes will be able to make more products
  They would be more diversified

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

- Countries that have more personbytes will be able to make products that require more personbytes
- Products that are less ubiquitous

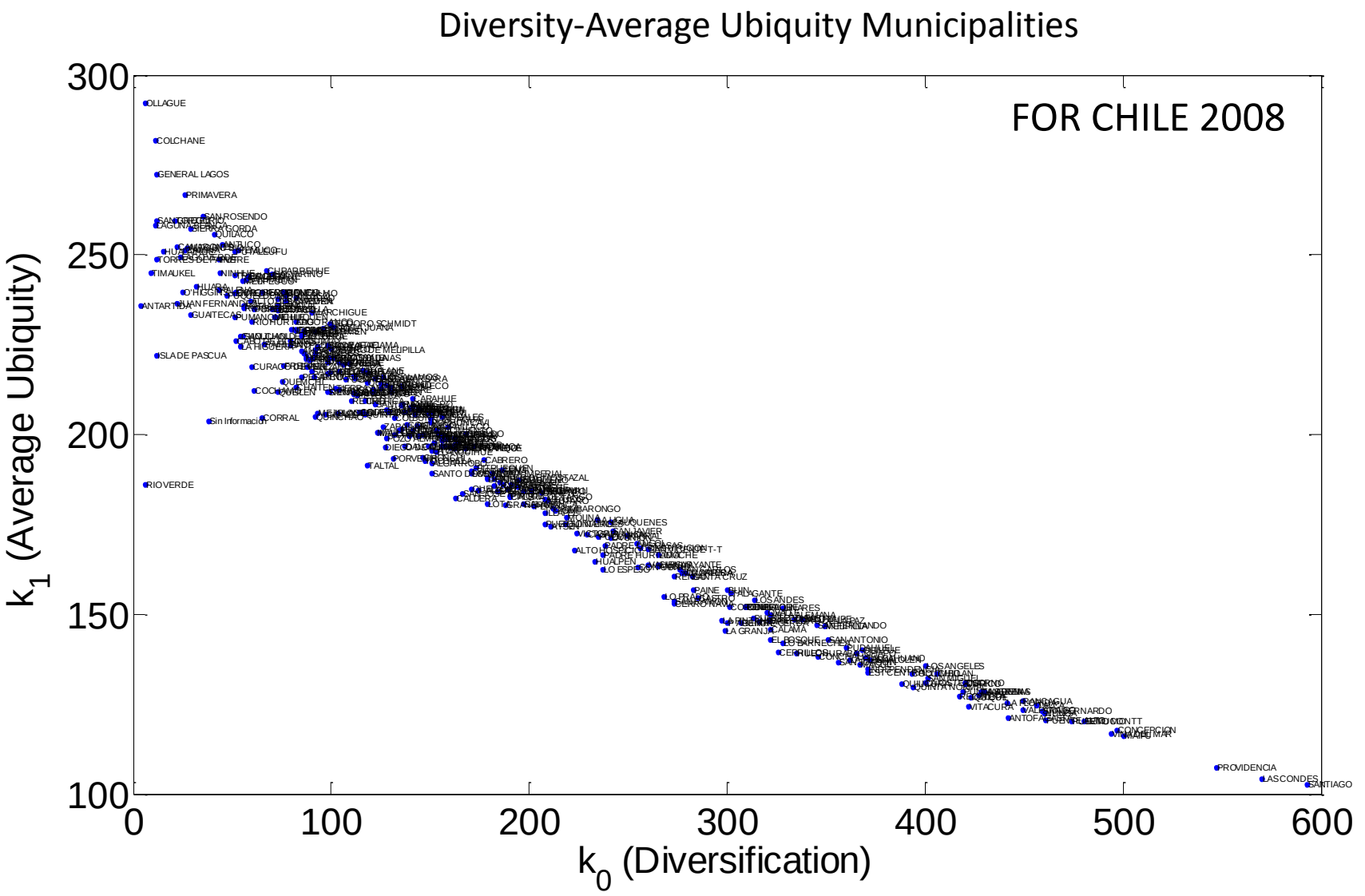
- Products that require many personbytes are made countries that have many personbytes, but countries with many personbytes should be more diversified

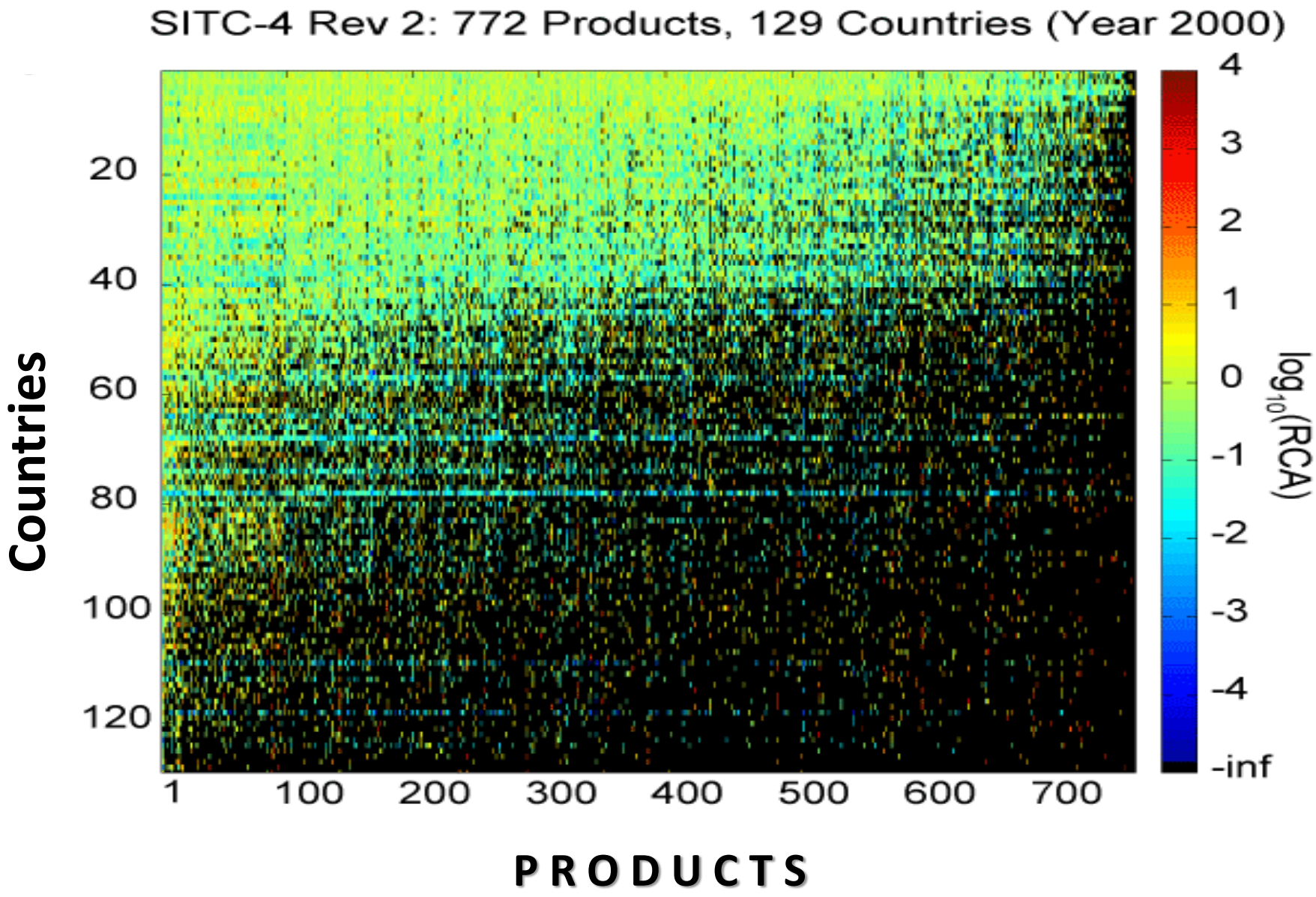
Evidence of the Connection between the diversity of inputs and that of outputs



Hidalgo, Hausmann (2009)
PNAS 106(**26**):10570-10575

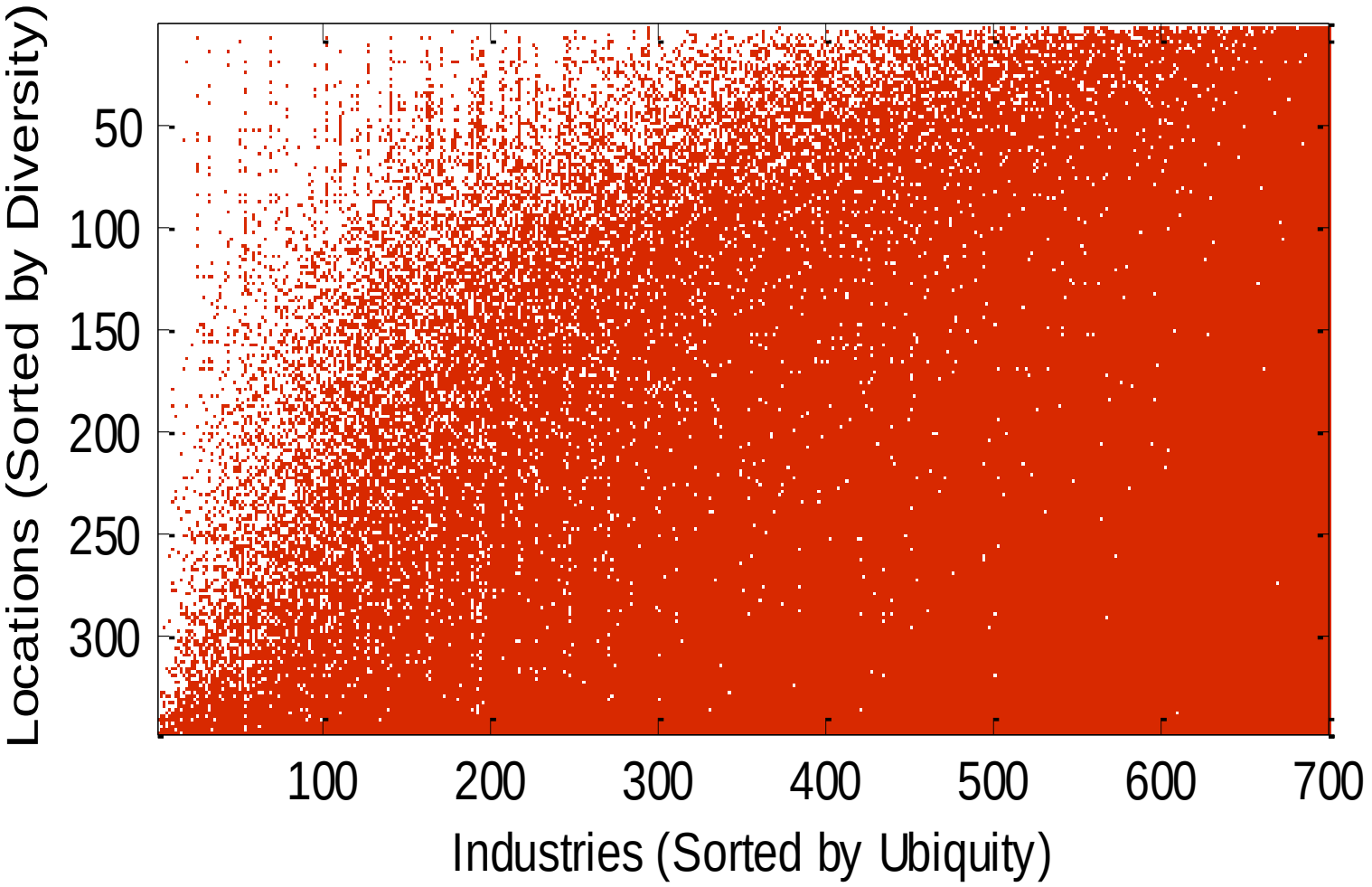
It also works within countries: Chile



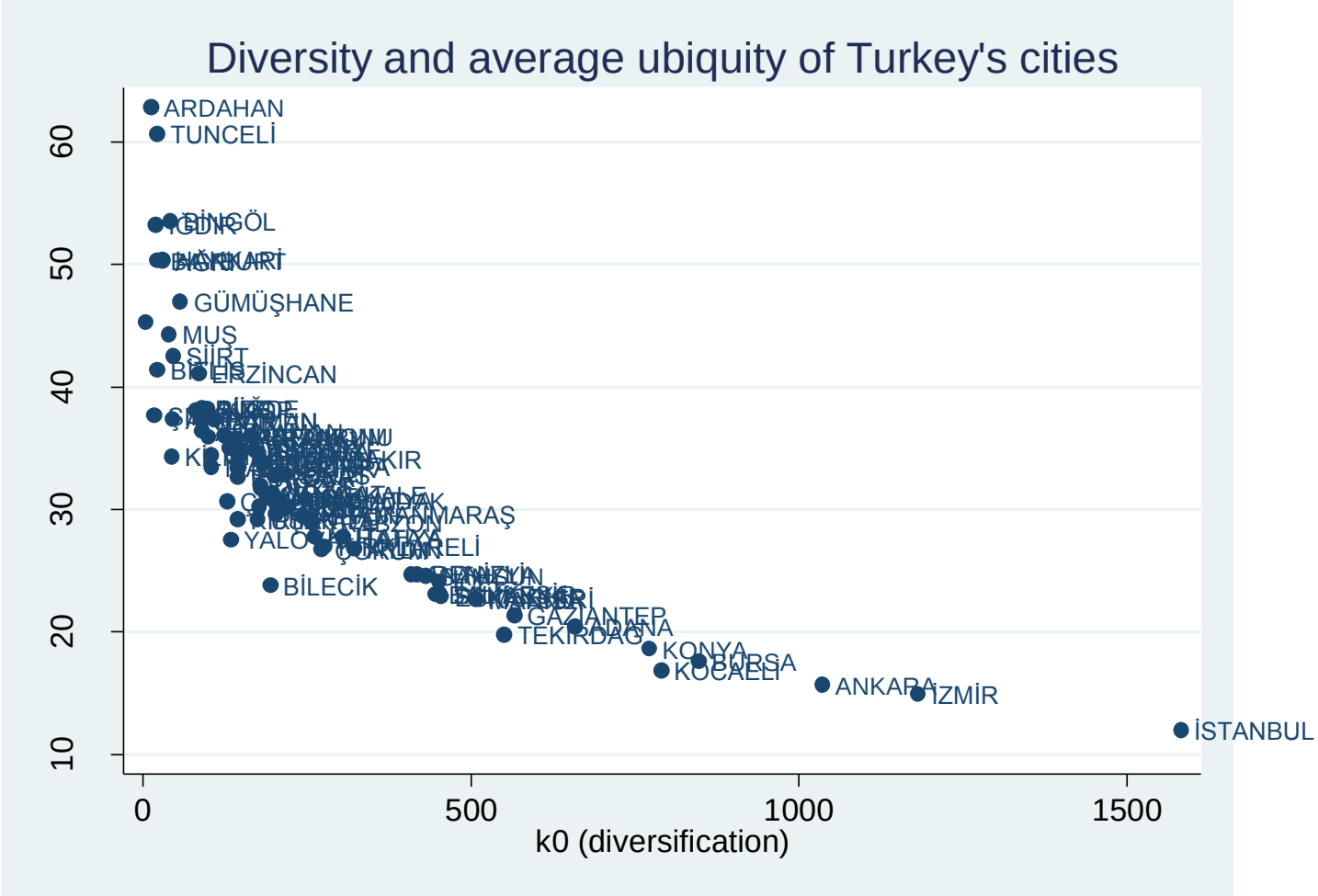

SITC-4 Rev 2: 772 Products, 129 Countries (Year 2000)
Countries
20
40
60
80
100
120
1
100
200
300
400
500
600
700
PRODUCTS
4
3
2
1
0
-1
-2
-3
-4
-inf
log10(RCA)

Happens within countries too:

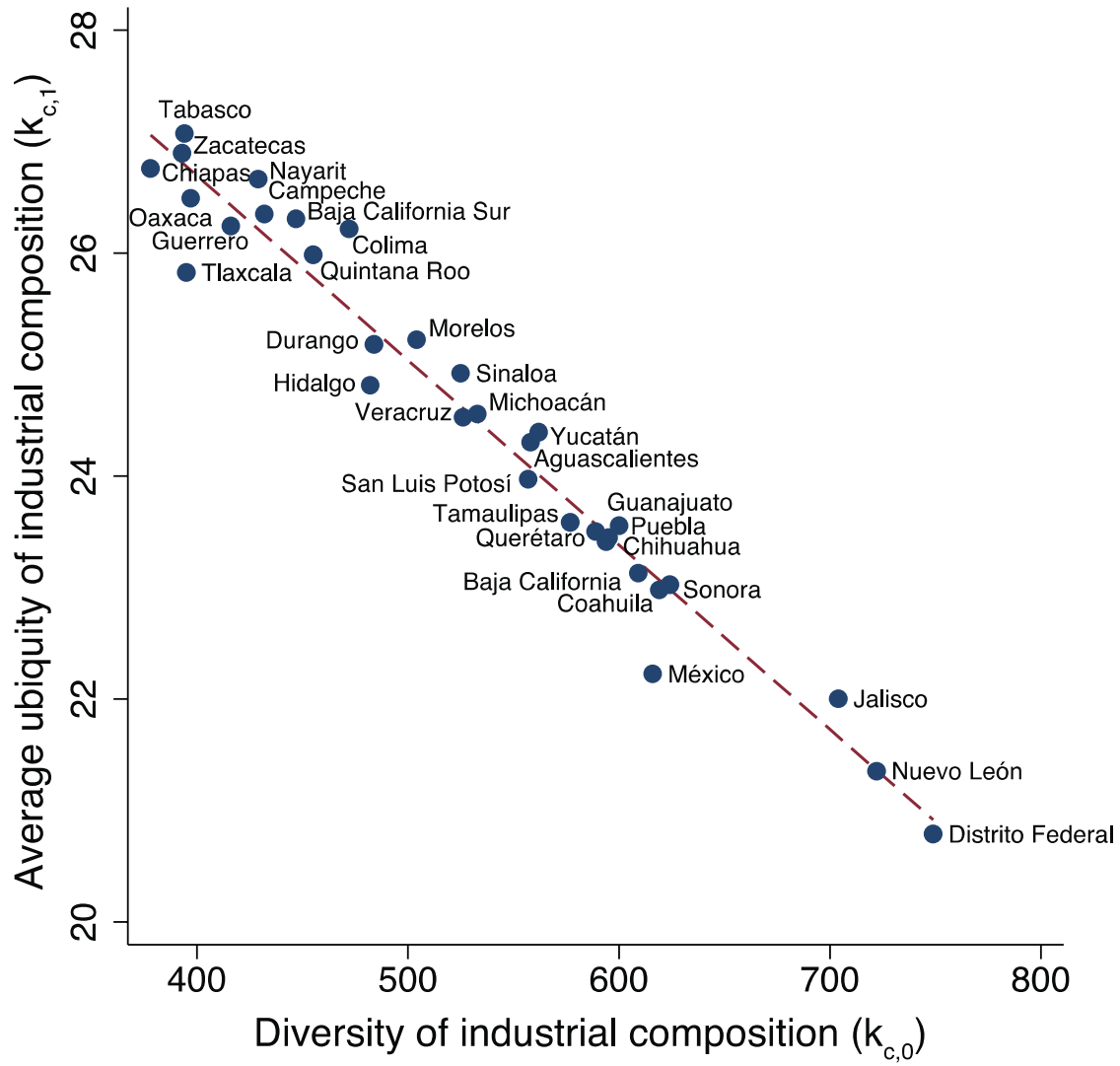
Chile



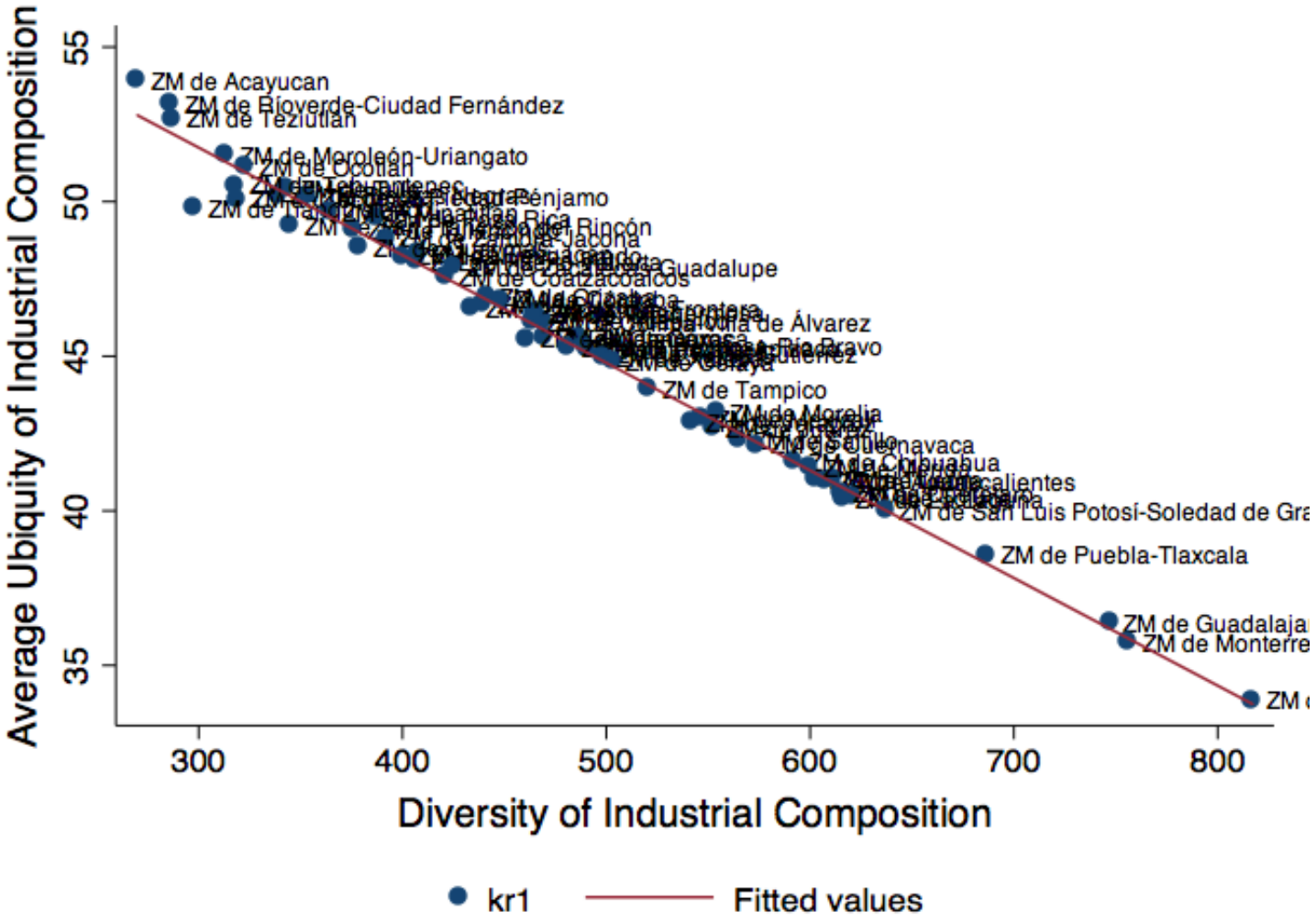
…and Turkey


Diversity and average ubiquity of Turkey's cities
ARDAHAN
TUNCELİ
GÜMÜŞHANE
MUŞ
ERZİNCAN
BİLECİK
GAZİANTEP
TEKİRDAĞ
KONYA
KOCAELİ
ANKARA
İZMİR
İSTANBUL
10
20
30
40
50
60
0
500
1000
1500
k0 (diversification)

Mexican States

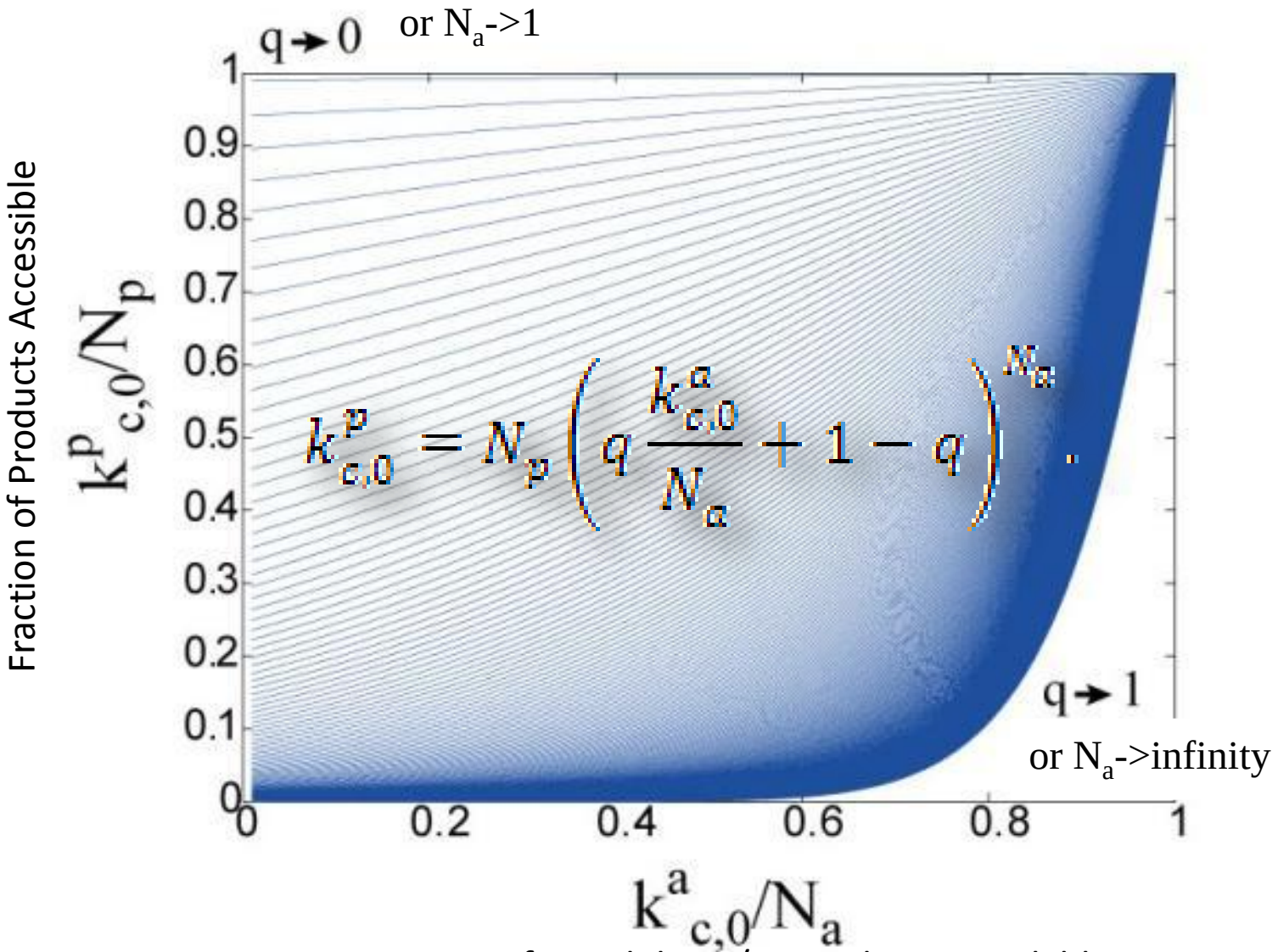


Mexican cities



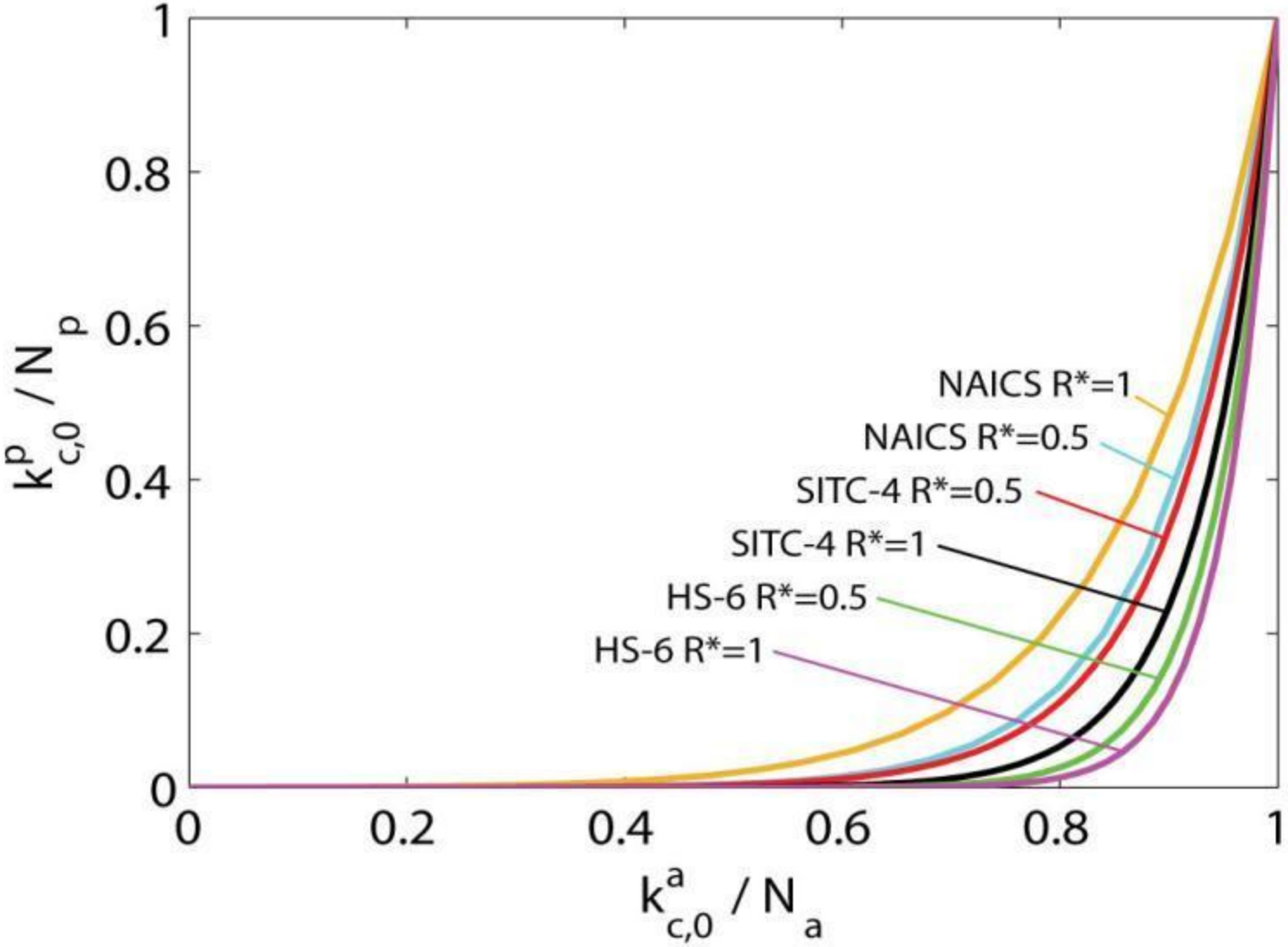
The Great Acceleration and the Great Divergence

Relationship between letters and words



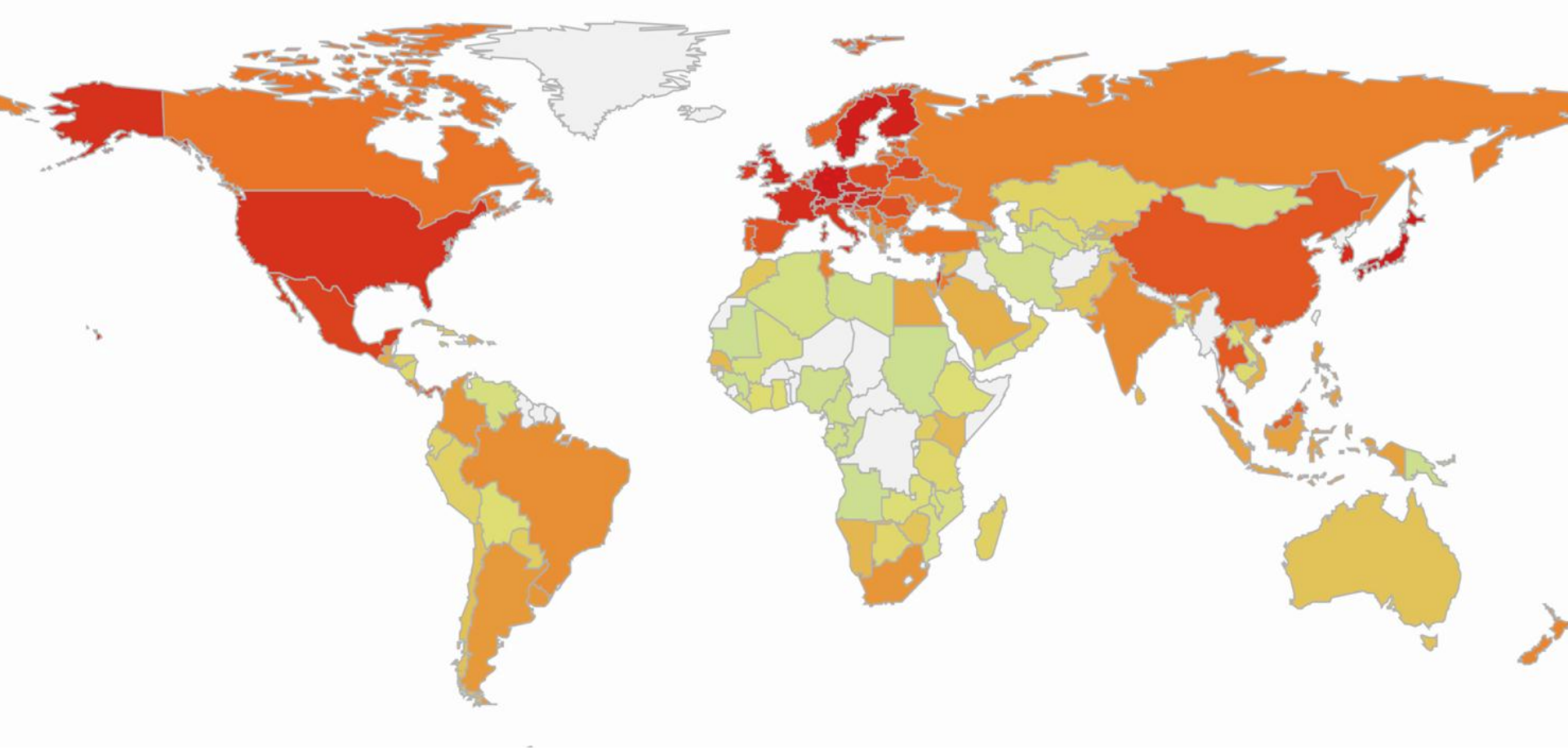
Hausmann and Hidalgo (2011) JOEG

The deep cause of the Great Divergence

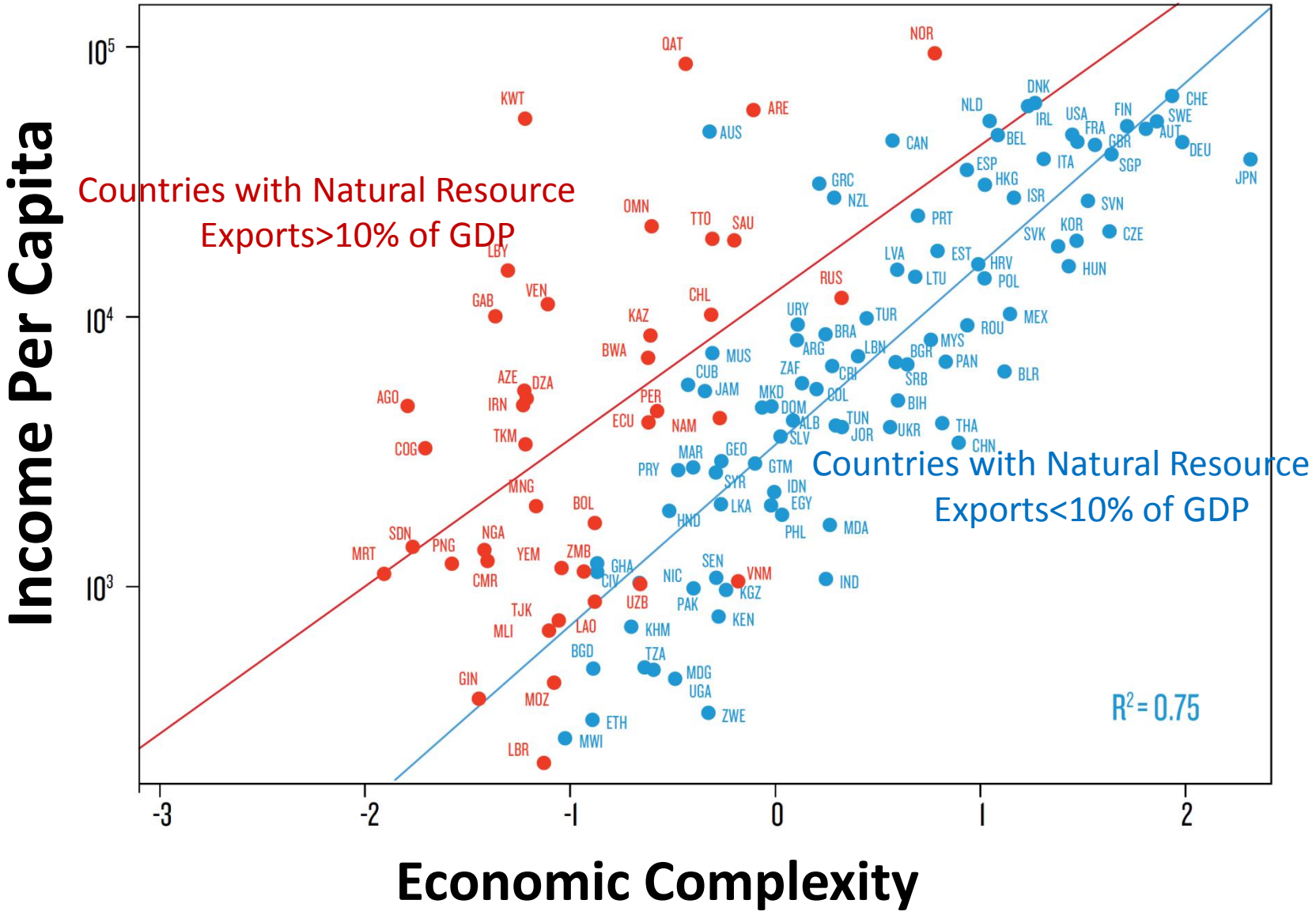


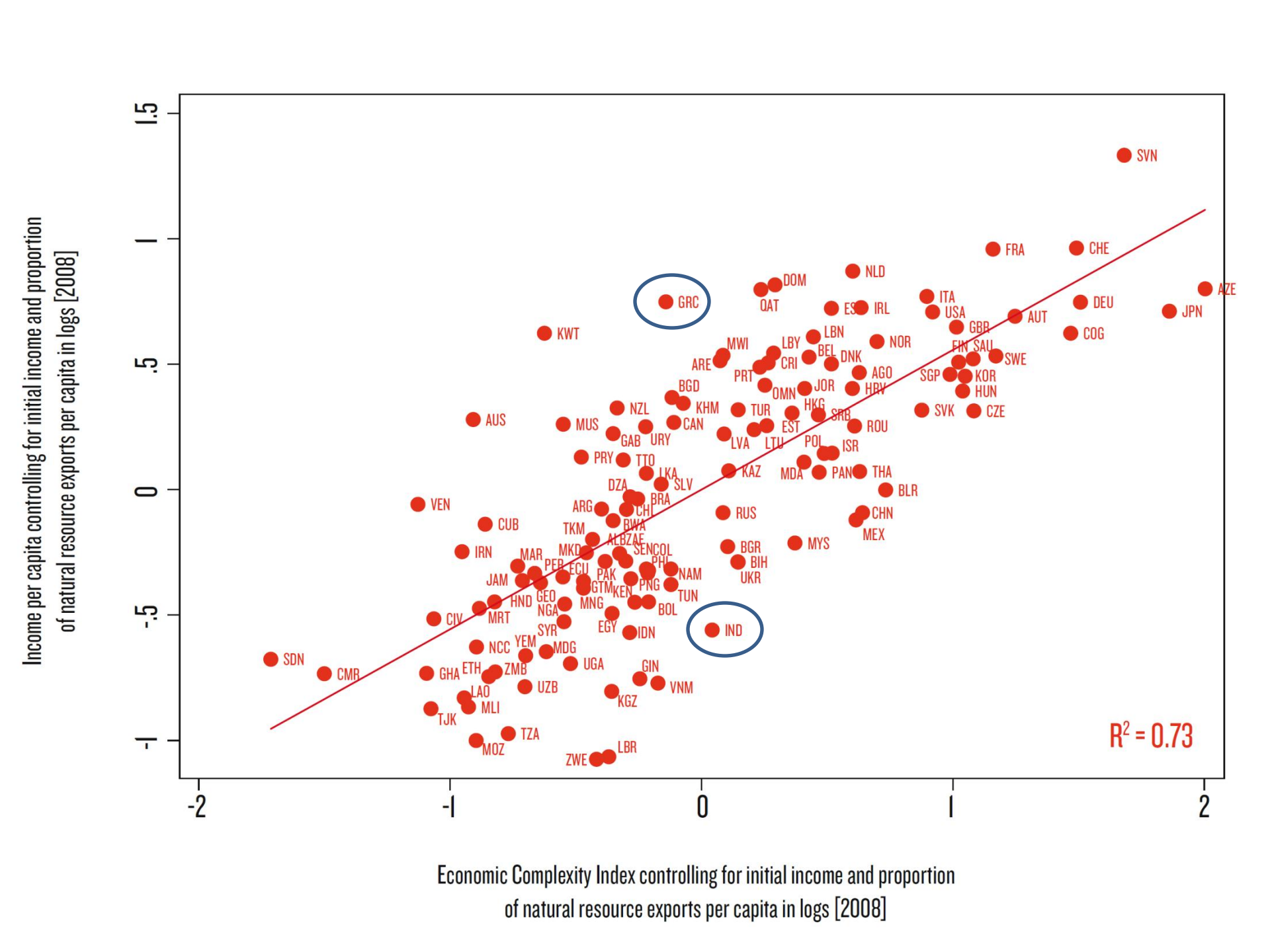
How do we measure a country's personbytes?

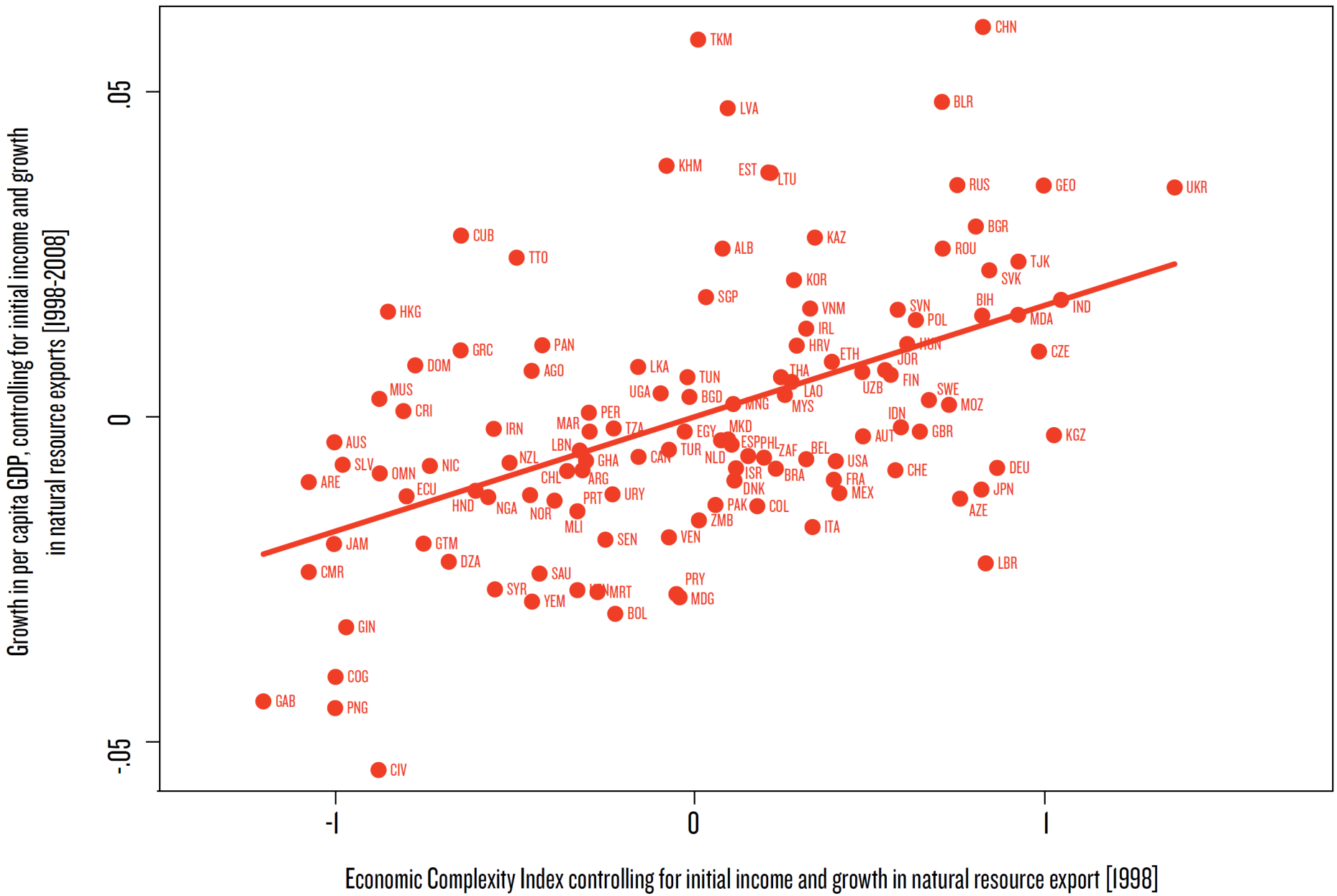
Economic Complexity Index



ECI correlates with GDP per capita




Income per capita controlling for initial income and proportion of natural resource exports per capita in logs [2008]
Economic Complexity Index controlling for initial income and proportion of natural resource exports per capita in logs [2008]
1.5
1
.5
0
-.5
-1
-2
-1
0
1
2
R^2 = 0.73
SVN
FRA
CHE
AZE
NLD
DOM
QAT
GRC
ITA
USA
DEU
JPN
ES
IRL
AUT
GBR
COG
KWT
LBN
NOR
MWI
LBY
BEL
DNK
FIN
SAU
SWE
ARE
CRI
PRT
AGO
SGP
KOR
BGD
OMN
JOR
HRV
HUN
HKG
NZL
KHM
TUR
SRB
SVK
CZE
AUS
MUS
CAN
EST
ROU
GAB
URY
LVA
LTU
POL
ISR
PRY
TTO
LKA
KAZ
MDA
PAN
THA
DZA
SLV
BLR
BRA
VEN
ARG
CHL
RUS
CHN
CUB
BWA
TKM
MEX
ALB
ZAE
IRN
MKD
SEN
COL
BGR
MYS
MAR
PHL
BIH
PER
ECU
PAK
NAM
UKR
JAM
GTM
KEN
PNG
TUN
HND
GEO
MNG
BOL
CIV
MRT
NGA
EGY
IND
SYR
IDN
NCC
YEM
MDG
SDN
CMR
UGA
GIN
GHA
ETH
ZMB
VNM
LAO
UZB
KGZ
MLI
TJK
TZA
MOZ
LBR
ZWE



Growth in per capita GDP, controlling for initial income and growth in natural resource exports [1998-2008]
.05
0
-.05
-1
0
1
Economic Complexity Index controlling for initial income and growth in natural resource export [1998]
CHN
TKM
LVA
BLR
KHM
EST
LTU
RUS
GEO
UKR
BGR
CUB
KAZ
ALB
ROU
TTO
TJK
SVK
KOR
SGP
BIH
IND
HKG
VNM
SVN
POL
MDA
IRL
HRV
HUN
CZE
GRC
PAN
ETH
JOR
DOM
AGO
LKA
TUN
THA
FIN
UZB
MUS
UGA
BGD
LAO
SWE
MNG
MYS
MOZ
CRI
PER
IDN
MAR
TZA
EGY
MKD
IRN
AUT
GBR
KGZ
AUS
LBN
ESP
PHL
ZAF
BEL
TUR
NLD
USA
SLV
NIC
NZL
GHA
CAN
ISR
BRA
CHE
DEU
OMN
CHL
ARG
FRA
ARE
ECU
DNK
MEX
JPN
HND
NGA
PRT
URY
PAK
COL
AZE
NOR
ZMB
MLI
ITA
JAM
GTM
SEN
VEN
DZA
LBR
CMR
SAU
PRY
SYR
MRT
MDG
YEM
BOL
GIN
COG
GAB
PNG
CIV

How are personbytes accumulated?

SO, HOW **DO** SOCIETIES ACQUIRE PRODUCTIVE KNOWLEDGE?

- *Productive knowledge is tacit: very hard to acquire*
  - Knowledge resides in the brains of people...
  - ... It is easier to move the brains than the knowledge
  - As a result, knowledge diffuses only slowly and across narrow channels

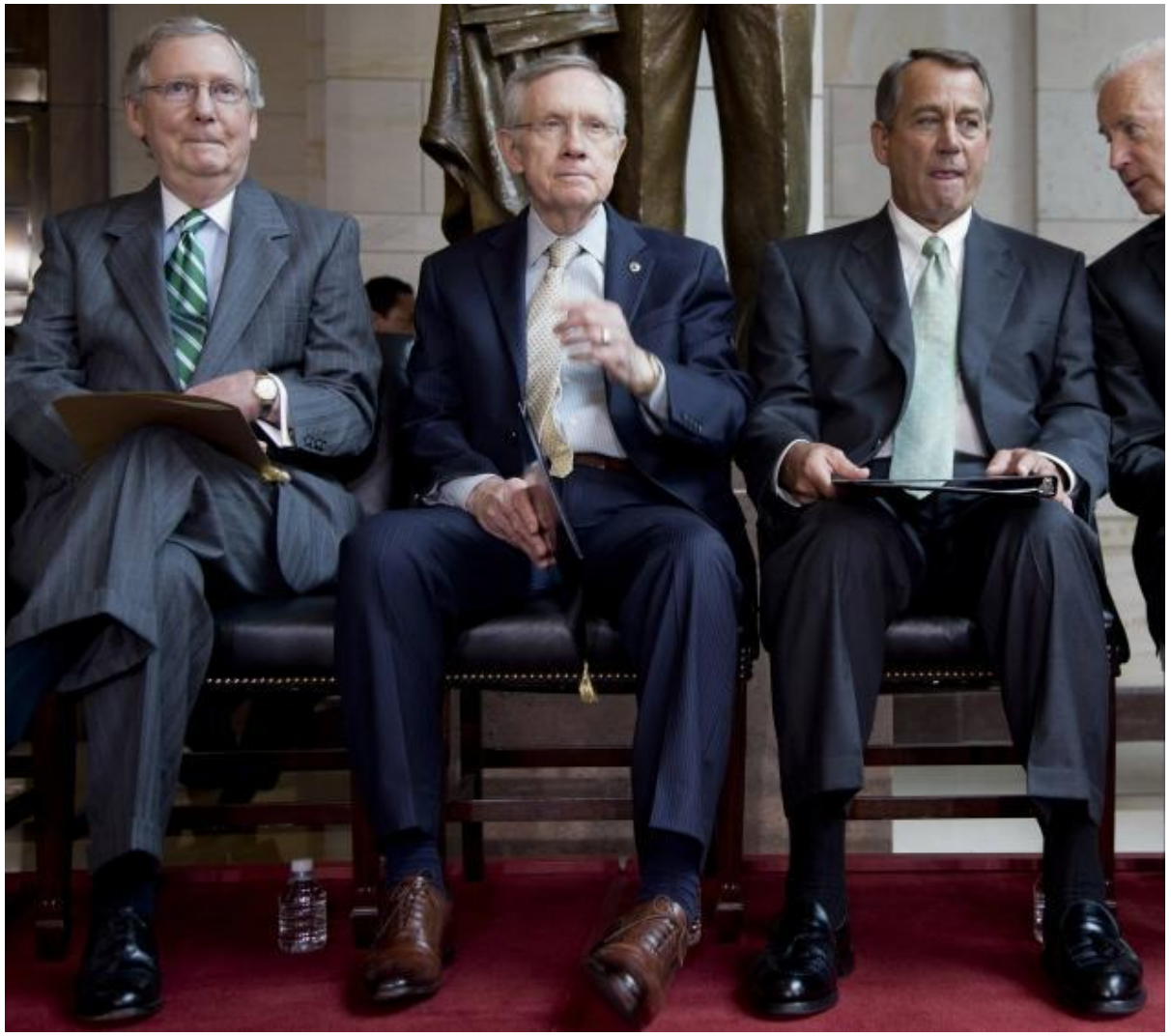
- *… and requires teams with complementary skills*
  - You need all the letters to make the word
  - In a world of increasing complexity, teams become more and more intricate
  - This makes the coordination problem exponentially harder

LEARNING AS AN INDIVIDUAL

There is little-to-no delay between feeling the temperature of a hot pan and deciding to take your hand off it.

LEARNING AS A TEAM

LEARNING AS A TEAM IS HARD



THE BIRTH OF SUCCESSFUL INDUSTRIES
STEVEN KLEPPER

NEW INDUSTRIES….

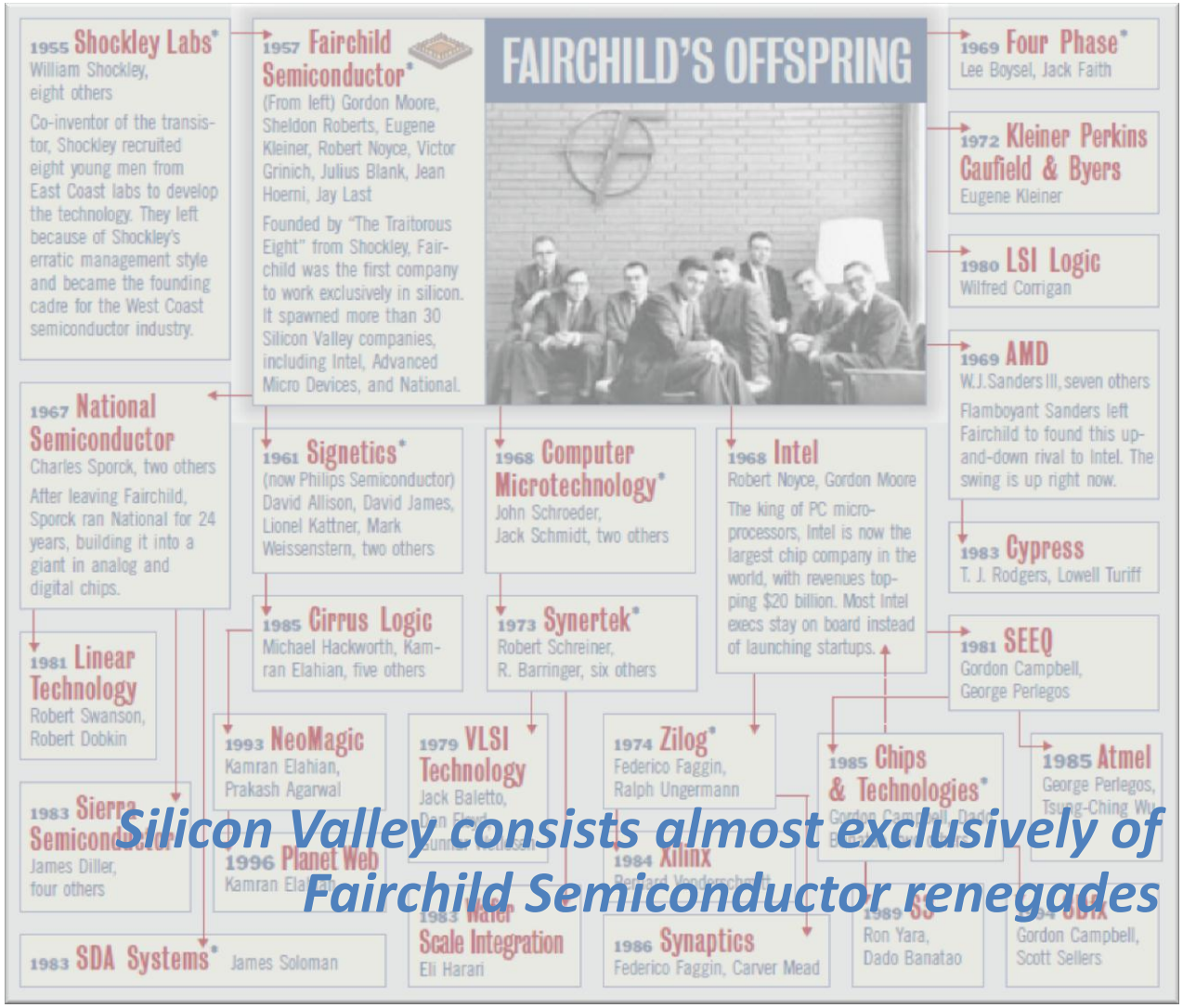
- a successful firm is established
- employees learn from the firm
- employees leave the firm to set up new firms
- spin-offs are often much more successful than other firms…
- ... and generate a new wave of spin-offs

= A CLUSTER OF HIGH PERFORMING FIRMS ARISE

Example 1: DETROIT

All successful car firms in Detroit came out of Olds Motor Works

Example 2: SILICON VALLEY



2. HOW DO SOCIETIES ACQUIRE PRODUCTIVE KNOWLEDGE

CHICKEN & EGG PROBLEM: ACQUIRING NEW PERSONBYTES

- You cannot make watches without watchmakers
- You don't want to be watchmaker if nobody makes watches
- You cannot become a watchmaker because there are no watchmakers to learn from
- You need not only watchmakers but also precision machinists, marketing teams, etc.
- How do societies overcome this problem?
- By moving into products that are "nearby"

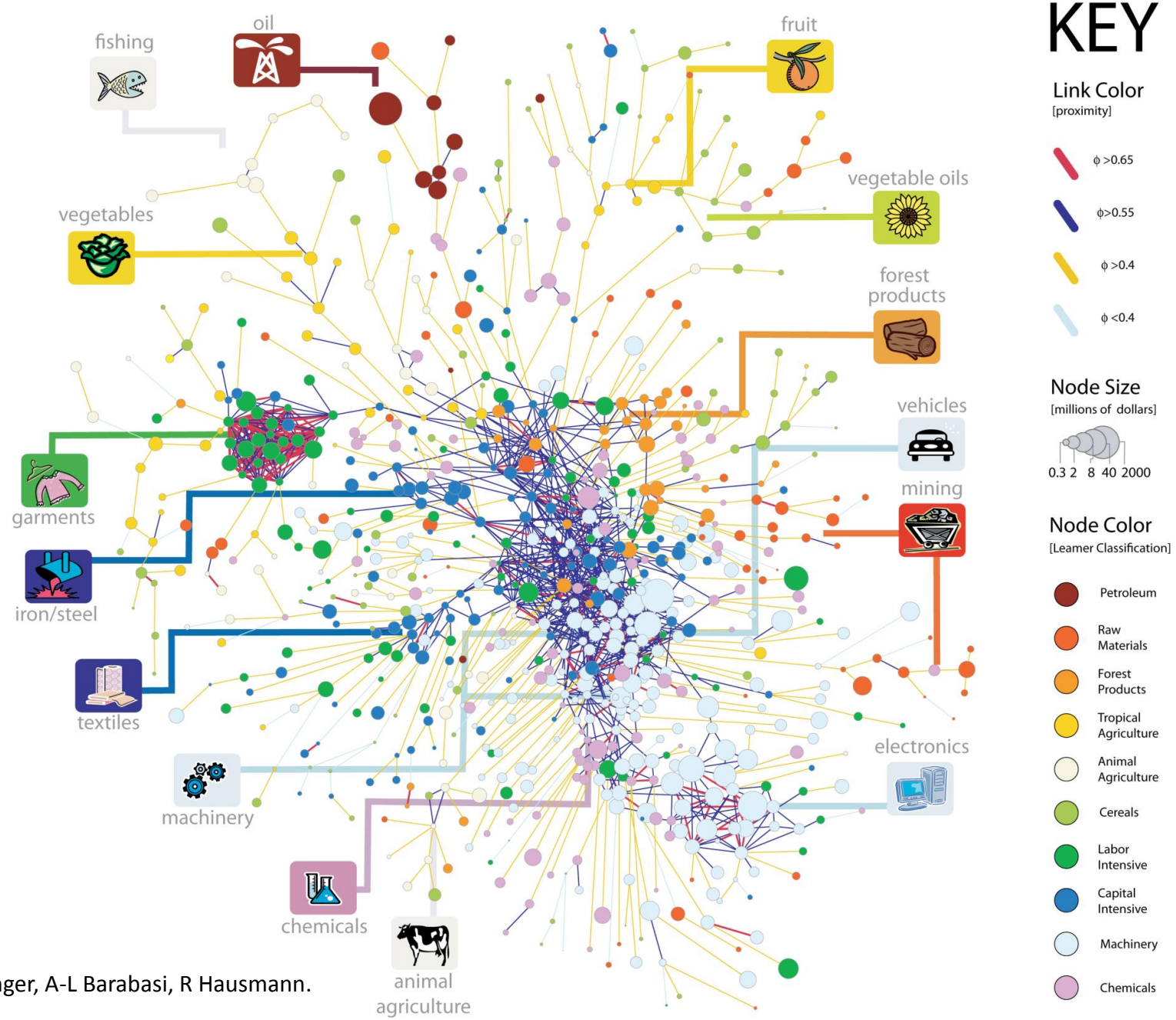
What does nearby mean?

- If two products require similar productive knowledge, countries that can make one should also be able to make the other

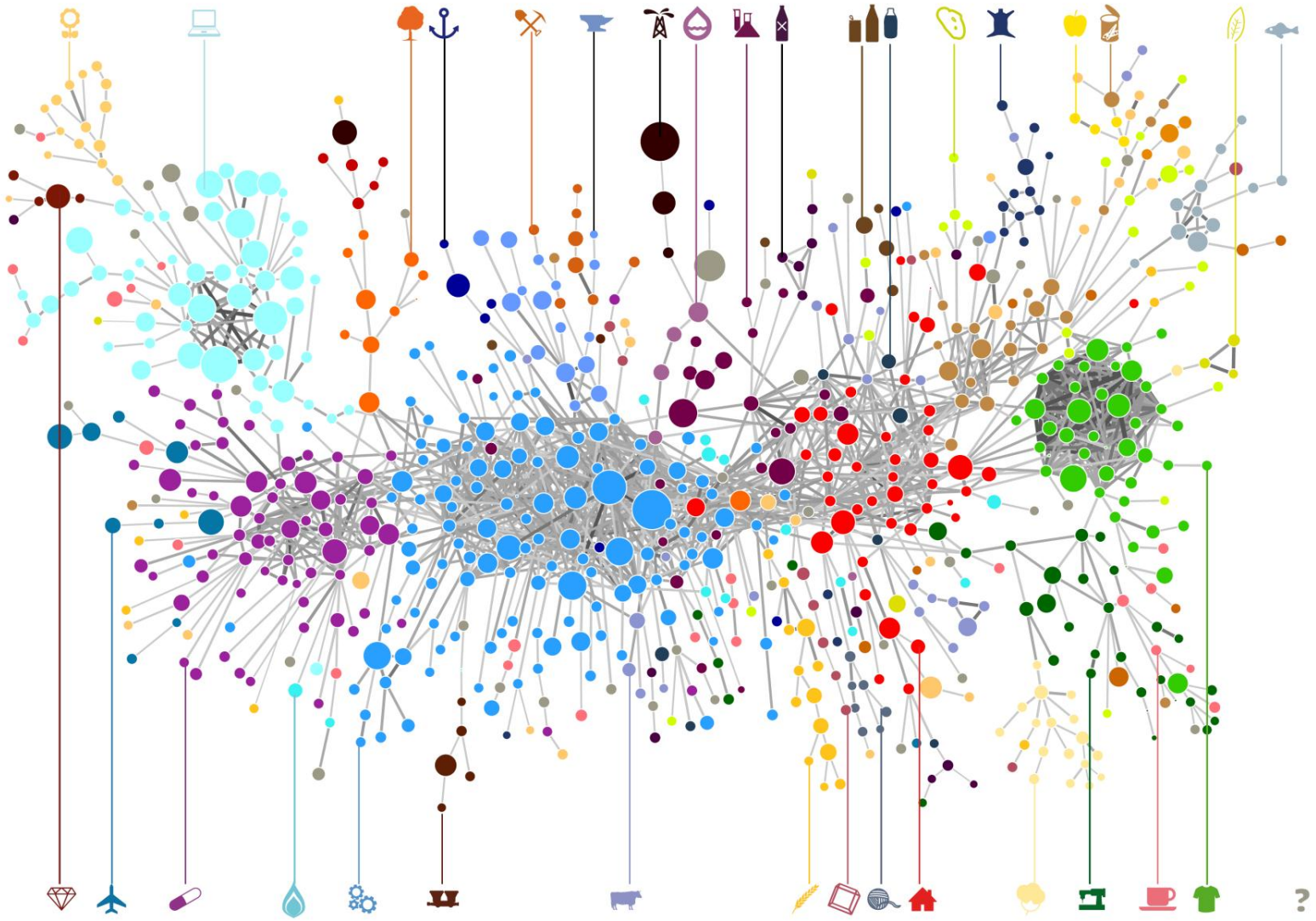
$$\emptyset_{pp'} = \frac{\sum_c M_{cp} M_{cp'}}{max(k_{p,0}, k_{p',0})}$$

- Divide by the maximum to minimize false positives

Mapping out the Forest

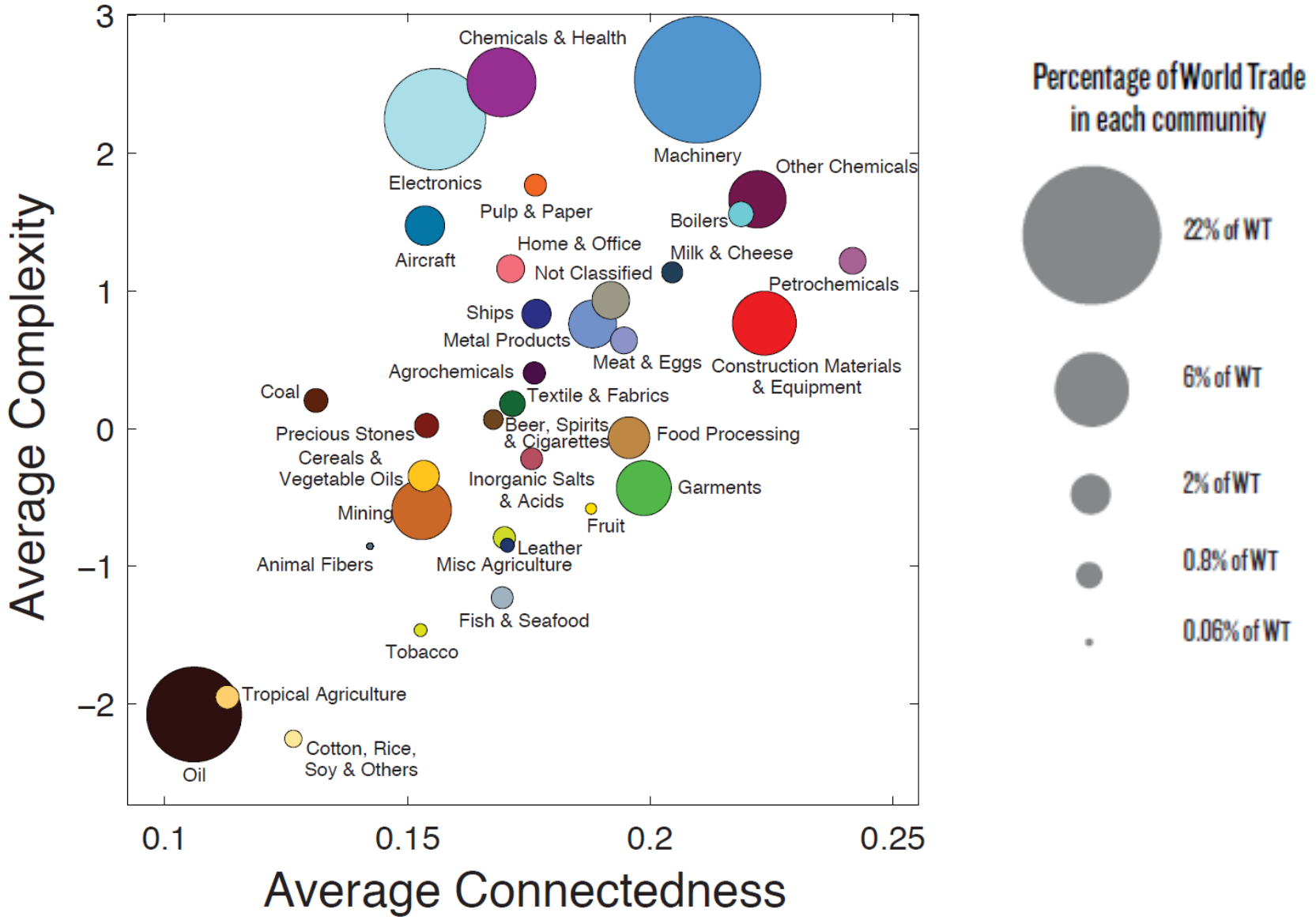


CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)

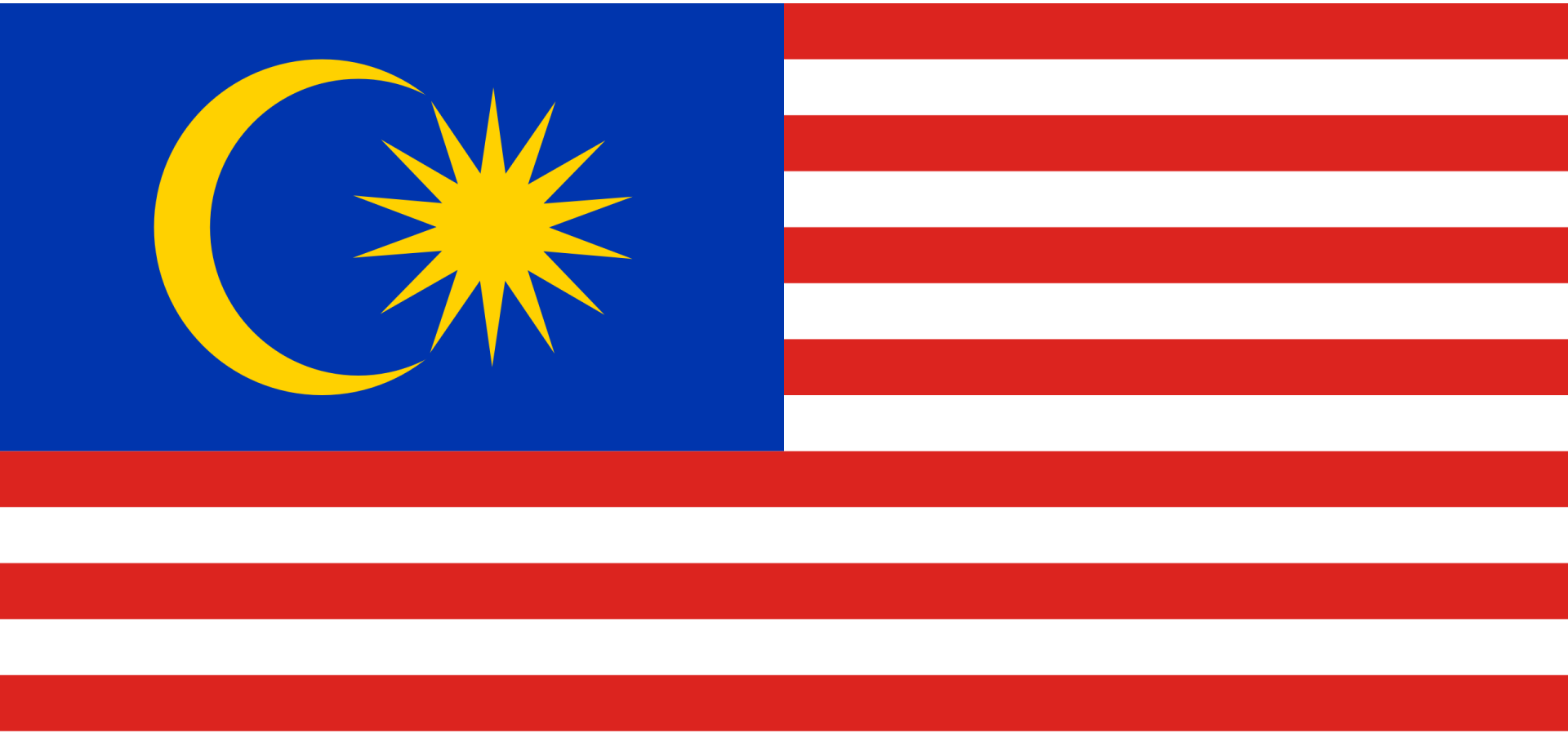


ELECTRONICS
MACHINERY
AIRCRAFT
BOILERS
SHIPS
METAL PRODUCTS
CONSTR. MATL. & EQPT.
HOME & OFFICE
PULP & PAPER
CHEMICALS & HEALTH
AGROCHEMICALS
OTHER CHEMICALS
INOR. SALTS & ACIDS
PETROCHEMICALS
LEATHER
MILK & CHEESE
ANIMAL FIBERS
MEAT & EGGS
FISH & SEAFOOD
TROPICAL AGRIC.
CEREALS & VEG. OILS
COTTON/RICE/SOY & OTHERS
TOBACCO
FRUIT
MISC. AGRICULTURE
NOT CLASSIFIED
TEXTILE & FABRICS
GARMENTS
FOOD PROCESSING
BEER/SPIRITS & CIGS.
PRECIOUS STONES
COAL
OIL
MINING

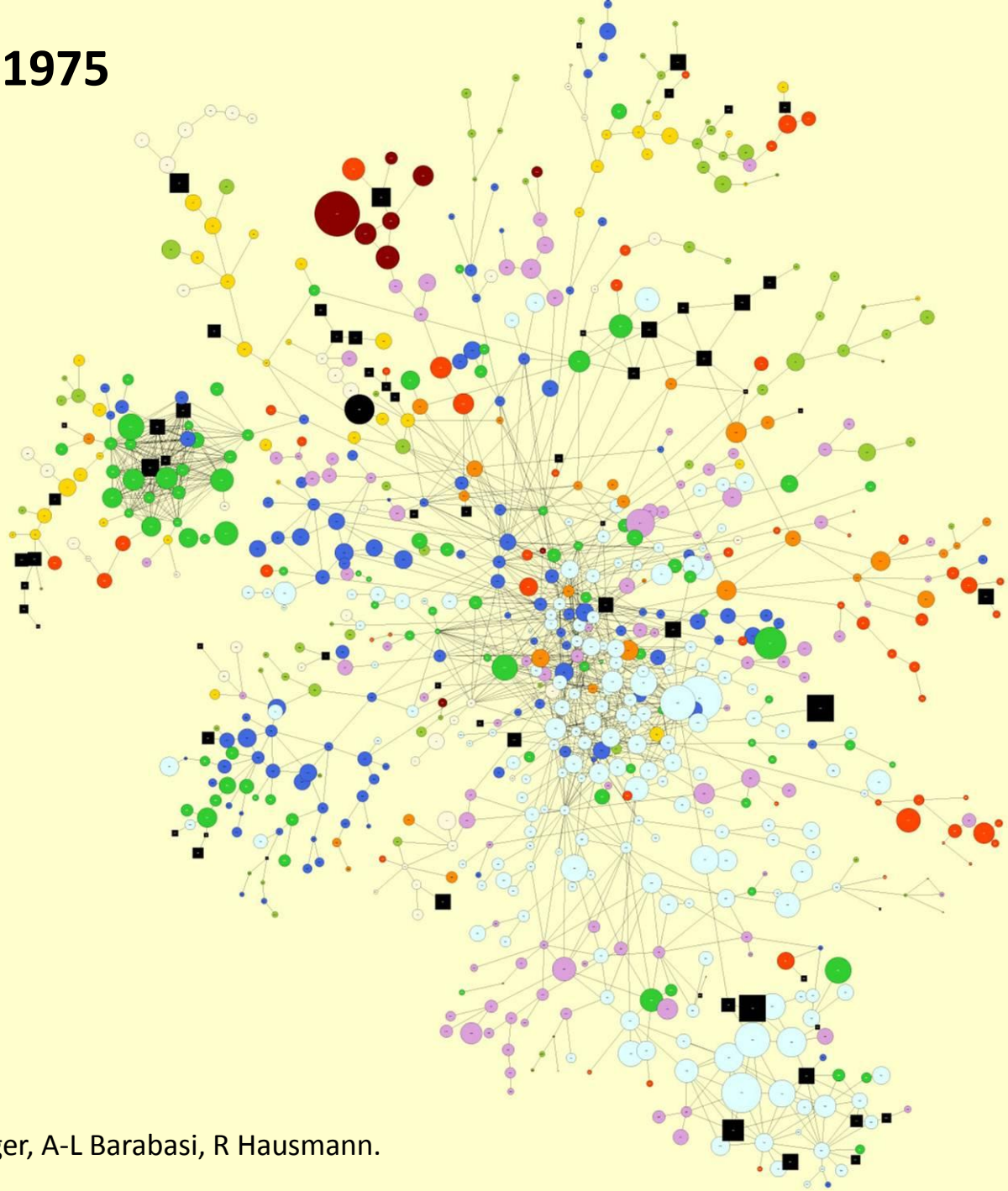
Community characteristics: Complexity, Connectedness and Market Size



How do monkeys jump?

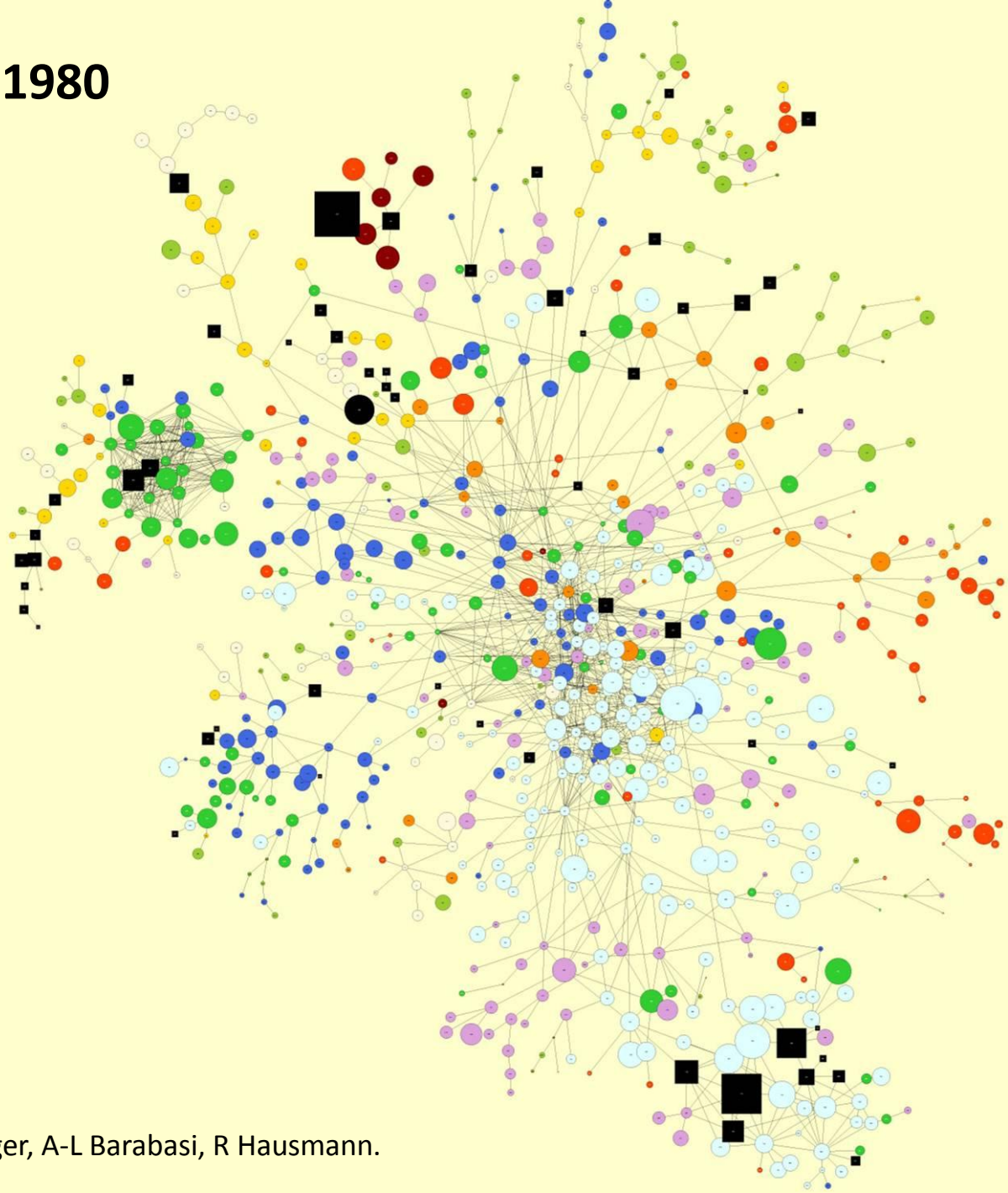


Malaysia 1975



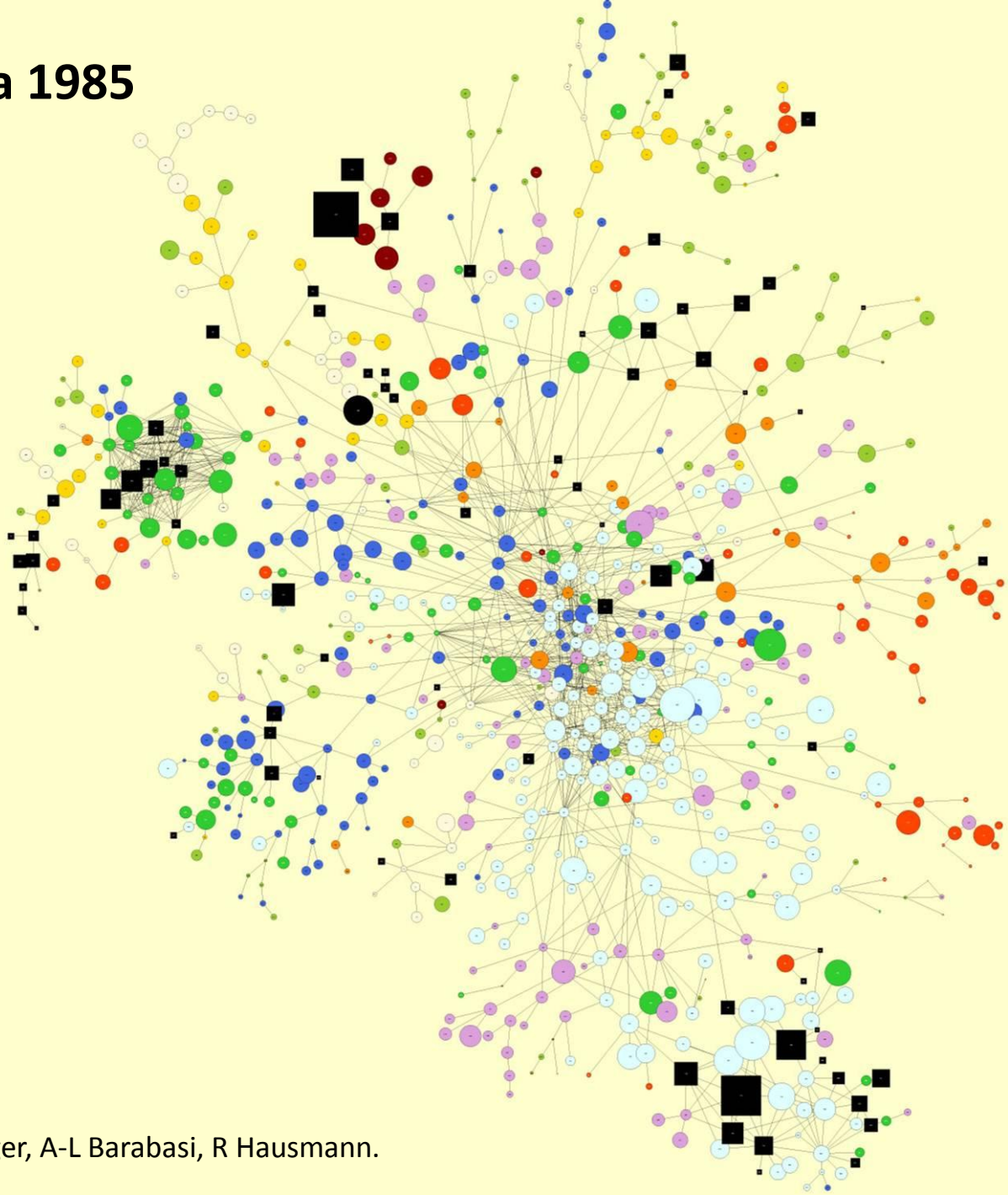
CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)

Malaysia 1980



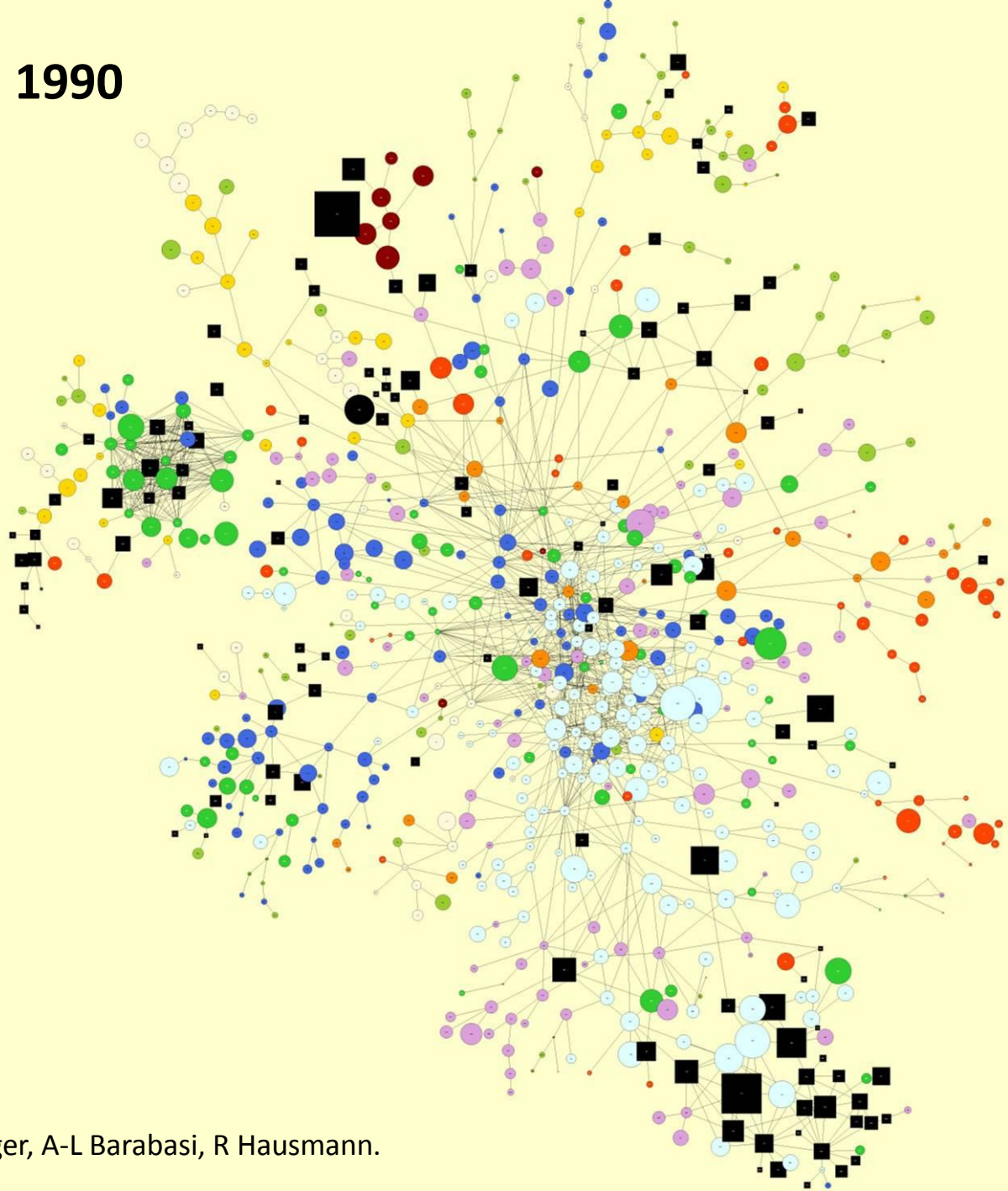
CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)

Malaysia 1985



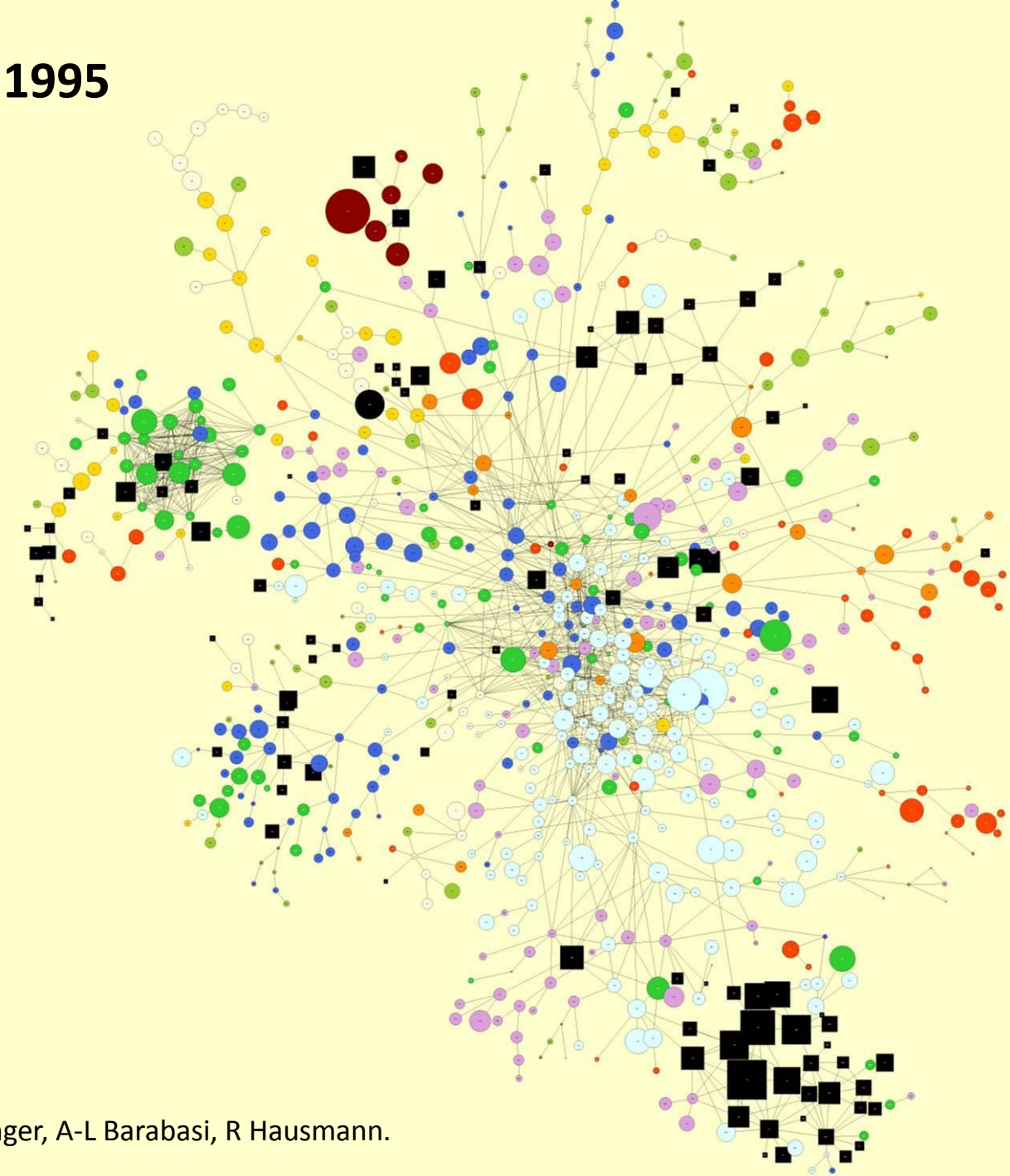
CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)

Malaysia 1990



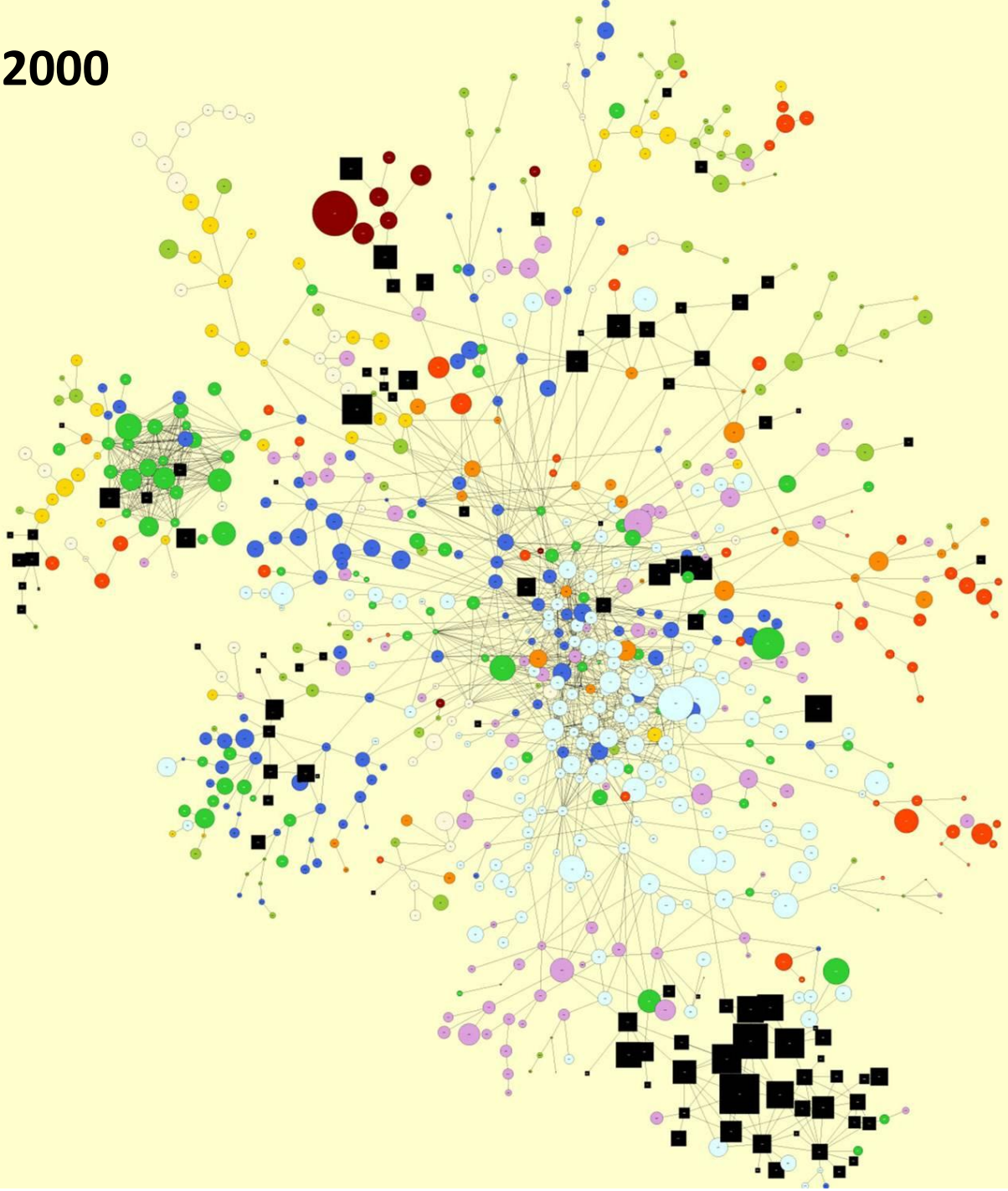
CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)

Malaysia 1995

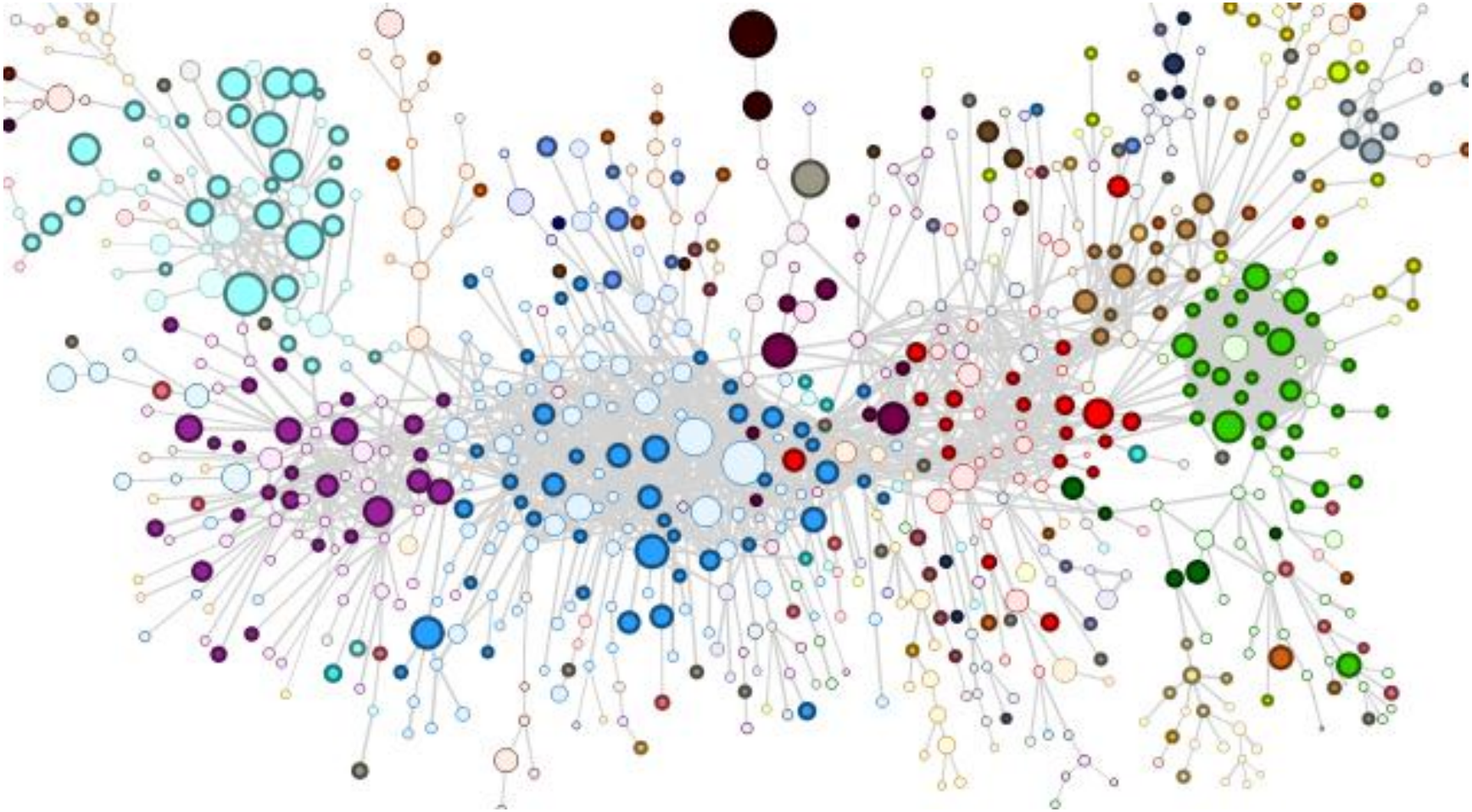


CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)

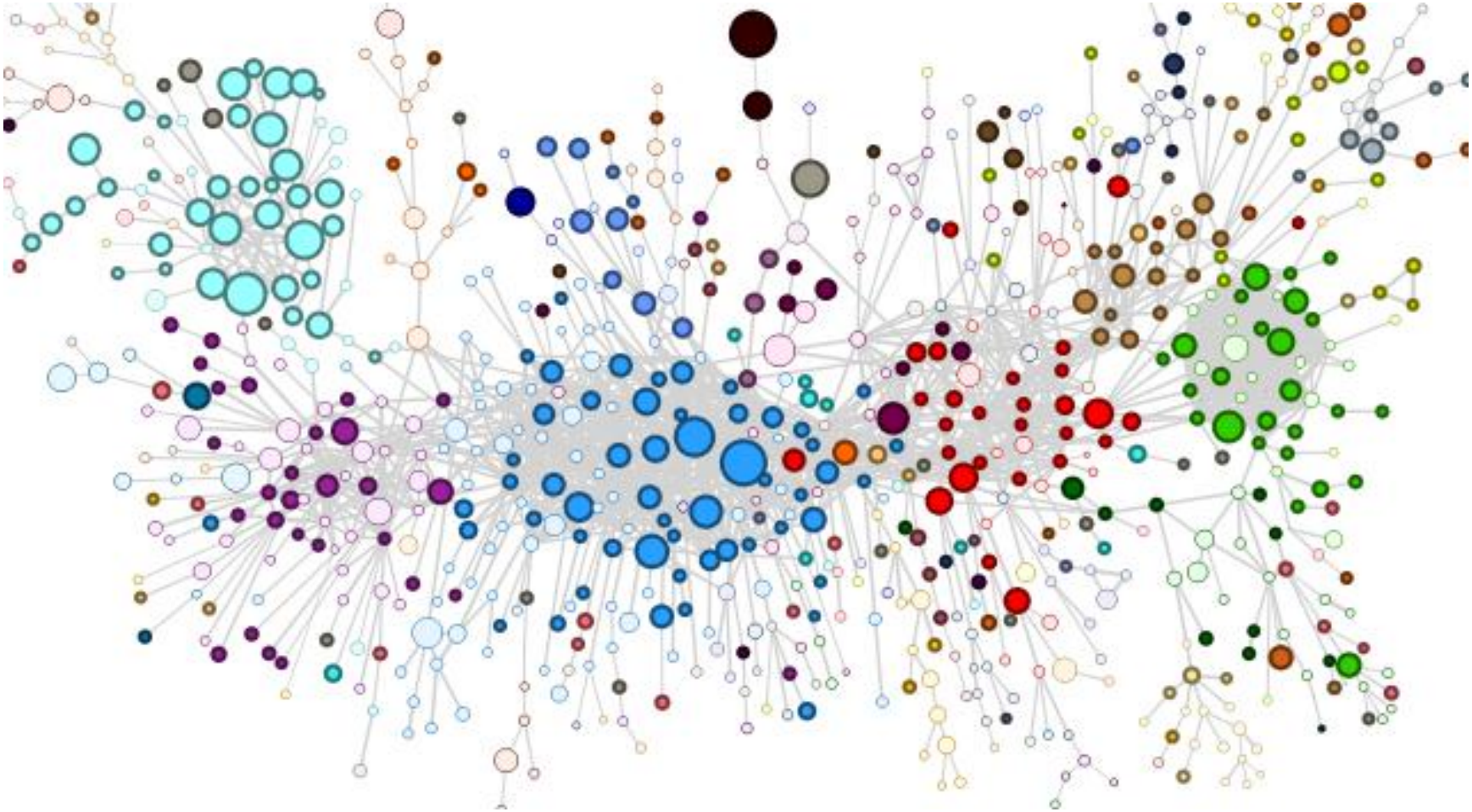
Malaysia 2000



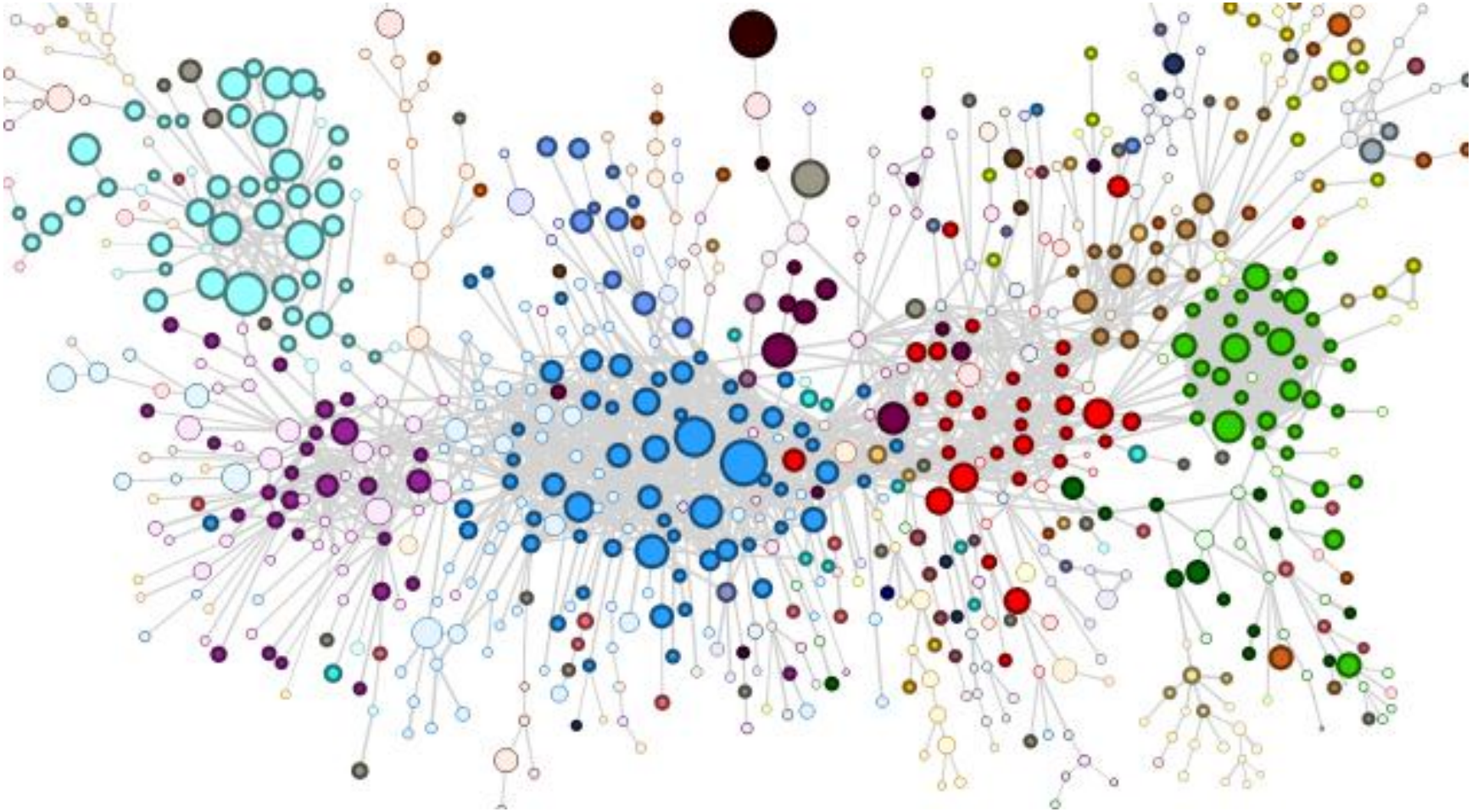
Mexico 1979



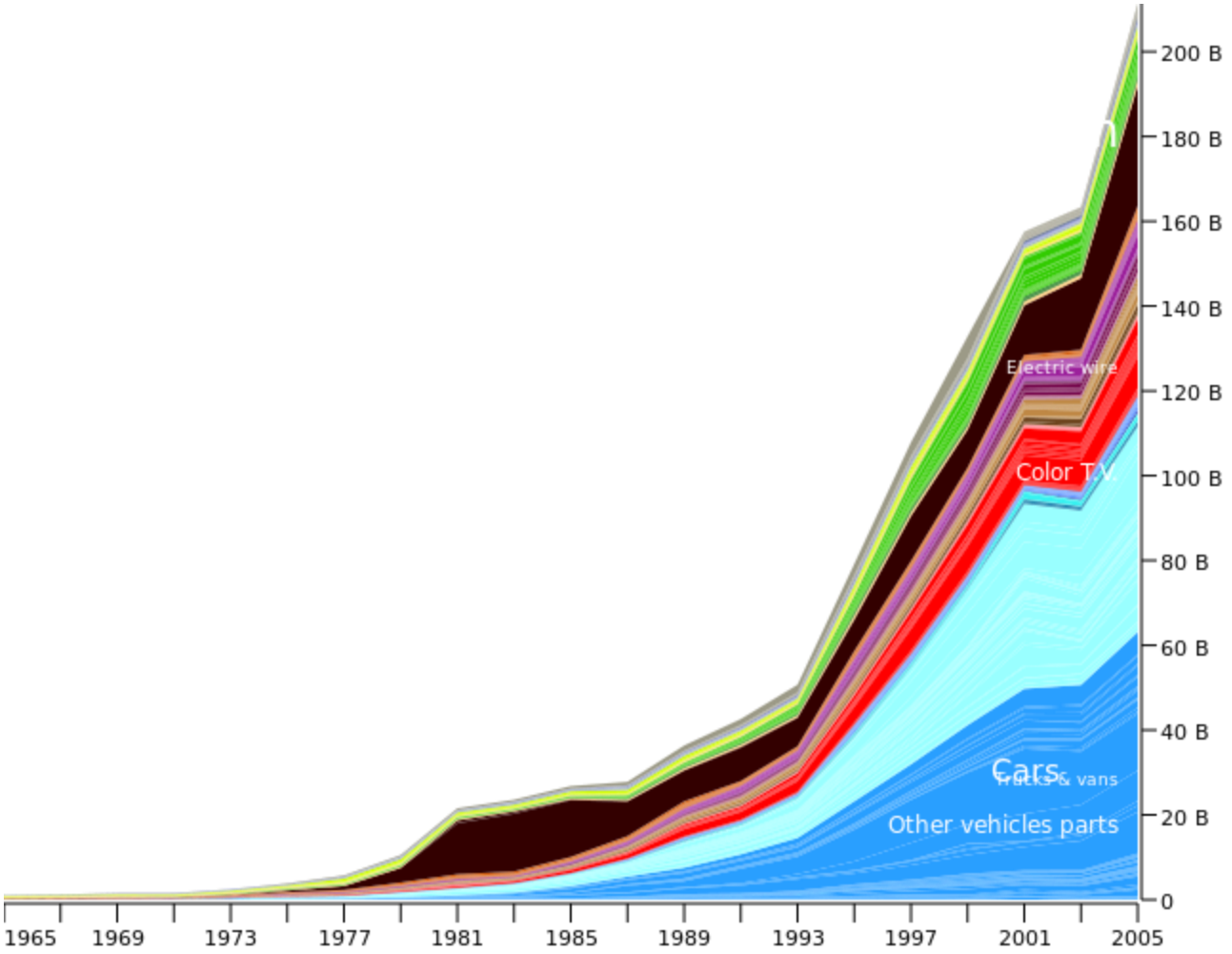
Mexico 1989



Mexico 1999



Mexico


200 B
180 B
160 B
140 B
120 B
100 B
80 B
60 B
40 B
20 B
0
Electric wire
Color T.V.
Cars
Trucks & vans
Other vehicles parts
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005

A tale of two countries

Ghana

Thailand

1962: Roughly equal income

Ghana

$295

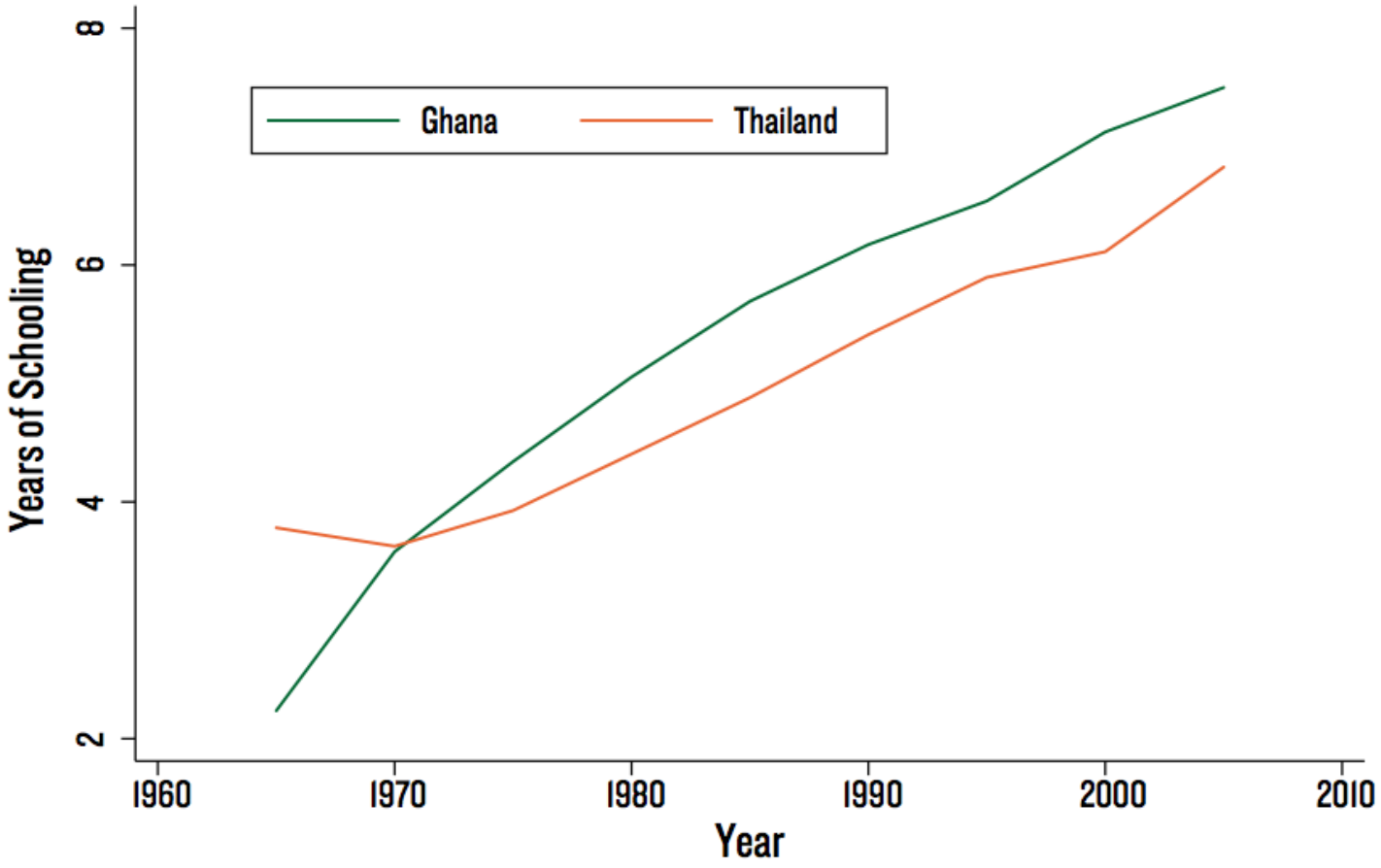
Thailand

$363

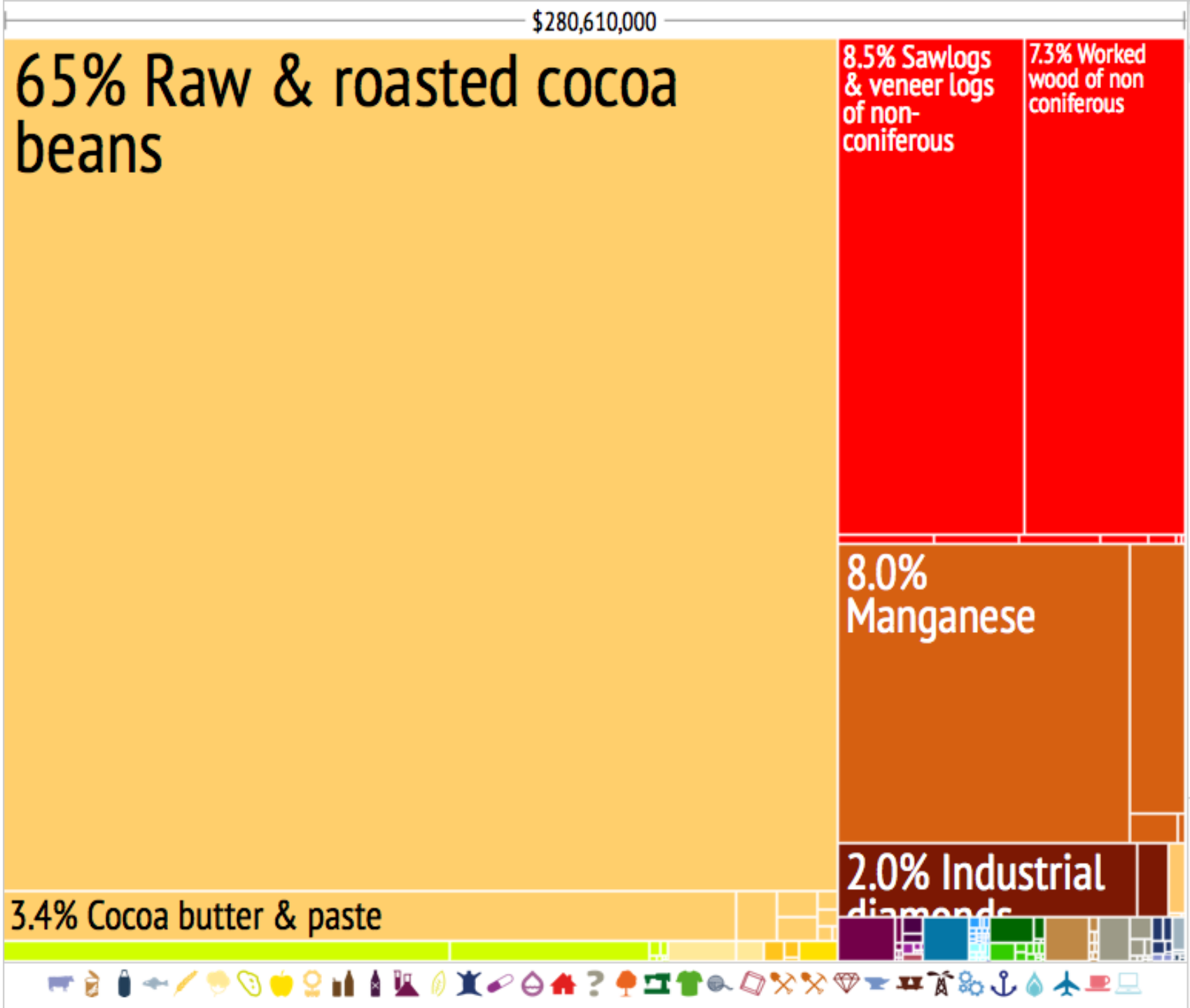
GDP per capita (constant 2000 US$)

Human capital story:

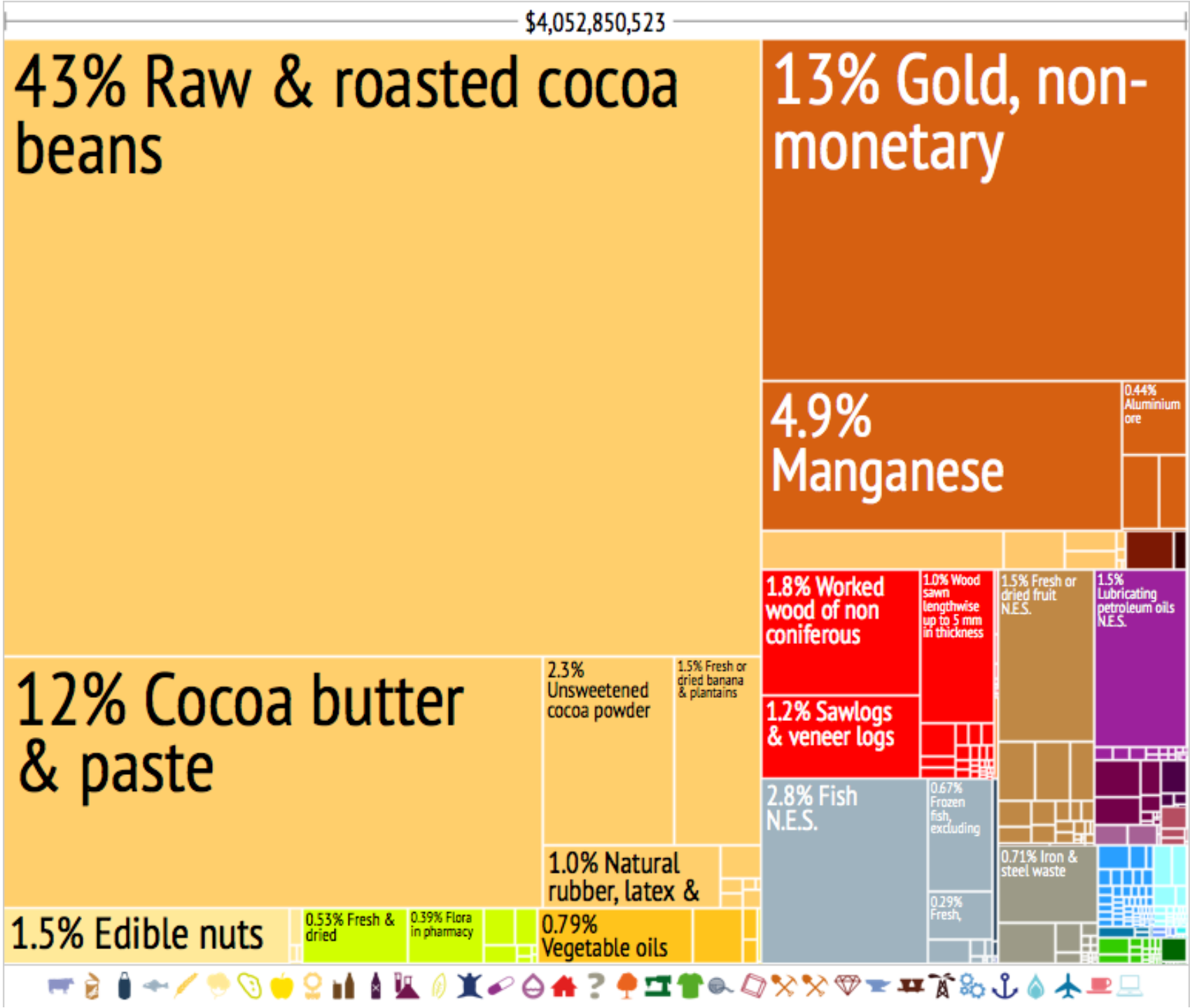
Years of schooling of Thailand and Ghana as a function of time.

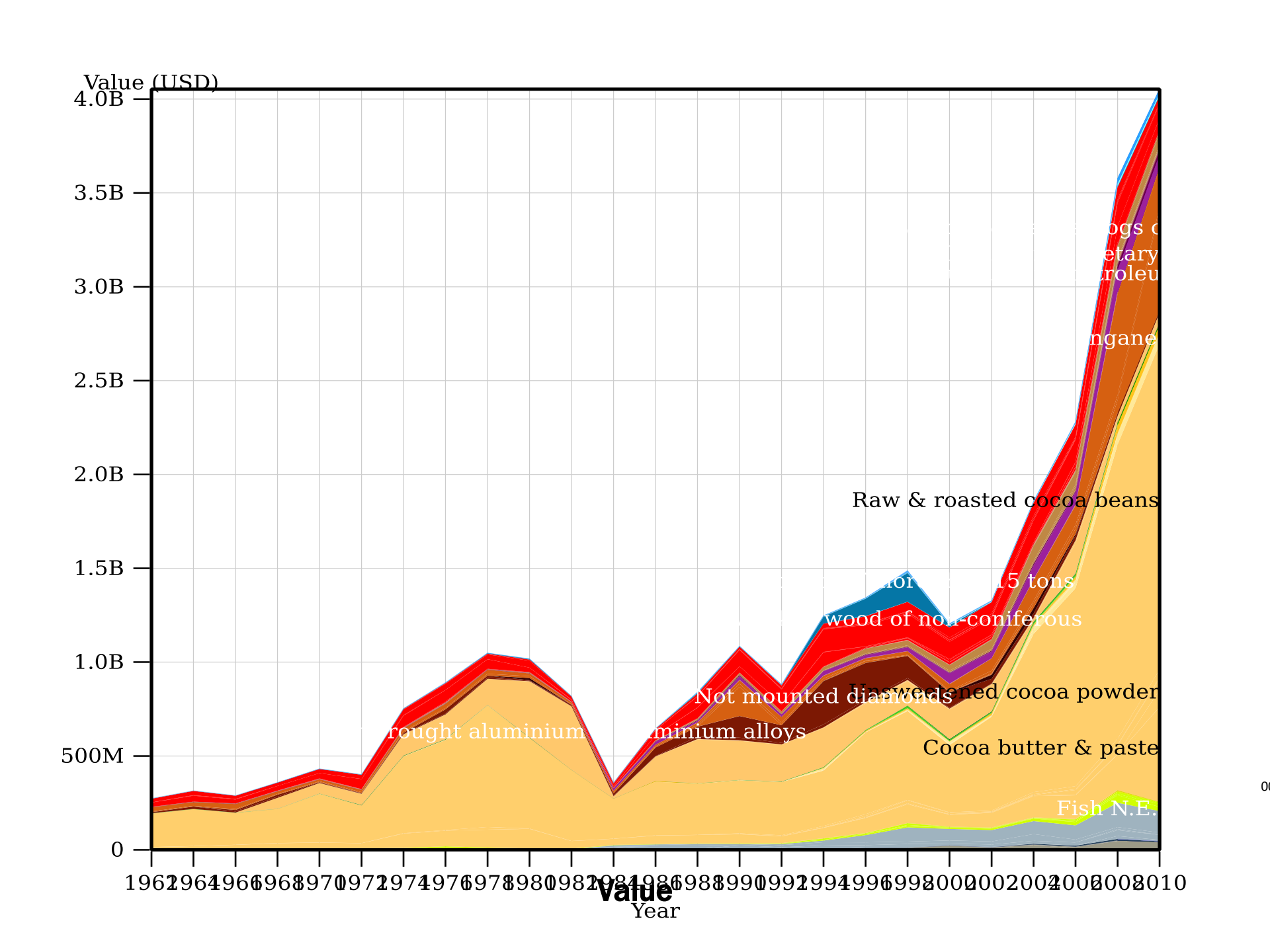


Ghana's exports in 1962



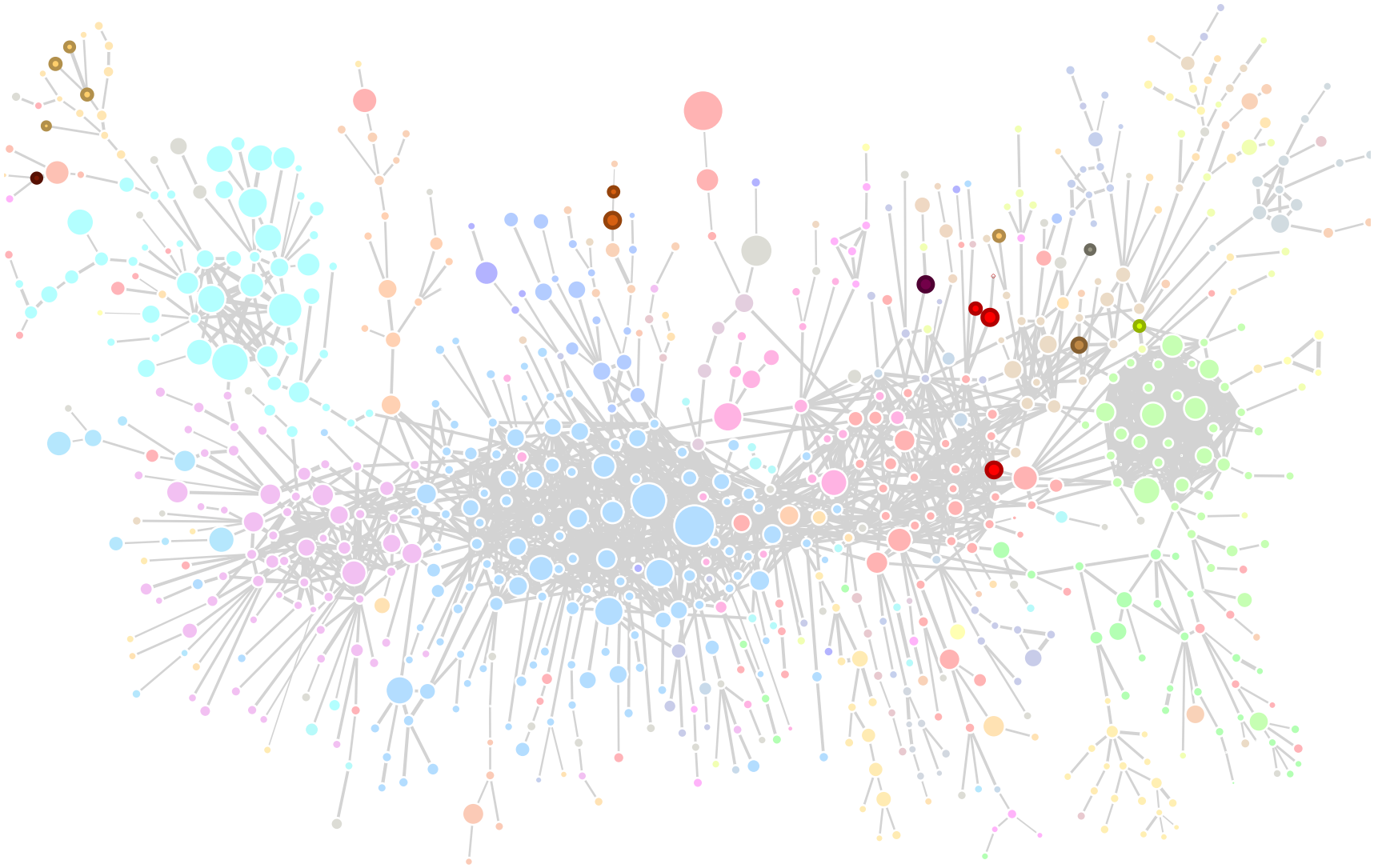
Ghana's exports in 2010




Value (USD)
4.0B
3.5B
3.0B
2.5B
2.0B
1.5B
1.0B
500M
0
Raw & roasted cocoa beans
Not mounted diamonds
Cocoa butter & paste
Fish N.E.
Value
Year

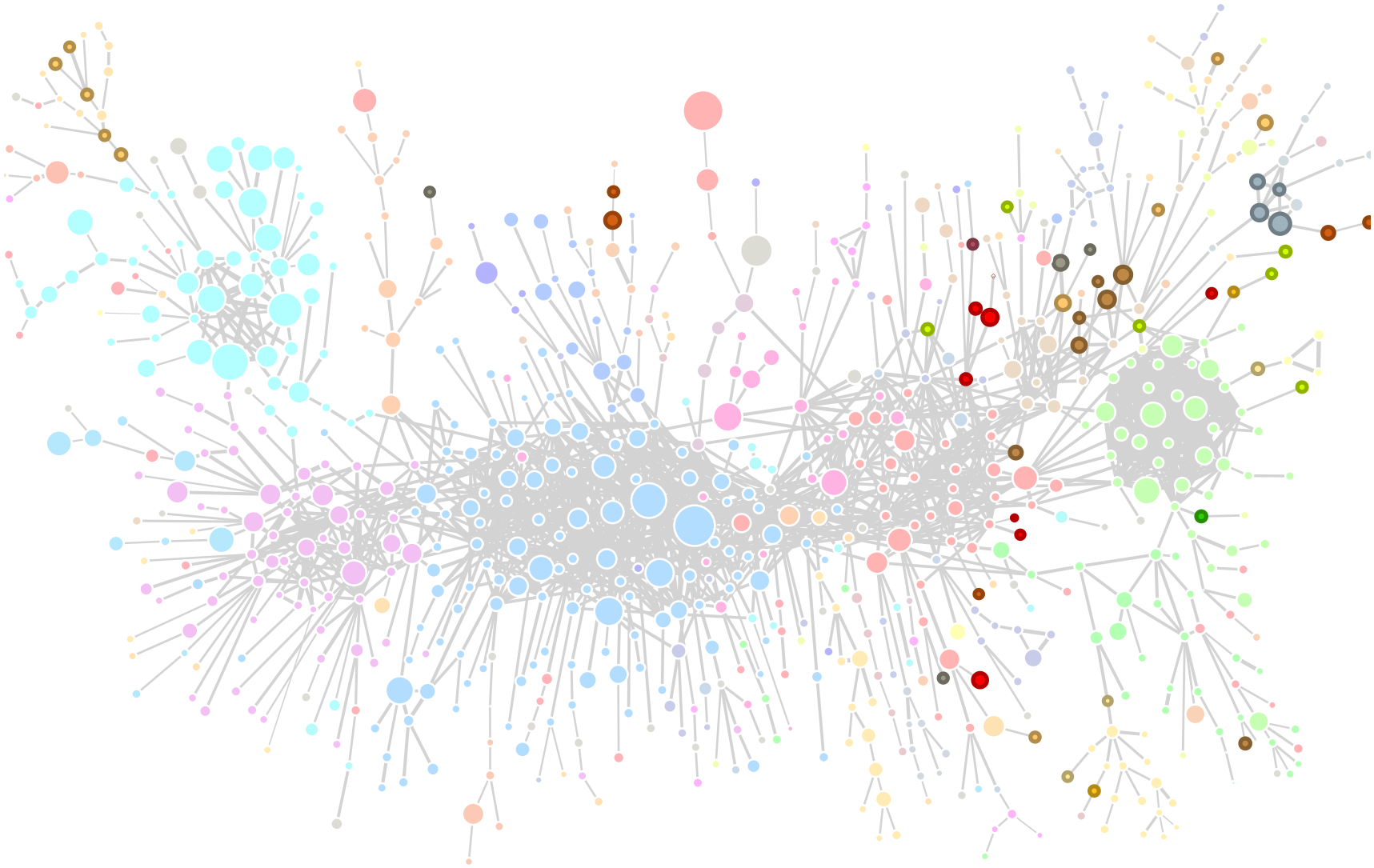
Total Value: $273,298,000

Ghana 1962



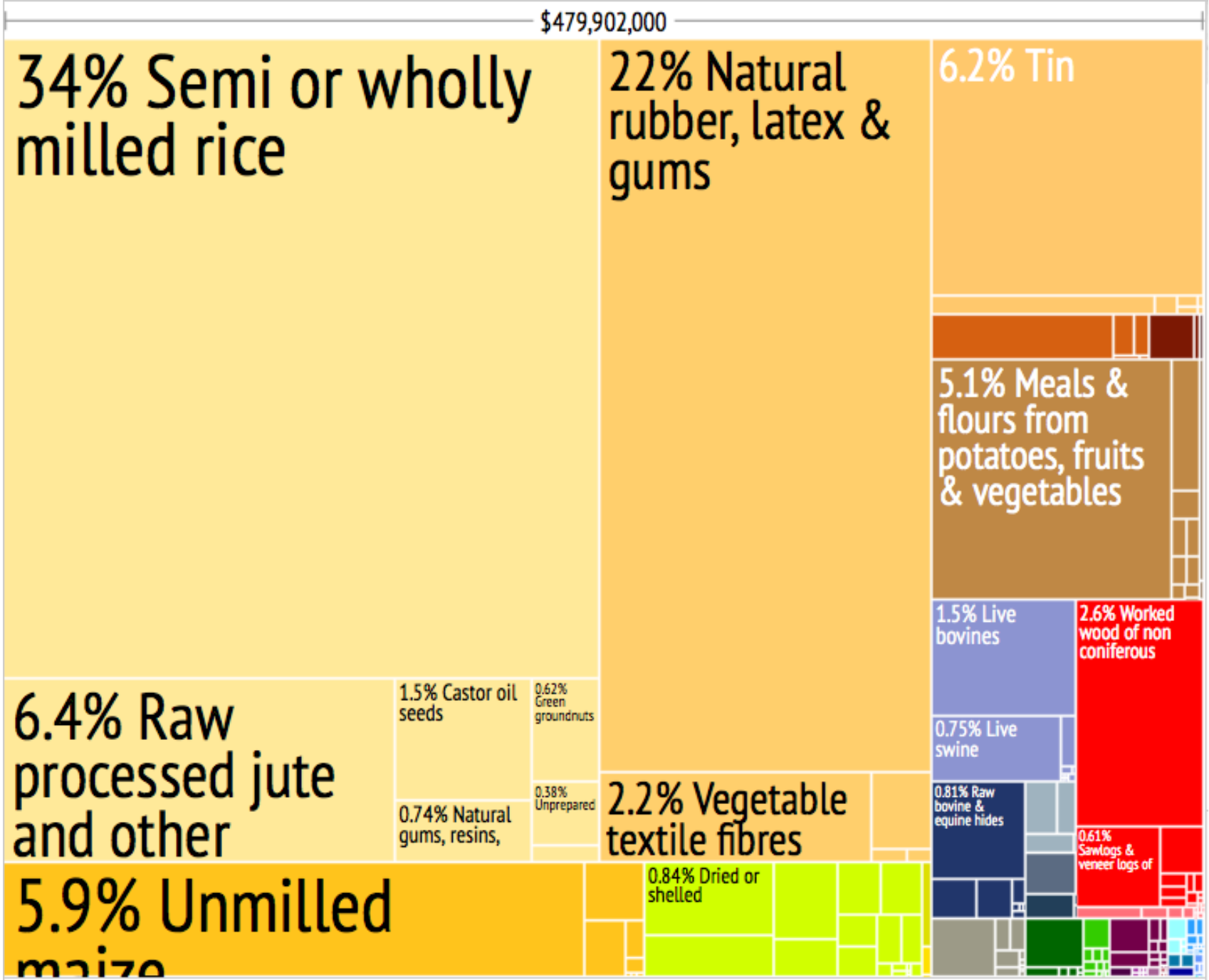
Total Value: $4,052,850,523

Ghana 2010

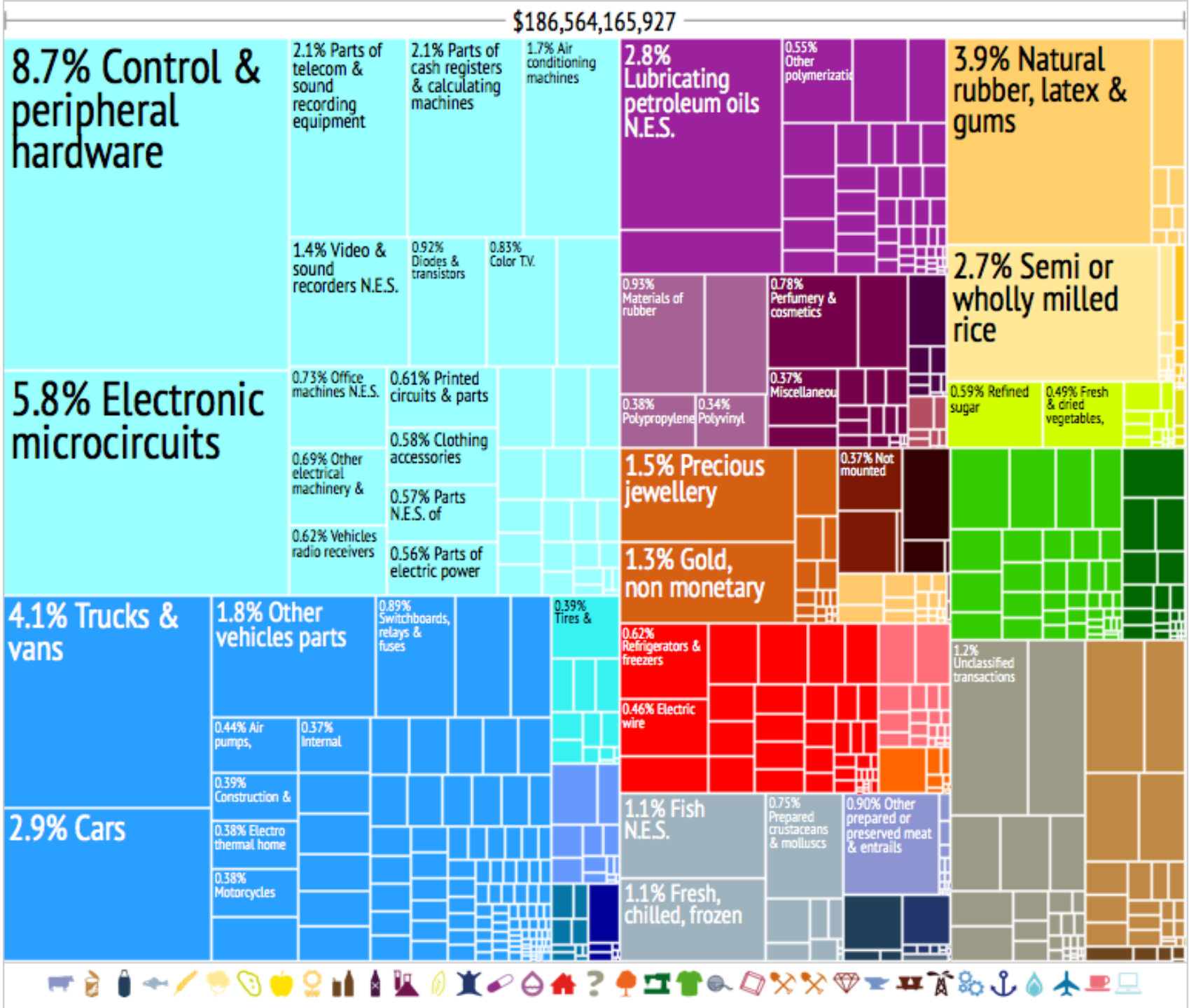


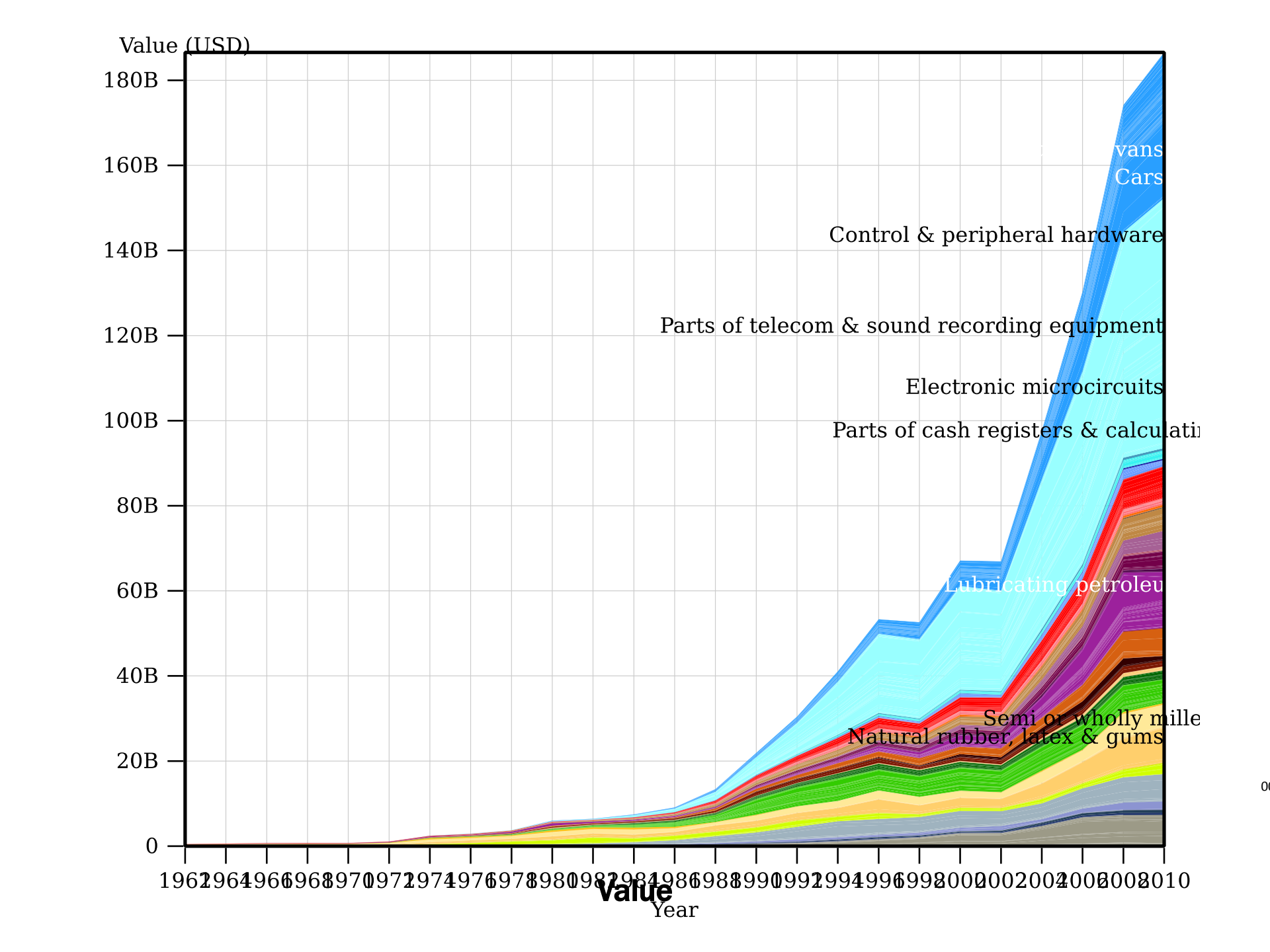
Thailand

Thailand's exports in 1962



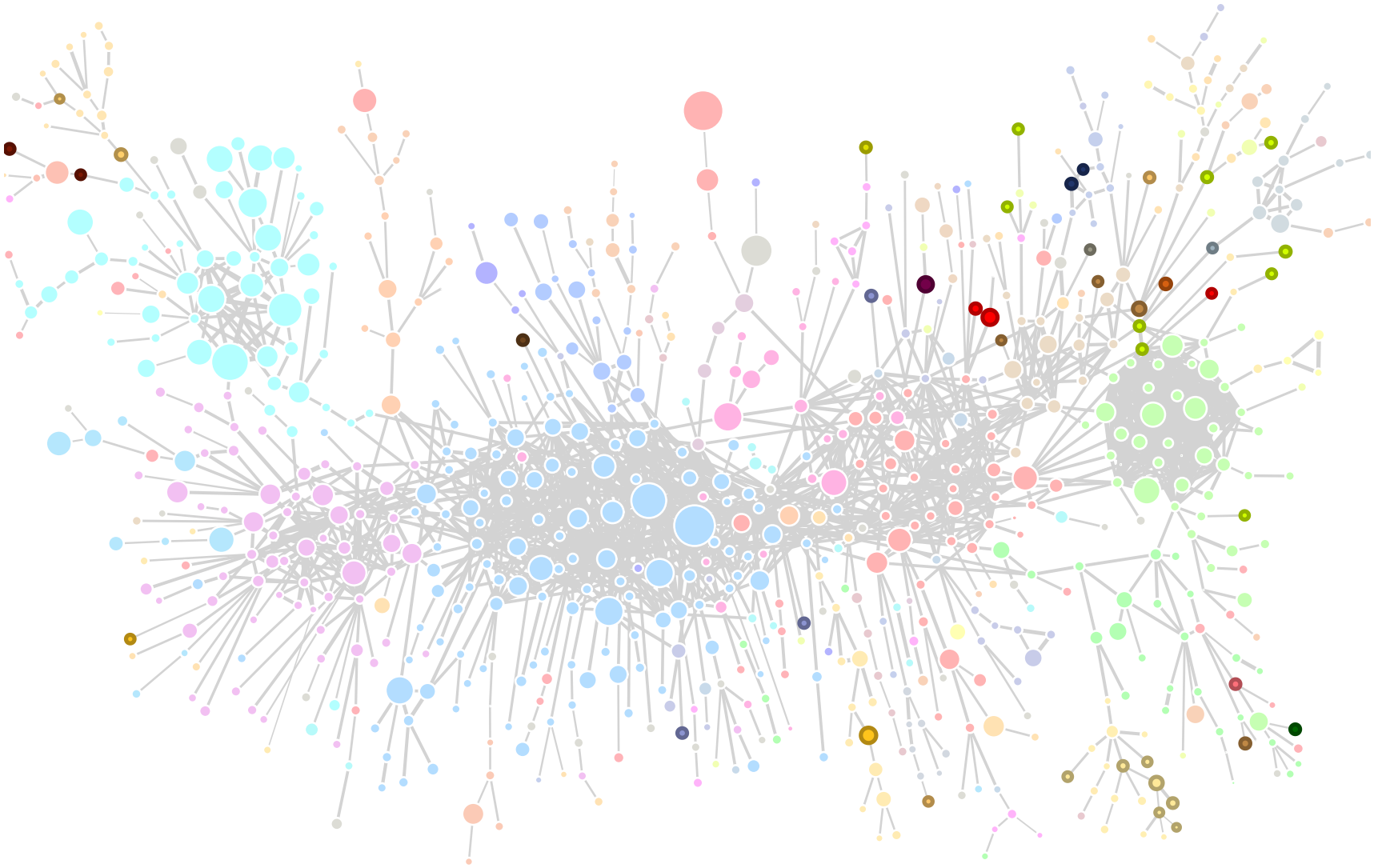
Thailand's exports in 2010




Value (USD)
180B
160B
140B
120B
100B
80B
60B
40B
20B
0
Vans
Cars
Control & peripheral hardware
Parts of telecom & sound recording equipment
Electronic microcircuits
Parts of cash registers & calculati
Lubricating petroleu
Semi or wholly mille
Natural rubber, latex & gums
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Value
Year

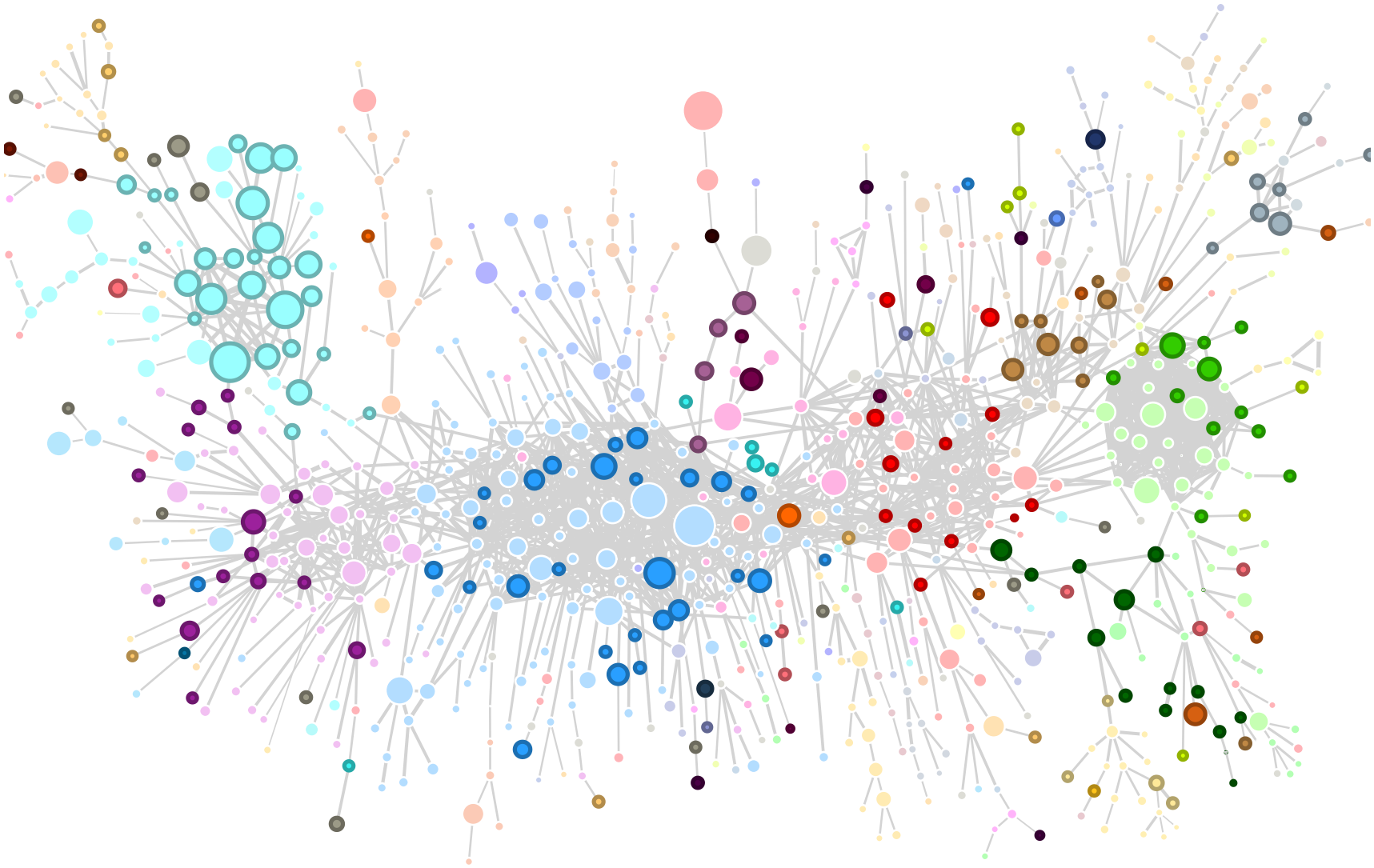
Total Value: $454,294,000

Thailand 1962



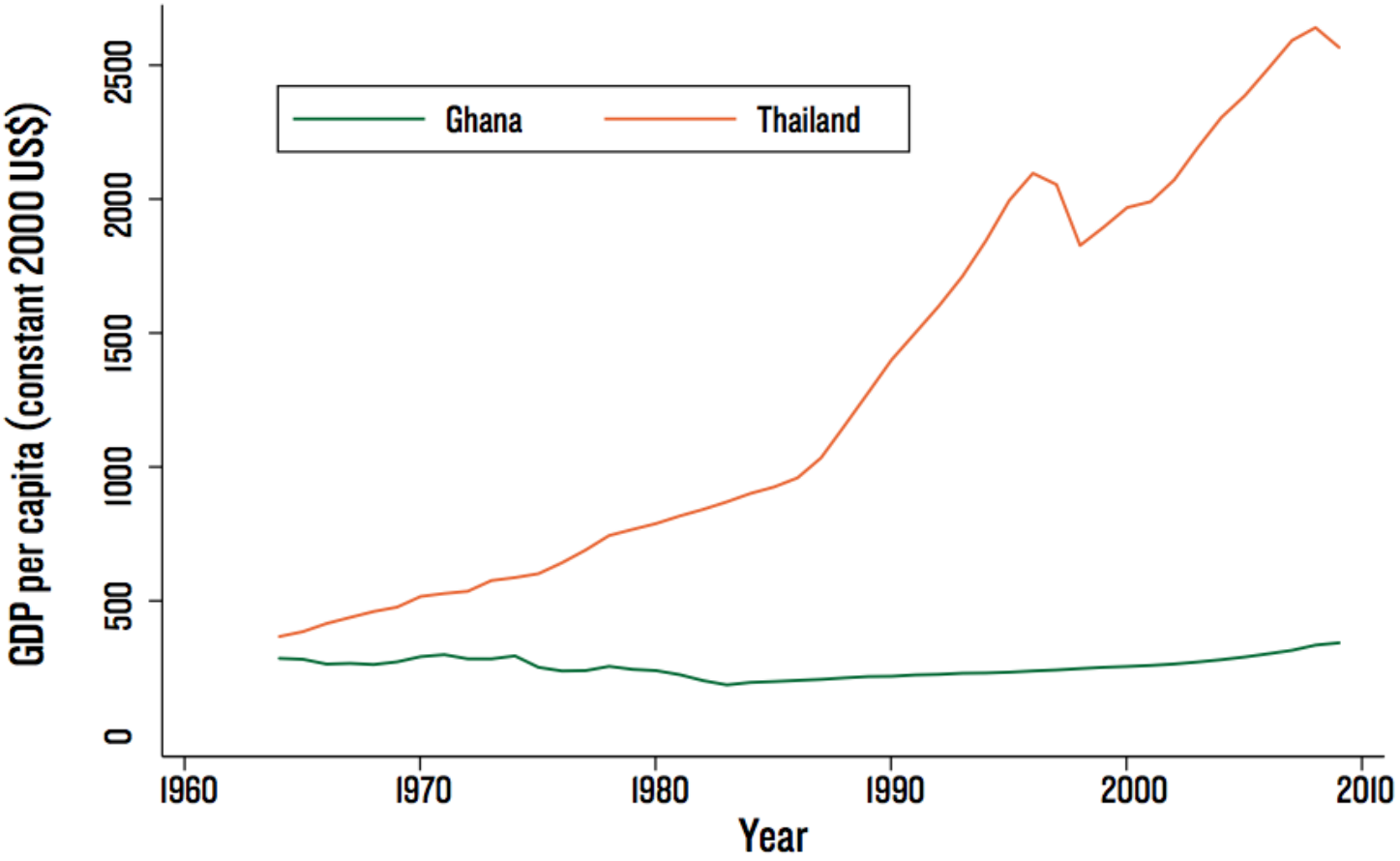
Total Value: $186,564,165,927

Thailand 2010



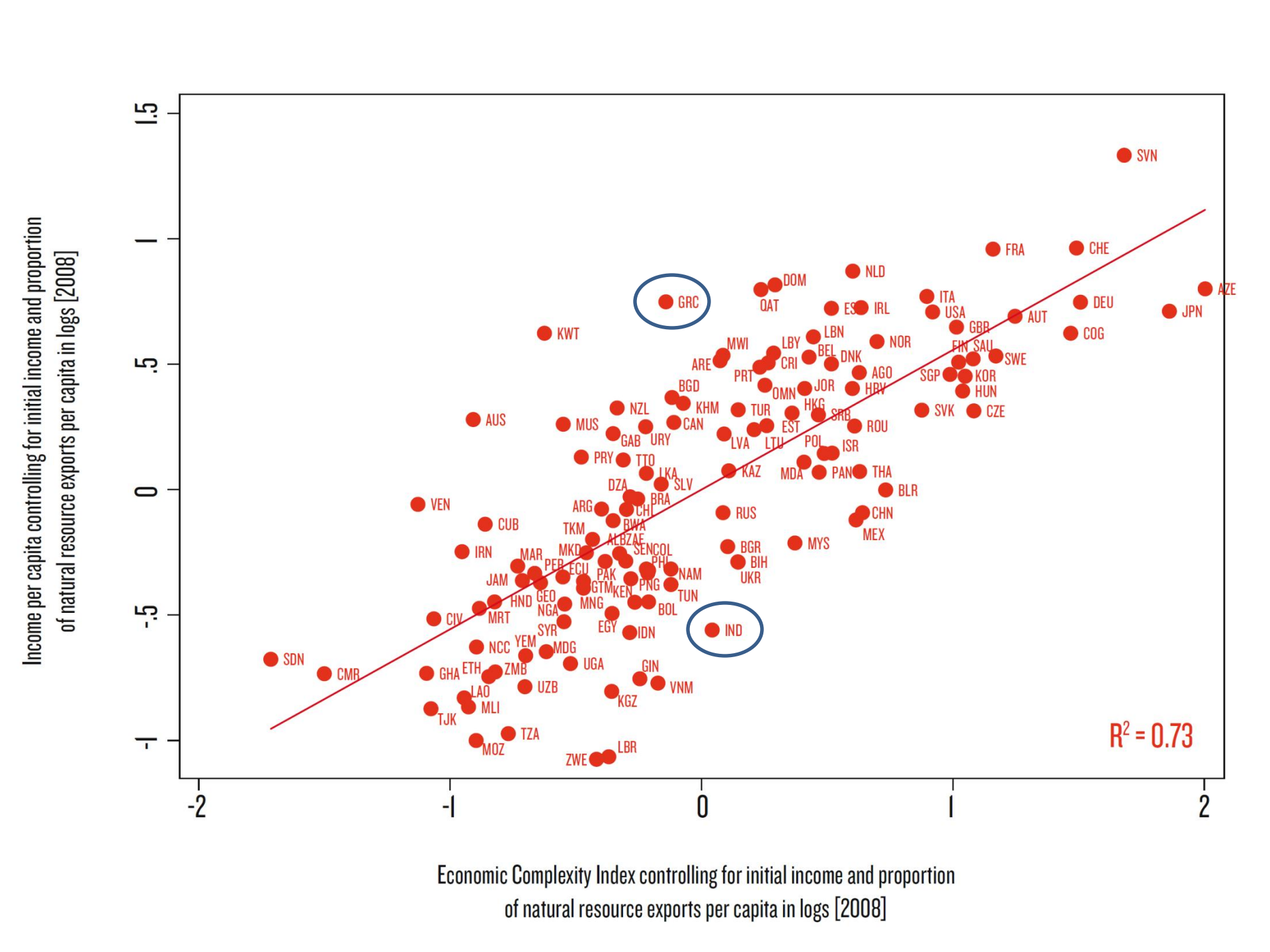
Divergence, big time

Evolution of the GDP per capita of Thailand and Ghana as a function of time.



How do we explain growth?

- Countries converge to the level of income that can be supported by their personbytes
- Therefore the gaps between income and personbytes affects future growth
- But long-run growth should be affected by the accumulation of more personbytes
- This will depend on how easy it is to accumulate more personbytes
- …which is affected by the position of a country in the product space


Income per capita controlling for initial income and proportion of natural resource exports per capita in logs [2008]
Economic Complexity Index controlling for initial income and proportion of natural resource exports per capita in logs [2008]
1.5
1
.5
0
-.5
-1
-2
-1
0
1
2
R^2 = 0.73
SVN
FRA
CHE
AZE
NLD
DOM
QAT
GRC
ITA
USA
DEU
JPN
ES
IRL
AUT
GBR
COG
KWT
LBN
NOR
MWI
LBY
BEL
DNK
FIN
SAU
SWE
ARE
CRI
PRT
AGO
SGP
KOR
BGD
OMN
JOR
HRV
HUN
HKG
NZL
KHM
TUR
SRB
SVK
CZE
AUS
MUS
CAN
EST
ROU
GAB
URY
LVA
LTU
POL
ISR
PRY
TTO
LKA
KAZ
MDA
PAN
THA
DZA
SLV
BLR
BRA
VEN
ARG
CHL
RUS
CHN
CUB
BWA
TKM
MEX
ALB
ZAE
IRN
MKD
SEN
COL
BGR
MYS
MAR
PHL
BIH
PER
ECU
PAK
NAM
UKR
JAM
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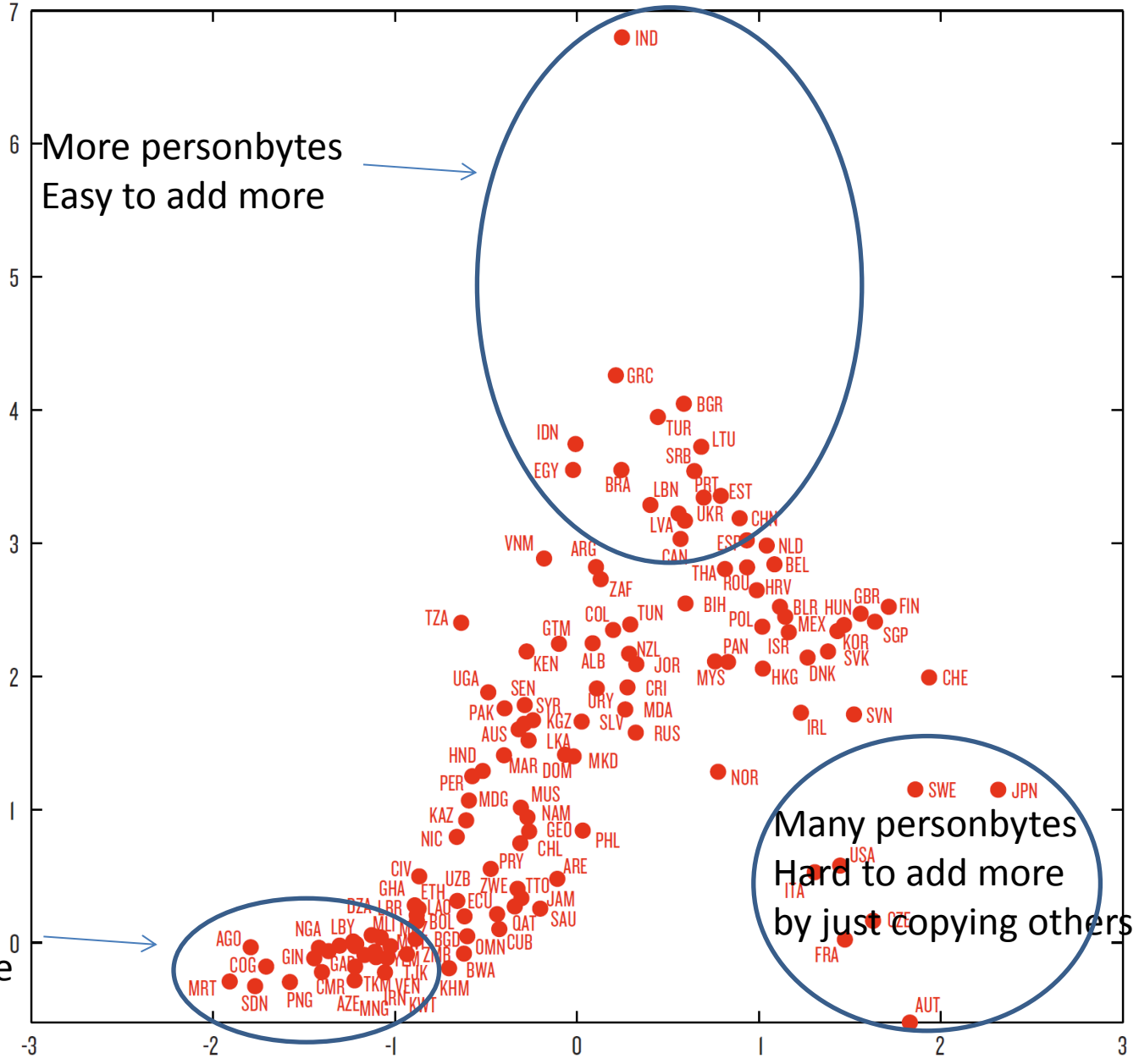
KEN
PNG
TUN
HND
GEO
MNG
BOL
CIV
MRT
NGA
EGY
IND
SYR
IDN
NCC
YEM
MDG
SDN
CMR
UGA
GIN
GHA
ETH
ZMB
VNM
LAO
UZB
KGZ
MLI
TJK
TZA
MOZ
LBR
ZWE

How close are you to other good products?



How many personbytes you have?

The position in the product space affects the growth of complexity

	Economic Complexity Index (1978-2008)	
	5-Year Periods	10-Year Periods
VARIABLES	(1)	(2)
Initial Economic Complexity Index	0.915***	0.857***
	(0,017)	(0,036)
Initial Complexity Outlook Index	0.078***	0.136***
	(0,017)	(0,034)
Constant	-0,016	-0.064**
	(0,035)	(0,030)
Observations	637	313
R^2	0,926	0,892
Year FE	Yes	Yes
Speed of adjustment, ß	0,085	0,143
Long run effect, Đ	0,918	0,951

Baseline

Dependent variable: 10 year real GDP growth per capita (%)

VARIABLES	(1)	(2)	(3)	(4)
Initial GDP per capita, logs	-0.009	-0.667***	-0.489***	-0.738***
	(0.125)	(0.163)	(0.142)	(0.145)
Increase in real NNRR exports pc	4.034***	3.794***	4.062***	3.905***
	(0.830)	(0.919)	(0.967)	(0.979)
Initial Economic Complexity Index		1.393***		0.859***
		(0.228)		(0.197)
Initial Opportunity value Index			1.235***	0.832***
			(0.226)	(0.215)
Constant	1.326	6.267***	4.894***	6.776***
	(1.097)	(1.323)	(1.173)	(1.177)
Observations	294	294	294	294
R-squared	0.269	0.390	0.399	0.431
Year FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

ROYAL

Education

Dependent variable: 10 year real GDP growth per capita (%)

VARIABLES	(1)	(2)	(3)	(4)	(5)
Initial GDP per capita, logs	-0.762***	-0.954***	-0.884***	-0.776***	-0.921***
	(0.144)	(0.170)	(0.154)	(0.149)	(0.162)
Increase in real NNRR exports pc	6.604***	6.146***	6.218***	6.593***	6.001***
	(1.257)	(1.303)	(1.331)	(1.262)	(1.339)
Initial Economic Complexity Index	0.958***	0.766***	0.774***	0.947***	0.744***
	(0.184)	(0.174)	(0.187)	(0.184)	(0.181)
Initial Opportunity value Index	0.851***	0.805***	0.869***	0.850***	0.827***
	(0.218)	(0.219)	(0.210)	(0.220)	(0.212)
Initial average years of schooling		0.211***			0.209*
		(0.066)			(0.113)
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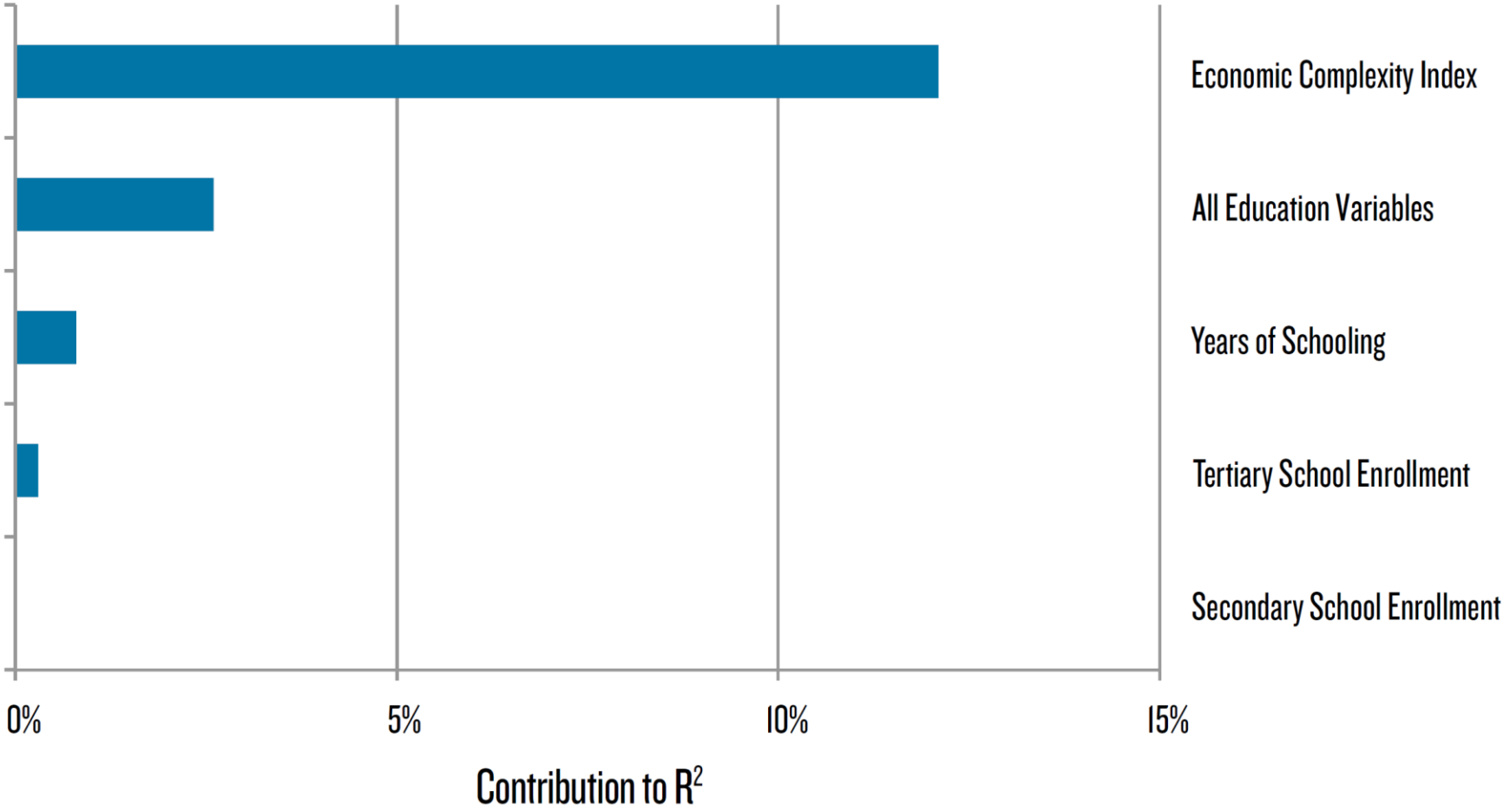

Institutions

Dependent variable: 10 year real GDP growth per capita (%)

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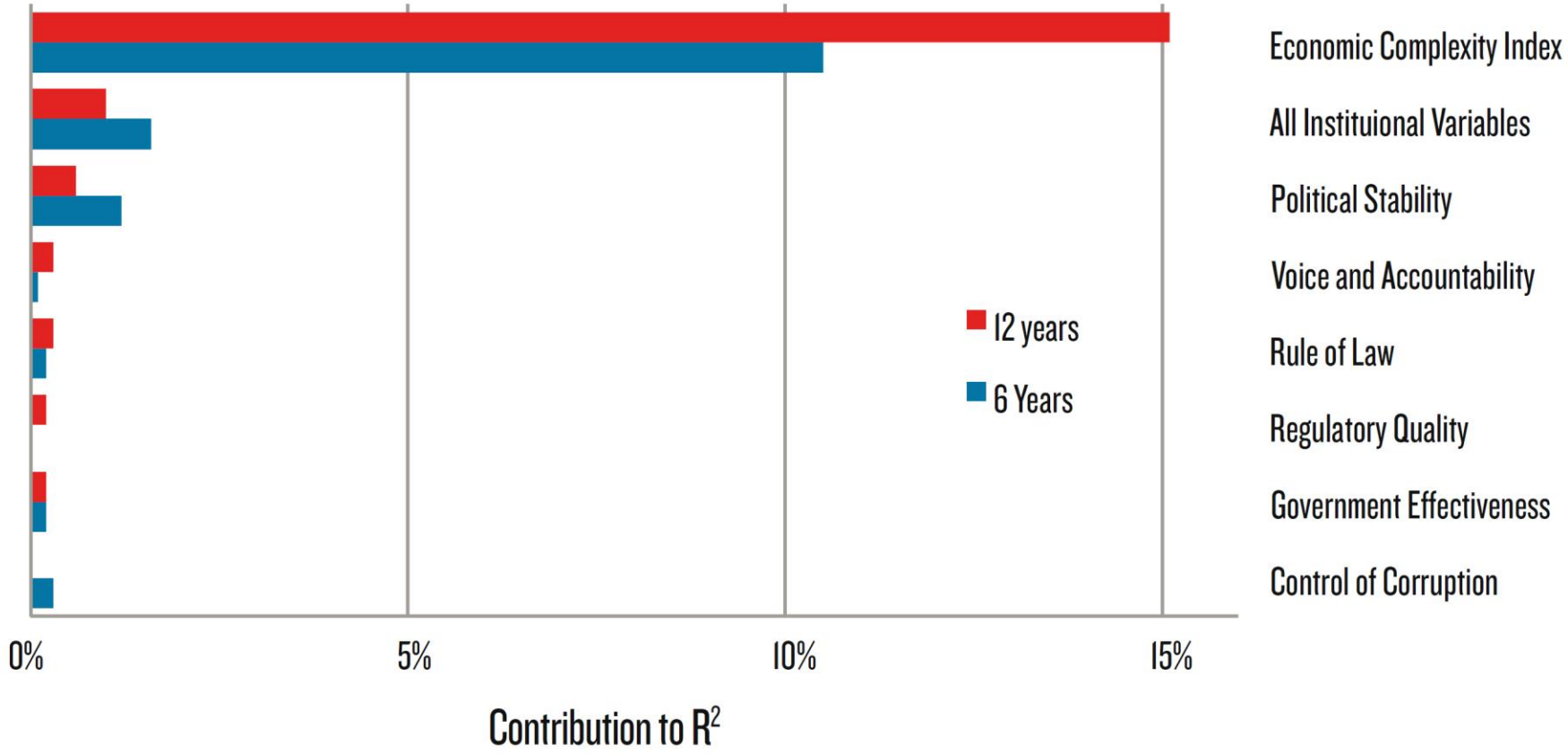

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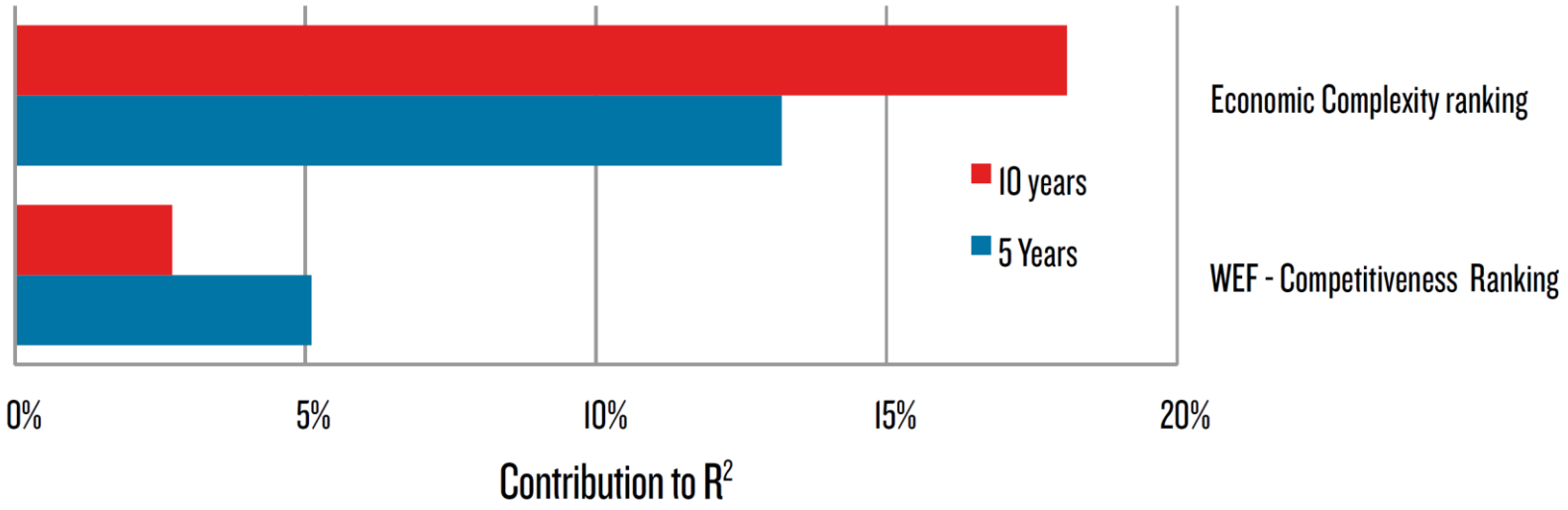

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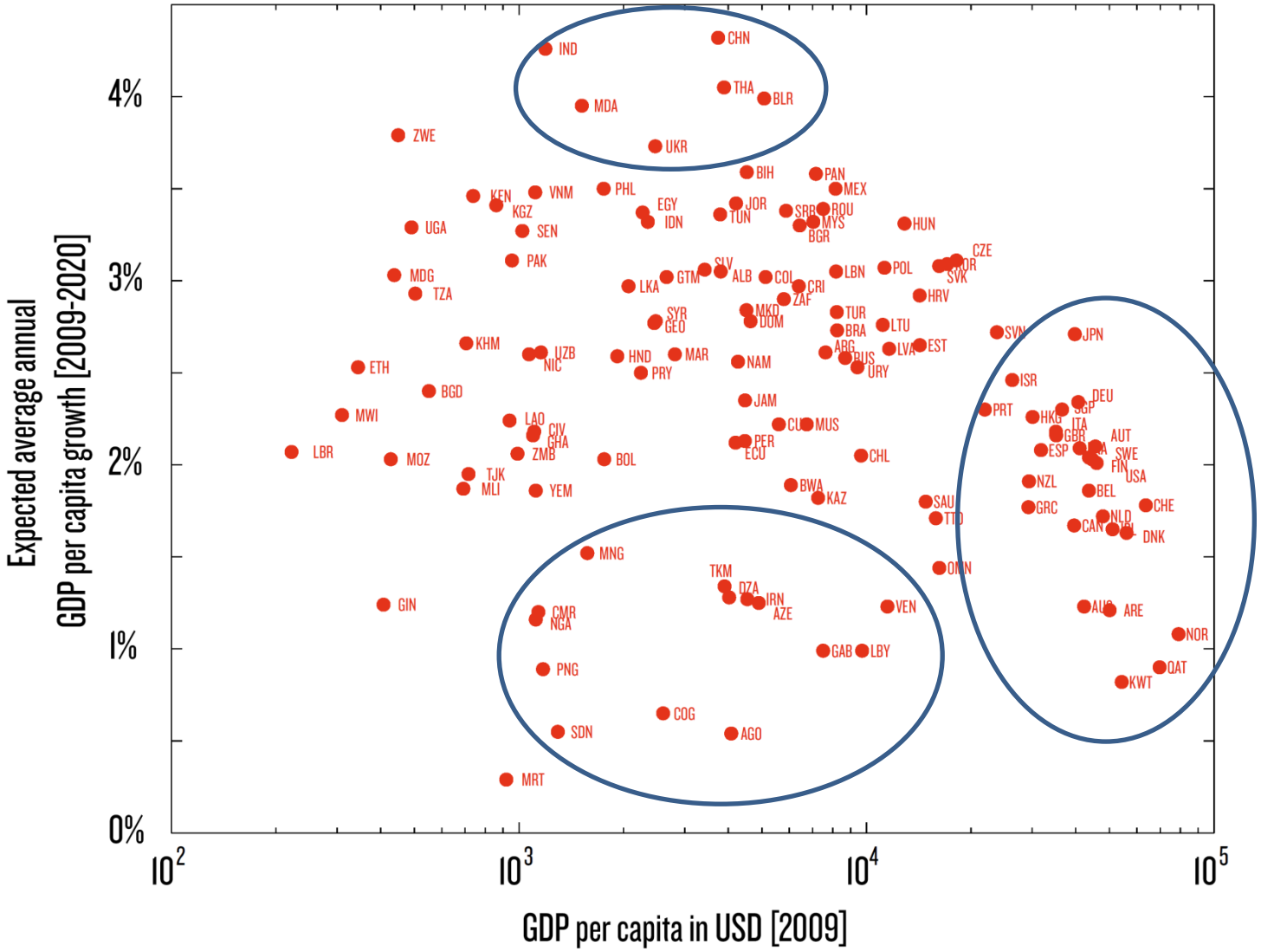
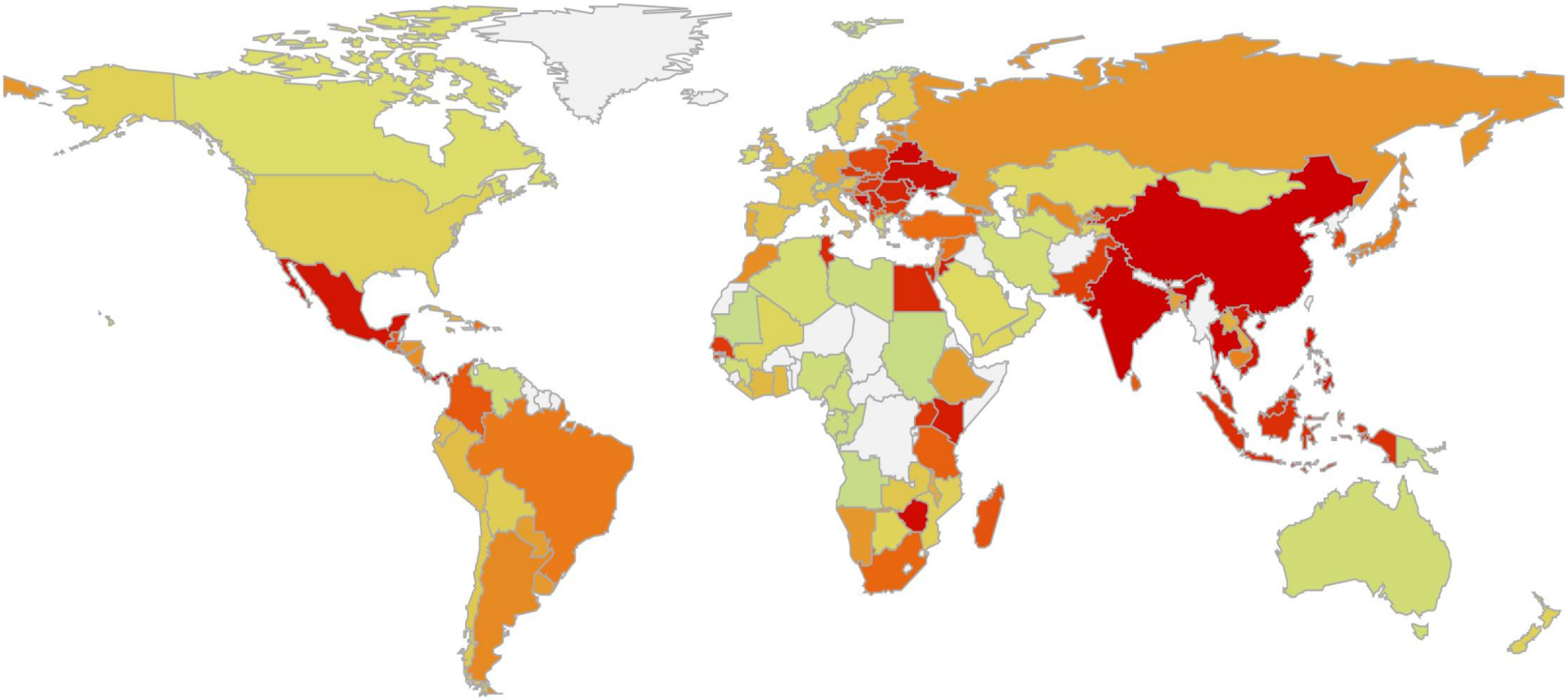
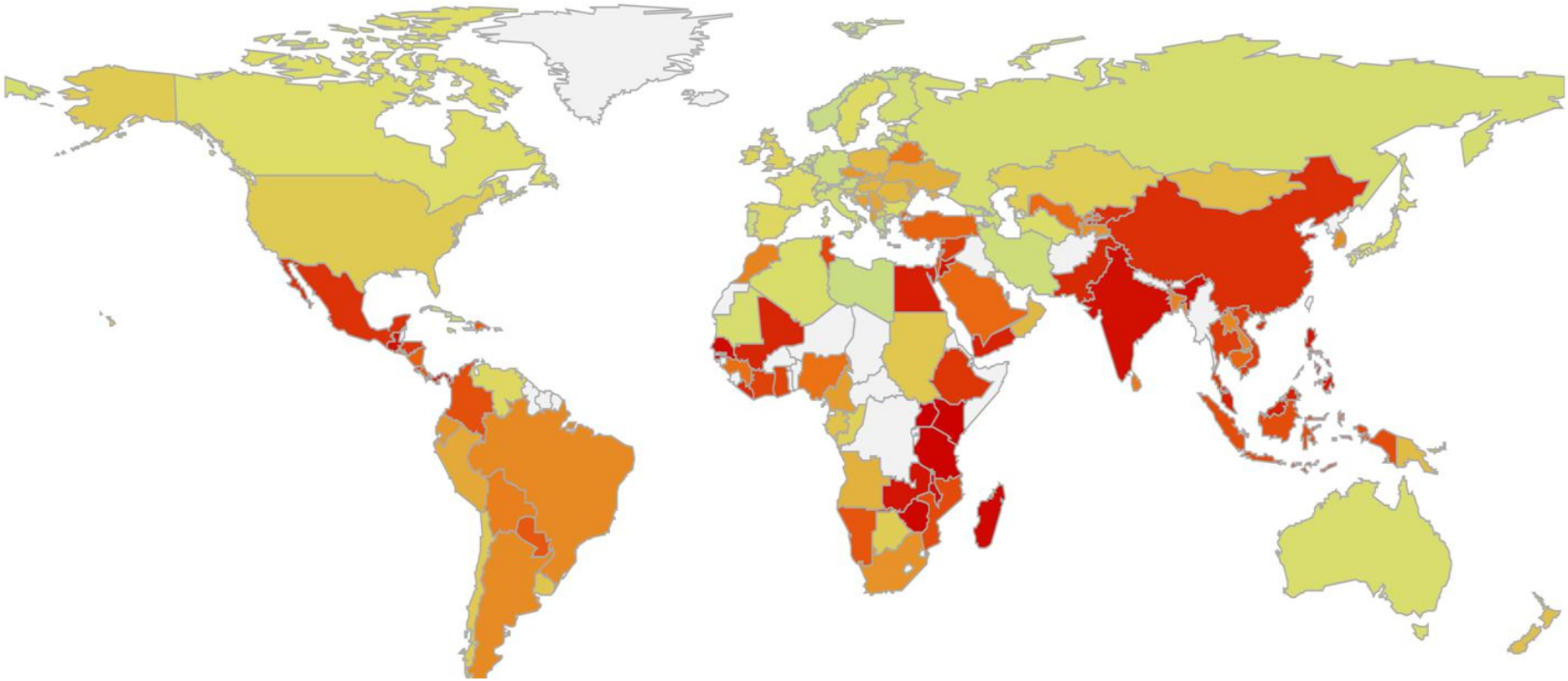
Who will grow? Who will catch up?



Who will grow faster?
Growth in GDP per capita to 2020



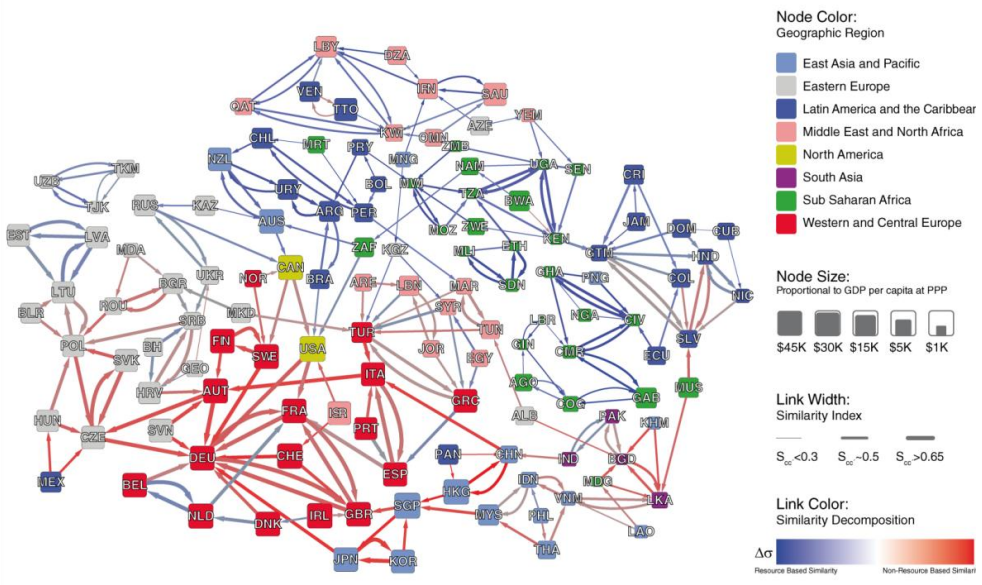
Who will grow faster?
Total GDP growth to 2020



DIFFUSION OF KNOWLEDGE ACROSS COUNTRIES

When the mobility of watchmakers is limited

- Products diffuse to <u>neighbors</u>
  - A country is more likely to start building products that its neighboring countries are good at
  - Bahar, Hausmann and Hidalgo (2013)



THE COUNTRY SPACE

DIFFUSION OF KNOWLEDGE ACROSS COUNTRIES

- Products diffuse through migrants
  - Bahar and Rapoport (2013)

Franschhoek Valley, South Africa

SO, WHERE DO FIRMS ACQUIRE NEW PRODUCTIVE KNOWLEDGE?

- *Who brings new kinds of industries to towns in Sweden*
  - New industries brought in by entrepreneurs and firms from outside the region
  - Neffke/Hartog/Boschma/Henning 2013
- *Where do local pioneers get their workers from in Germany*
  - Pioneer firms have to bring their workers from far away
  - The higher the worker's skill level, the larger the distance over which he/she is sourced.
  - Hausmann/Neffke/Otto 2013

MOVEMENT OF ENTIRE TEAMS OF PERSONBYTES

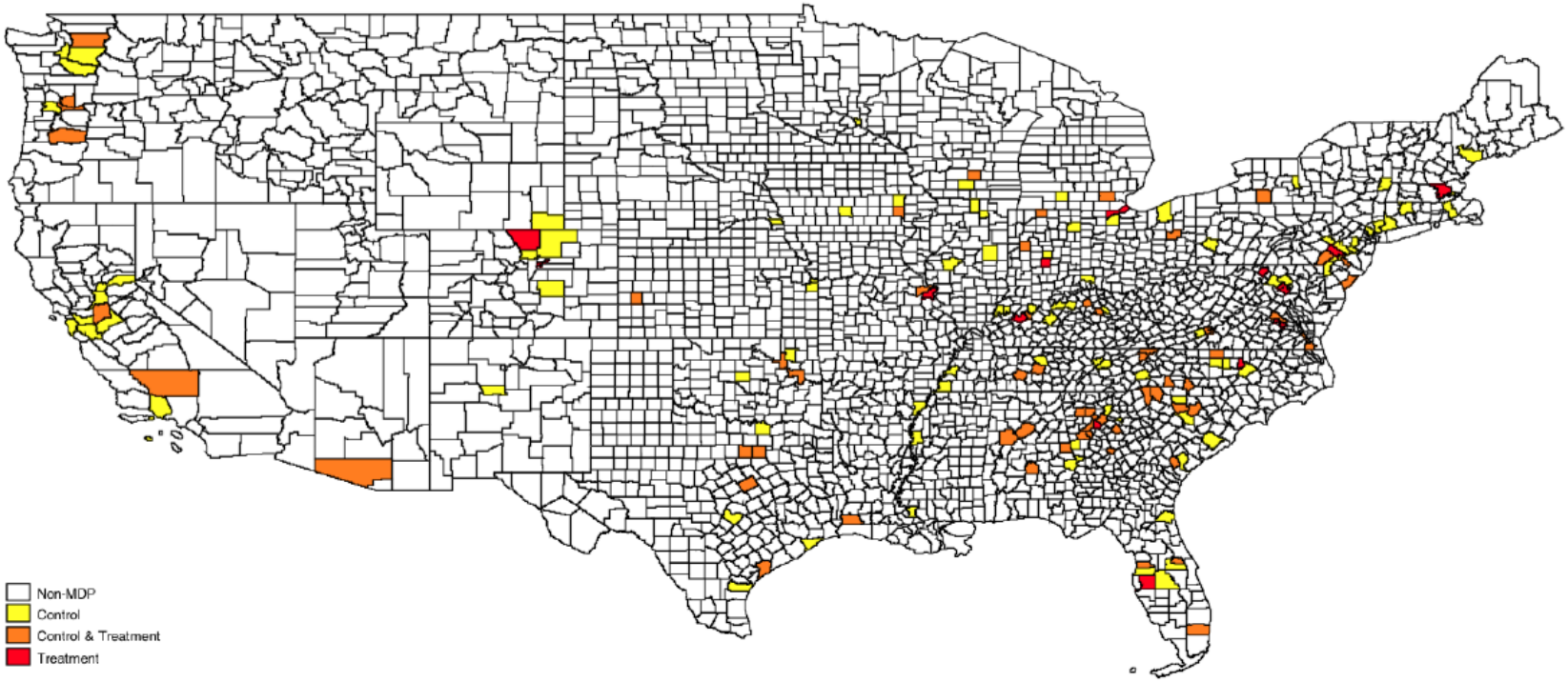
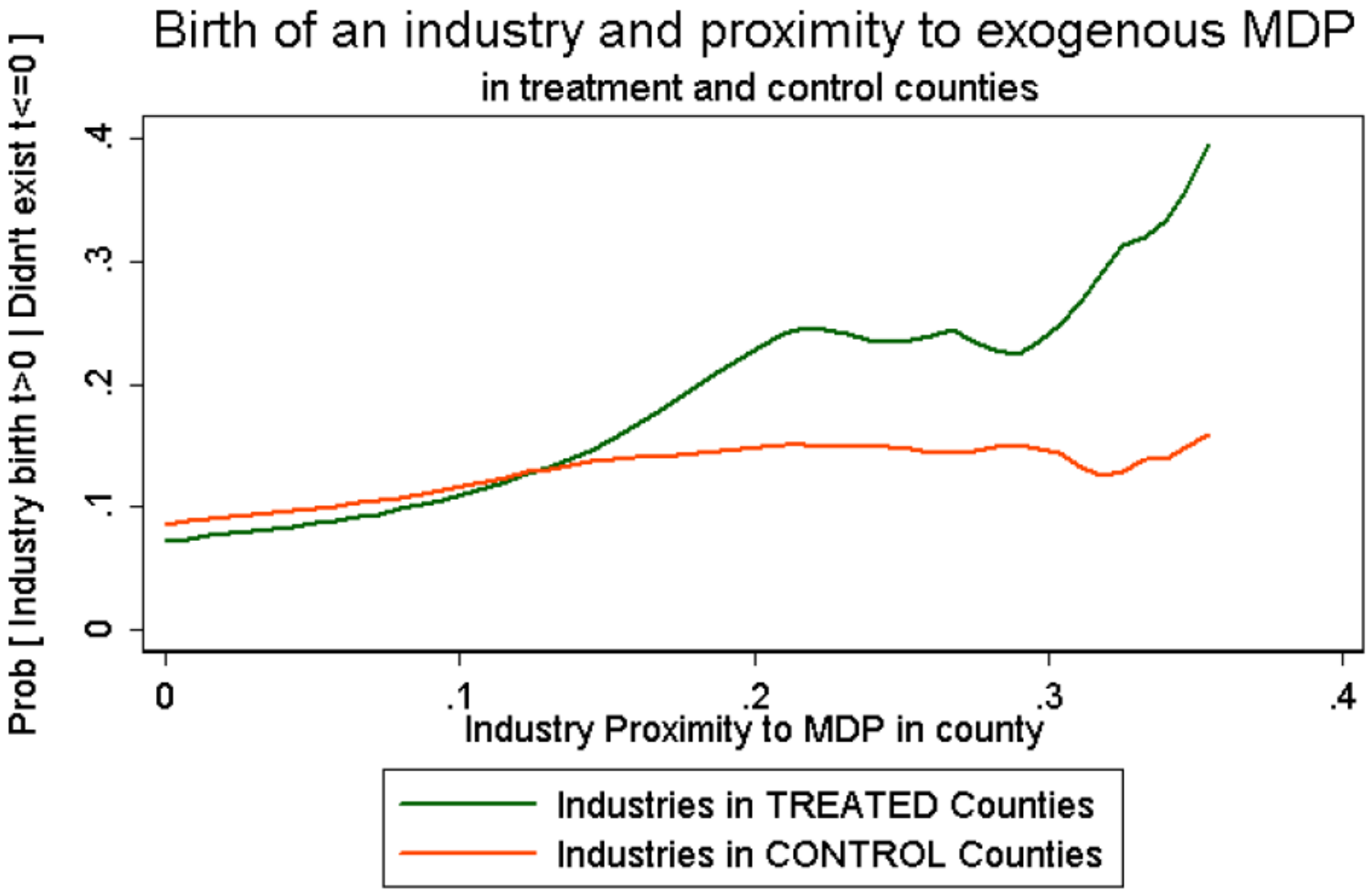


Figure 1. Map of counties in Million Dollar Plants

Locations of Million Dollar Plants and control groups

New industries appear in the vecinity of the MDP



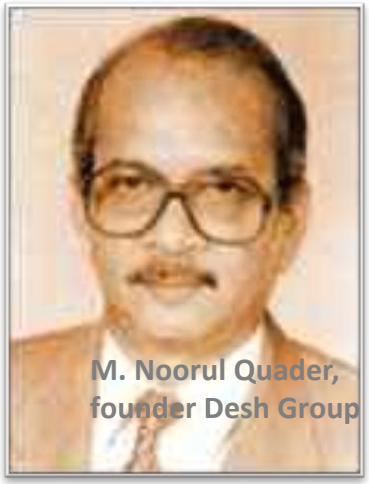
GETTING PERSONBYTES FROM ABROAD

TEXTILES IN DHAKA

Bangladesh has…

- A literacy rate of 55.9%
- 144 out of 176 in corruption perceptions ranking
- 146 out of 187 on human development index

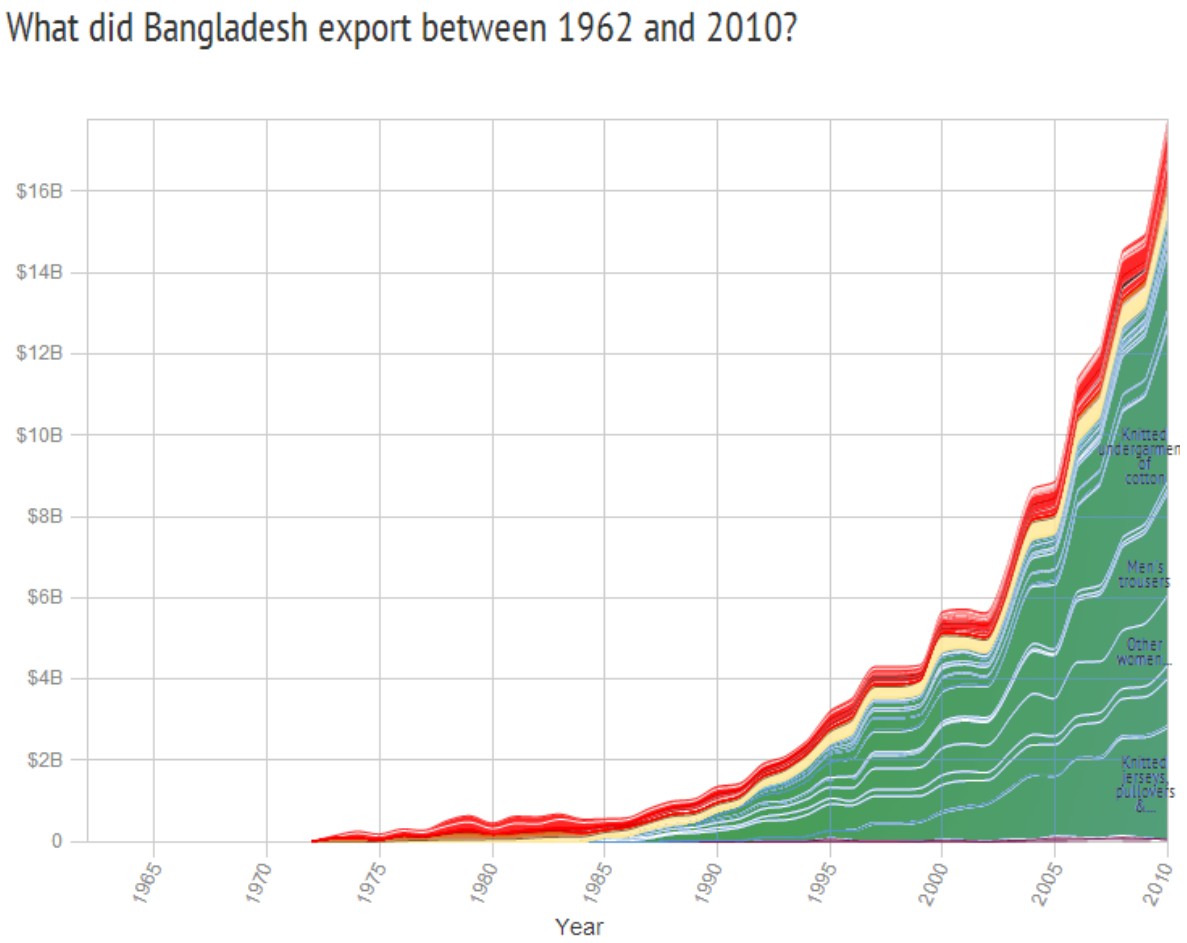
TEXTILES IN DHAKA


M. Noorul Quader, founder Desh Group

& DAEWOO

- 1979: Desh sends 126 Bangladeshi workers for a 6 month intensive training in Korea
- 1988: 56 spin-off companies by Desh workers have been established
- (Klepper and Mostafa 2011)

TEXTILES IN DHAKA



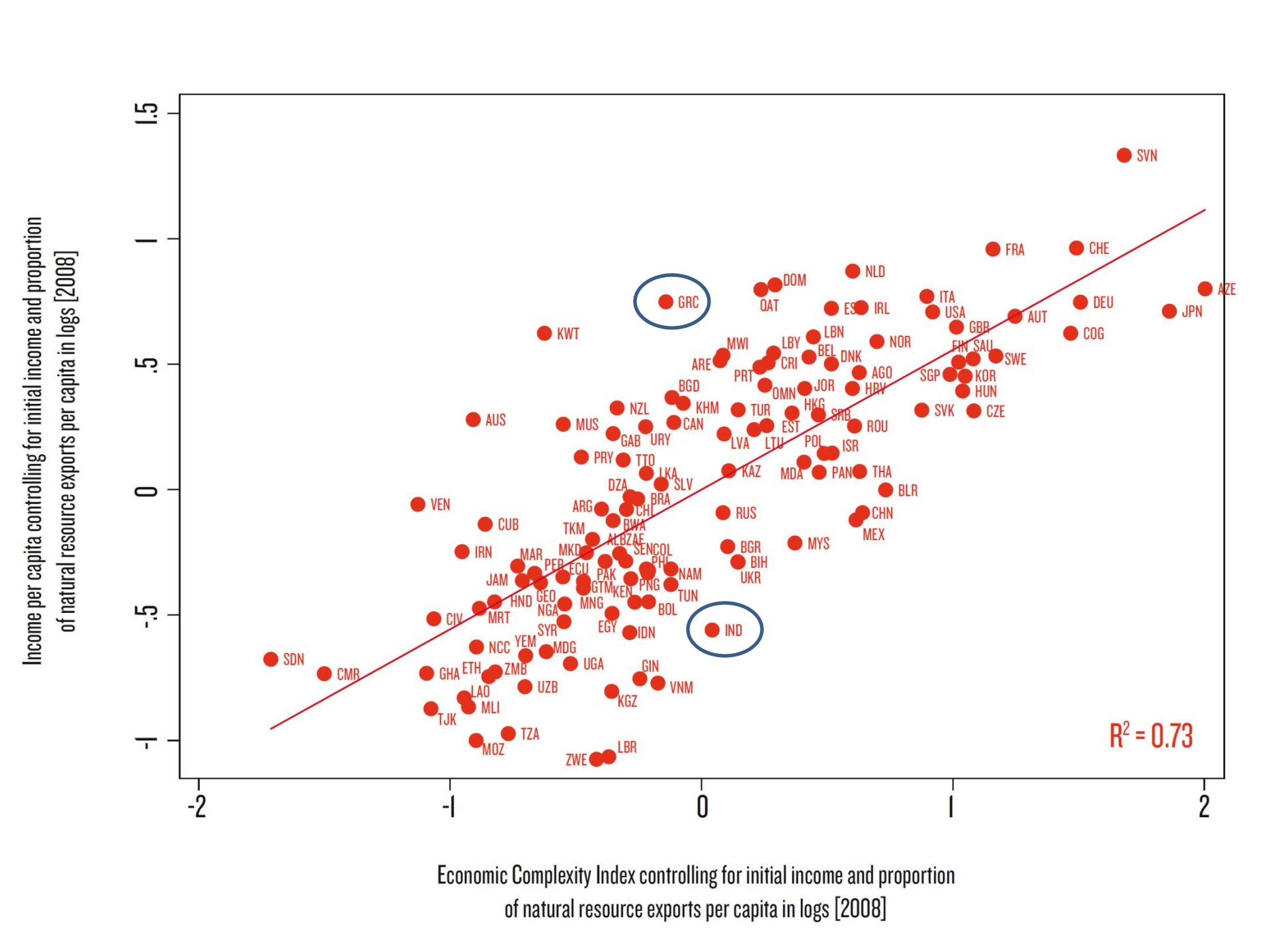
CID South Africa Economic Initiative January 2006

CID South Africa Economic Initiative January 2006

CID South Africa Economic Initiative January 2006

How do we explain growth?

- Countries converge to the level of income that can be supported by their personbytes
- Therefore the gaps between income and personbytes affects future growth
- But long-run growth should be affected by the accumulation of more personbytes
- This will depend on how easy it is to accumulate more personbytes
- …which is affected by the position of a country in the product space


Income per capita controlling for initial income and proportion of natural resource exports per capita in logs [2008]
Economic Complexity Index controlling for initial income and proportion of natural resource exports per capita in logs [2008]
1.5
1
.5
0
-.5
-1
-2
-1
0
1
2
R^2 = 0.73
SVN
FRA
CHE
AZE
NLD
DOM
QAT
GRC
ITA
USA
DEU
JPN
ES
IRL
AUT
GBR
COG
KWT
LBN
NOR
MWI
LBY
BEL
DNK
FIN
SAU
SWE
ARE
CRI
PRT
AGO
SGP
KOR
BGD
OMN
JOR
HRV
HUN
HKG
NZL
KHM
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CZE
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MUS
CAN
EST
ROU
GAB
URY
LVA
LTU
POL
ISR
PRY
TTO
LKA
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PAN
THA
DZA
SLV
BLR
BRA
VEN
ARG
CHL
RUS
CHN
CUB
BWA
TKM
MEX
ALB
ZAE
IRN
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BIH
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PAK
NAM
UKR
JAM
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KEN
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TUN
HND
GEO
MNG
BOL
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MRT
NGA
EGY
IND
SYR
IDN
NCC
YEM
MDG
SDN
CMR
UGA
GIN
GHA
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ZMB
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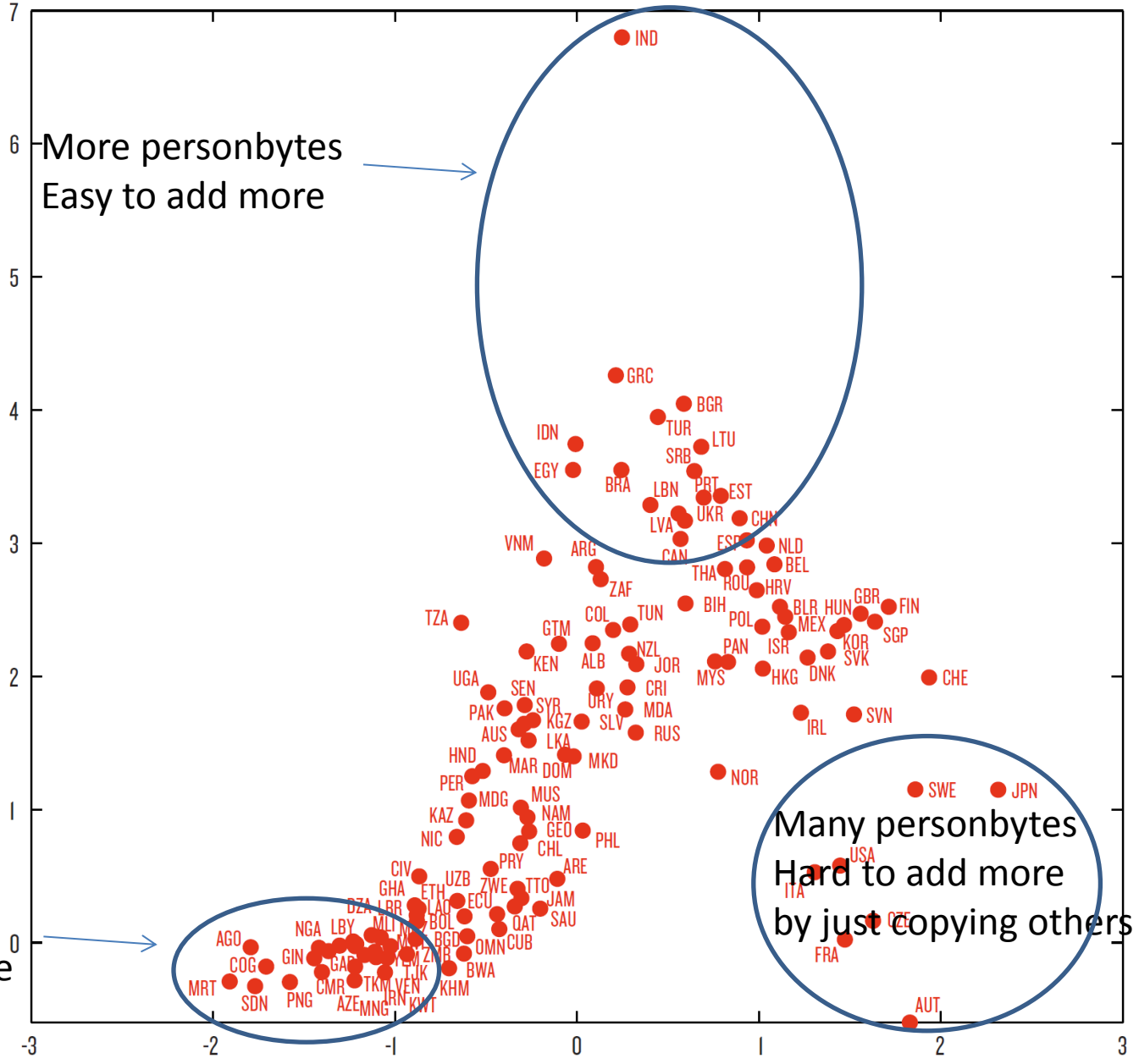
LAO
UZB
KGZ
MLI
TJK
TZA
MOZ
LBR
ZWE

How close are you to other good products?



How many personbytes you have?

The position in the product space affects the growth of complexity

	Economic Complexity Index (1978-2008)	
	5-Year Periods	10-Year Periods
VARIABLES	(1)	(2)
Initial Economic Complexity Index	0.915***	0.857***
	(0,017)	(0,036)
Initial Complexity Outlook Index	0.078***	0.136***
	(0,017)	(0,034)
Constant	-0,016	-0.064**
	(0,035)	(0,030)
Observations	637	313
R^2	0,926	0,892
Year FE	Yes	Yes
Speed of adjustment, ß	0,085	0,143
Long run effect, Đ	0,918	0,951

Baseline

Dependent variable: 10 year real GDP growth per capita (%)

VARIABLES	(1)	(2)	(3)	(4)
Initial GDP per capita, logs	-0.009	-0.667***	-0.489***	-0.738***
	(0.125)	(0.163)	(0.142)	(0.145)
Increase in real NNRR exports pc	4.034***	3.794***	4.062***	3.905***
	(0.830)	(0.919)	(0.967)	(0.979)
Initial Economic Complexity Index		1.393***		0.859***
		(0.228)		(0.197)
Initial Opportunity value Index			1.235***	0.832***
			(0.226)	(0.215)
Constant	1.326	6.267***	4.894***	6.776***
	(1.097)	(1.323)	(1.173)	(1.177)
Observations	294	294	294	294
R-squared	0.269	0.390	0.399	0.431
Year FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

ROYAL

Education

Dependent variable: 10 year real GDP growth per capita (%)

VARIABLES	(1)	(2)	(3)	(4)	(5)
Initial GDP per capita, logs	-0.762***	-0.954***	-0.884***	-0.776***	-0.921***
	(0.144)	(0.170)	(0.154)	(0.149)	(0.162)
Increase in real NNRR exports pc	6.604***	6.146***	6.218***	6.593***	6.001***
	(1.257)	(1.303)	(1.331)	(1.262)	(1.339)
Initial Economic Complexity Index	0.958***	0.766***	0.774***	0.947***	0.744***
	(0.184)	(0.174)	(0.187)	(0.184)	(0.181)
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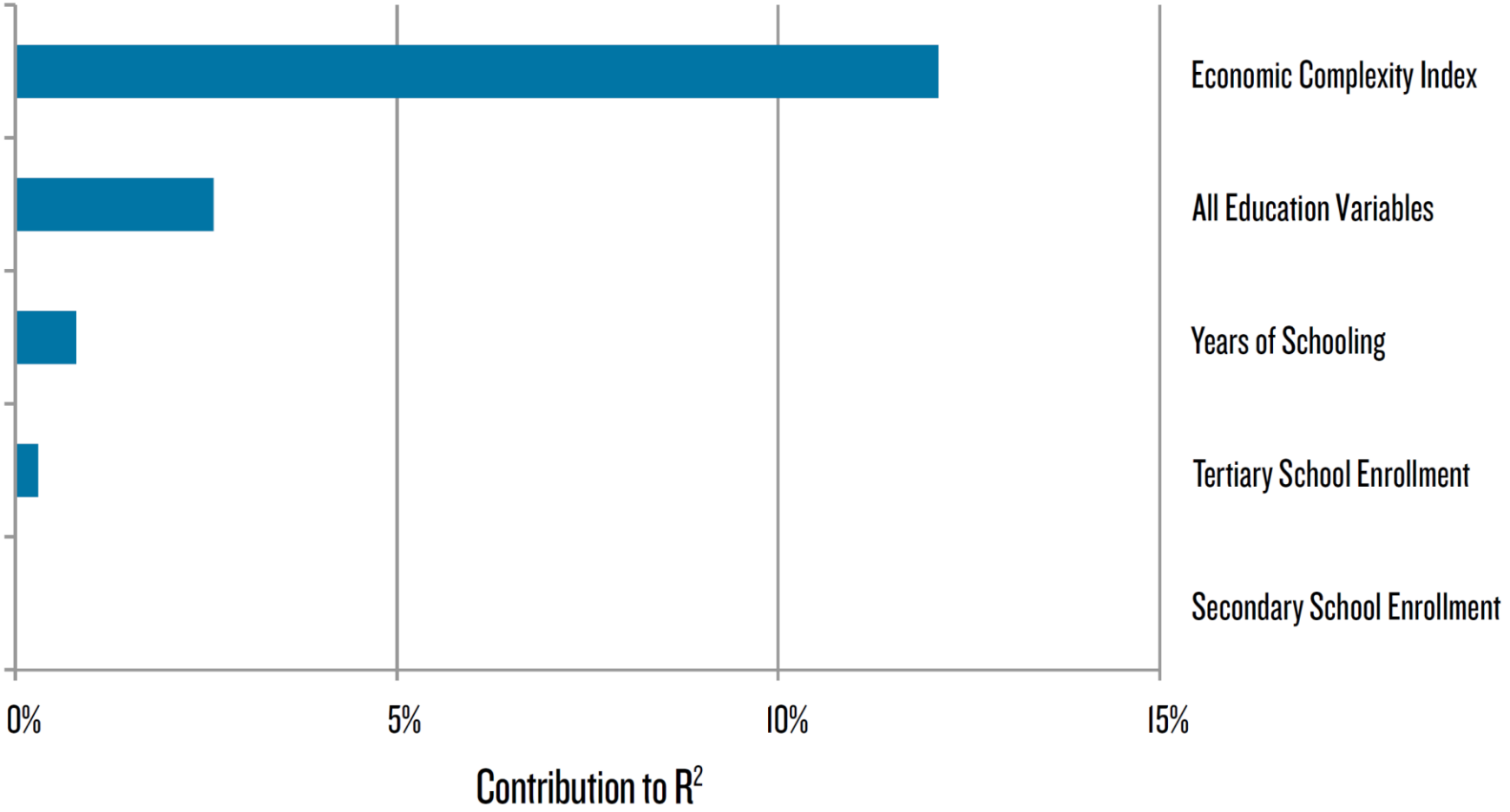

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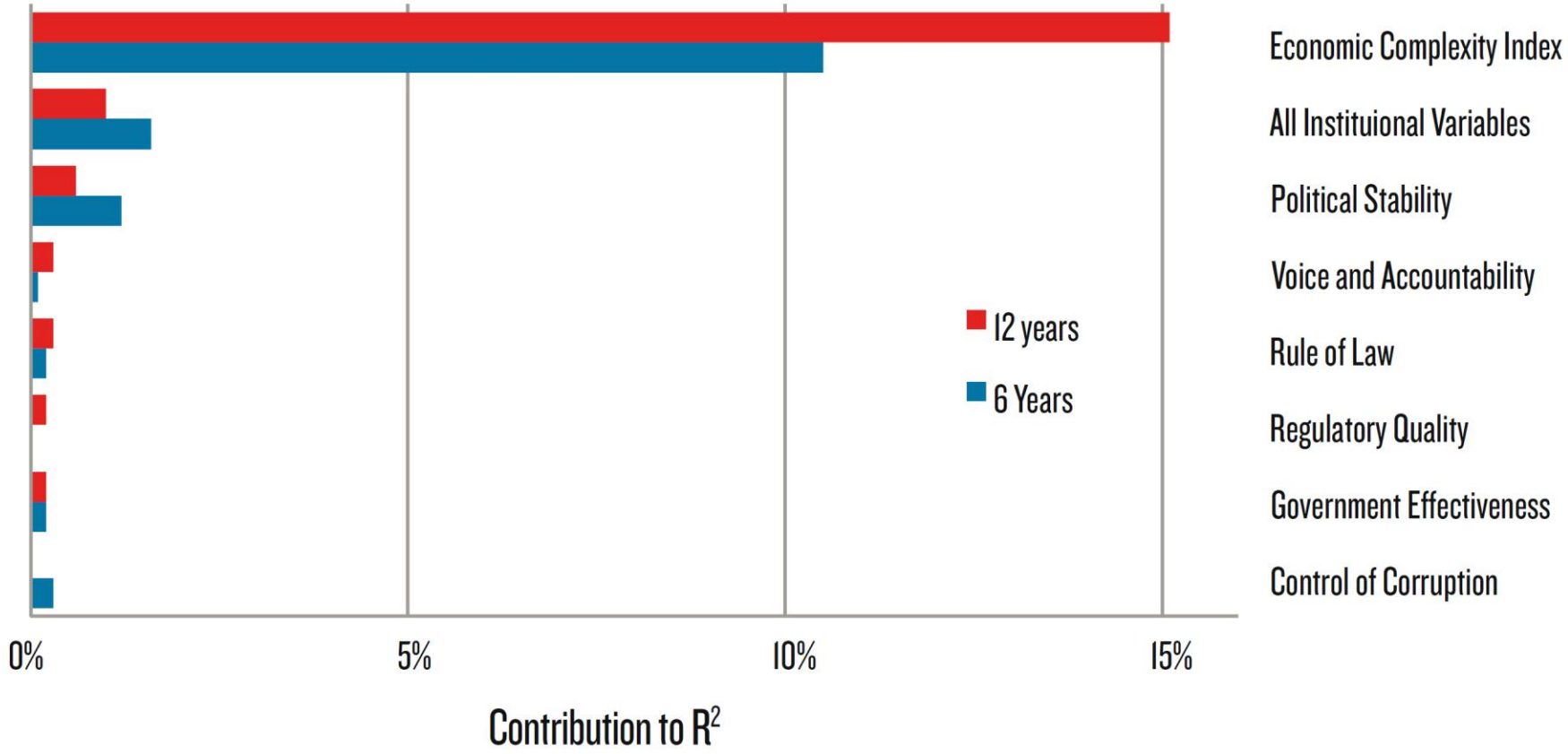

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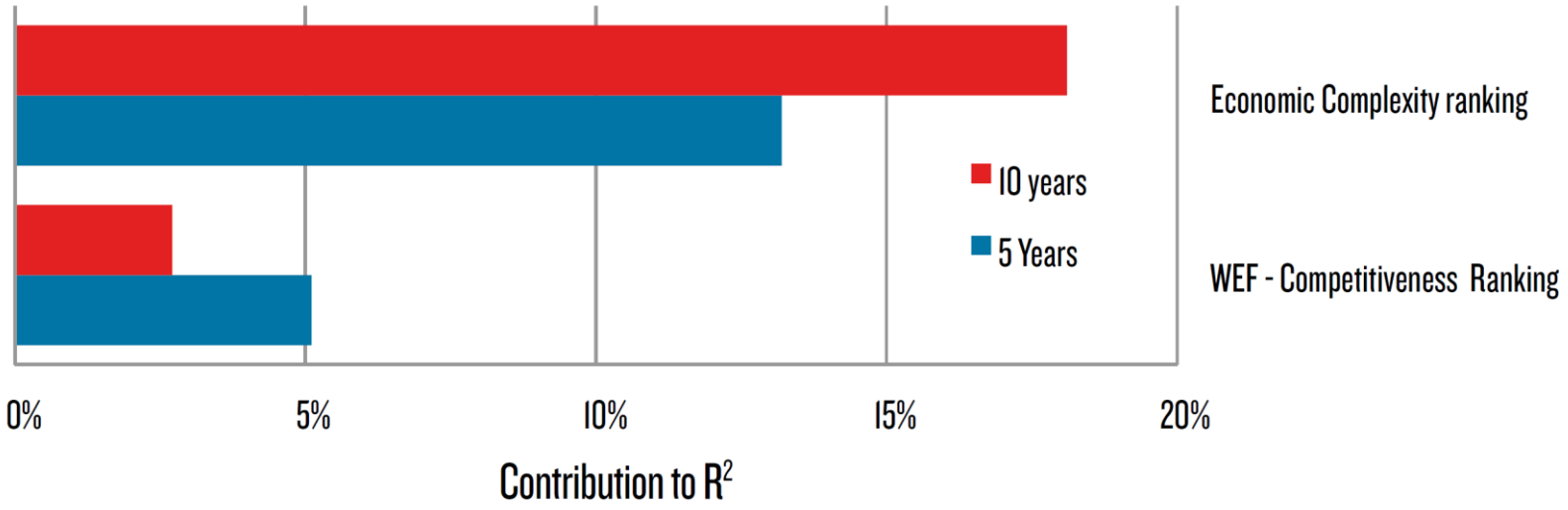

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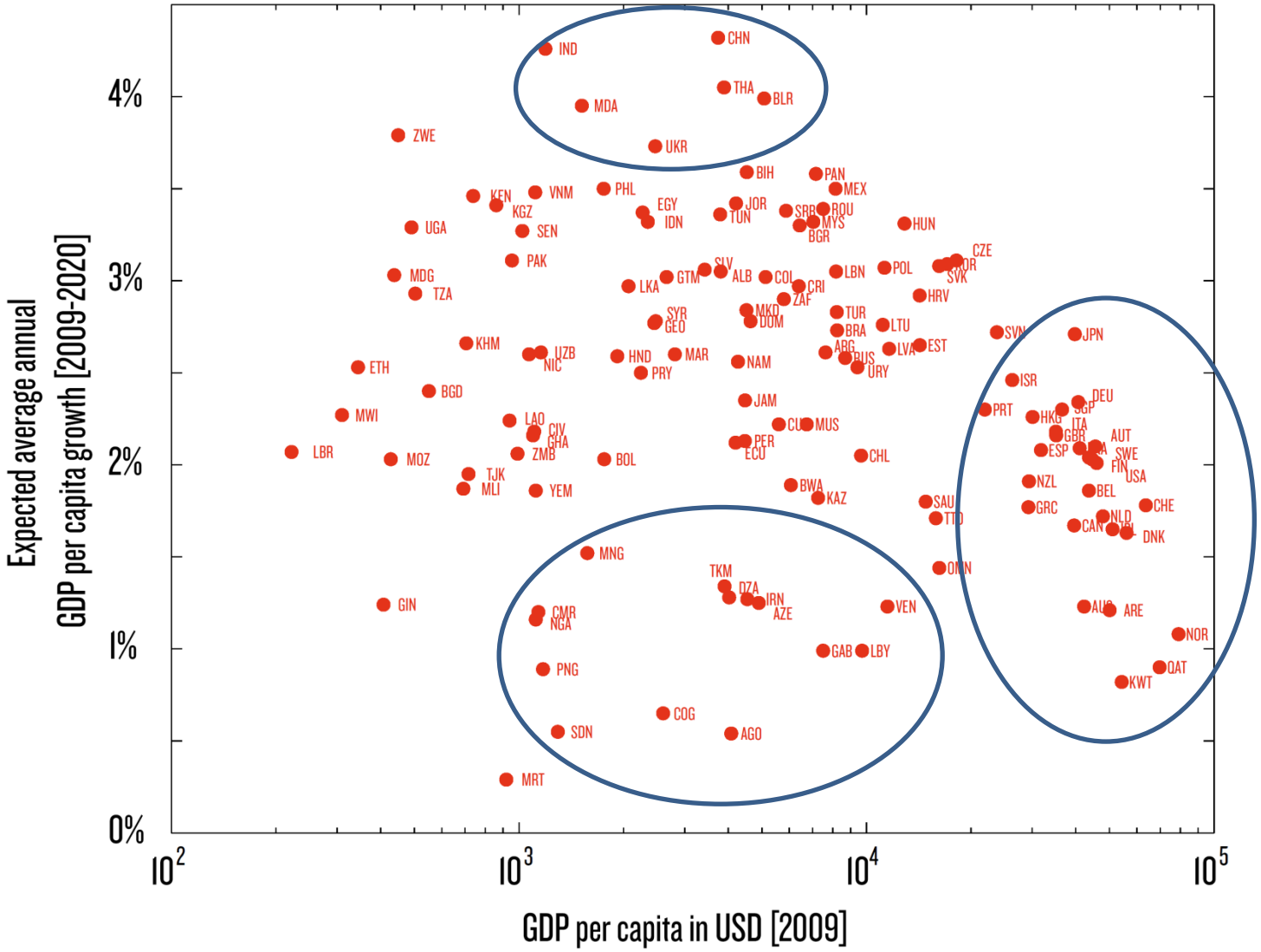

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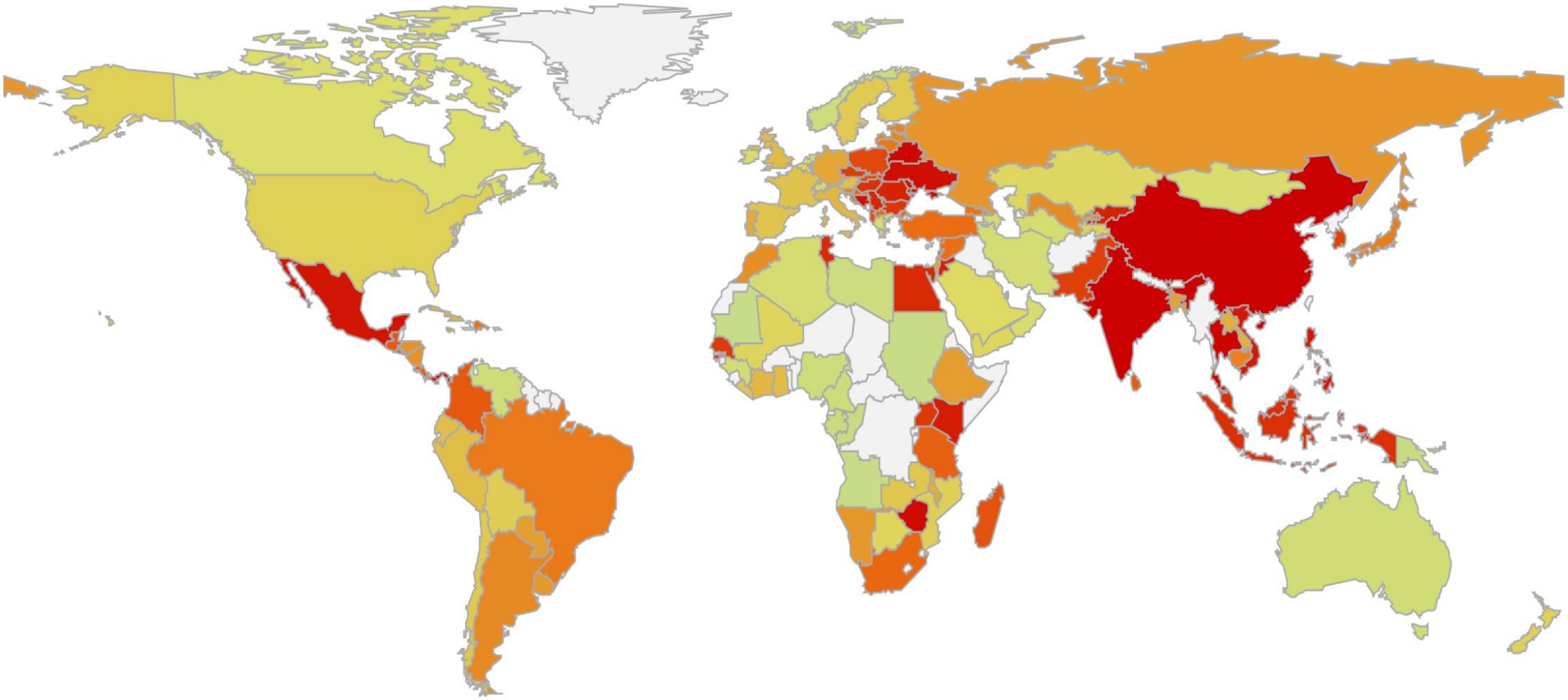
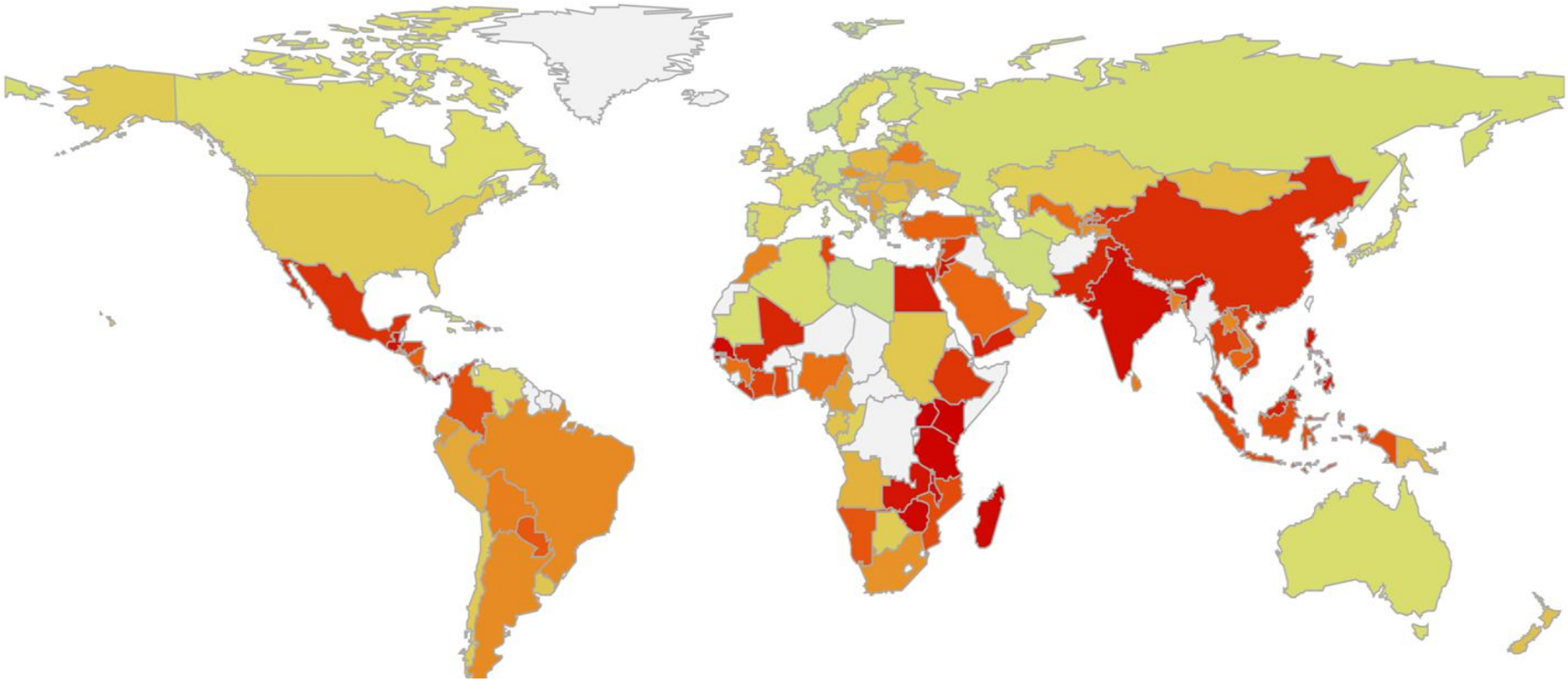
Growth in GDP per capita to 2020

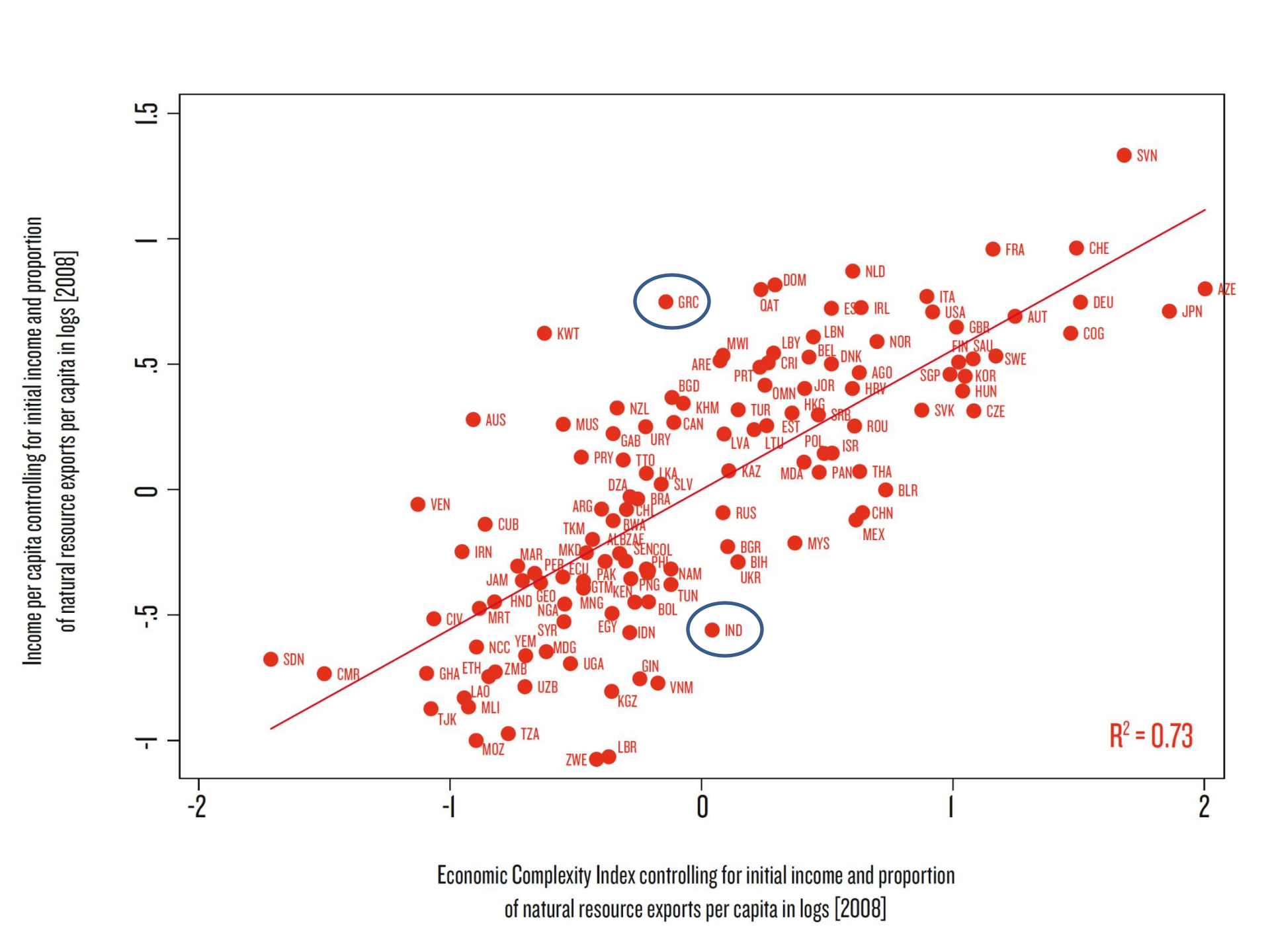


Who will grow faster?
Total GDP growth to 2020



How to think about strategy?

Strategic concepts


Income per capita controlling for initial income and proportion of natural resource exports per capita in logs [2008]
Economic Complexity Index controlling for initial income and proportion of natural resource exports per capita in logs [2008]
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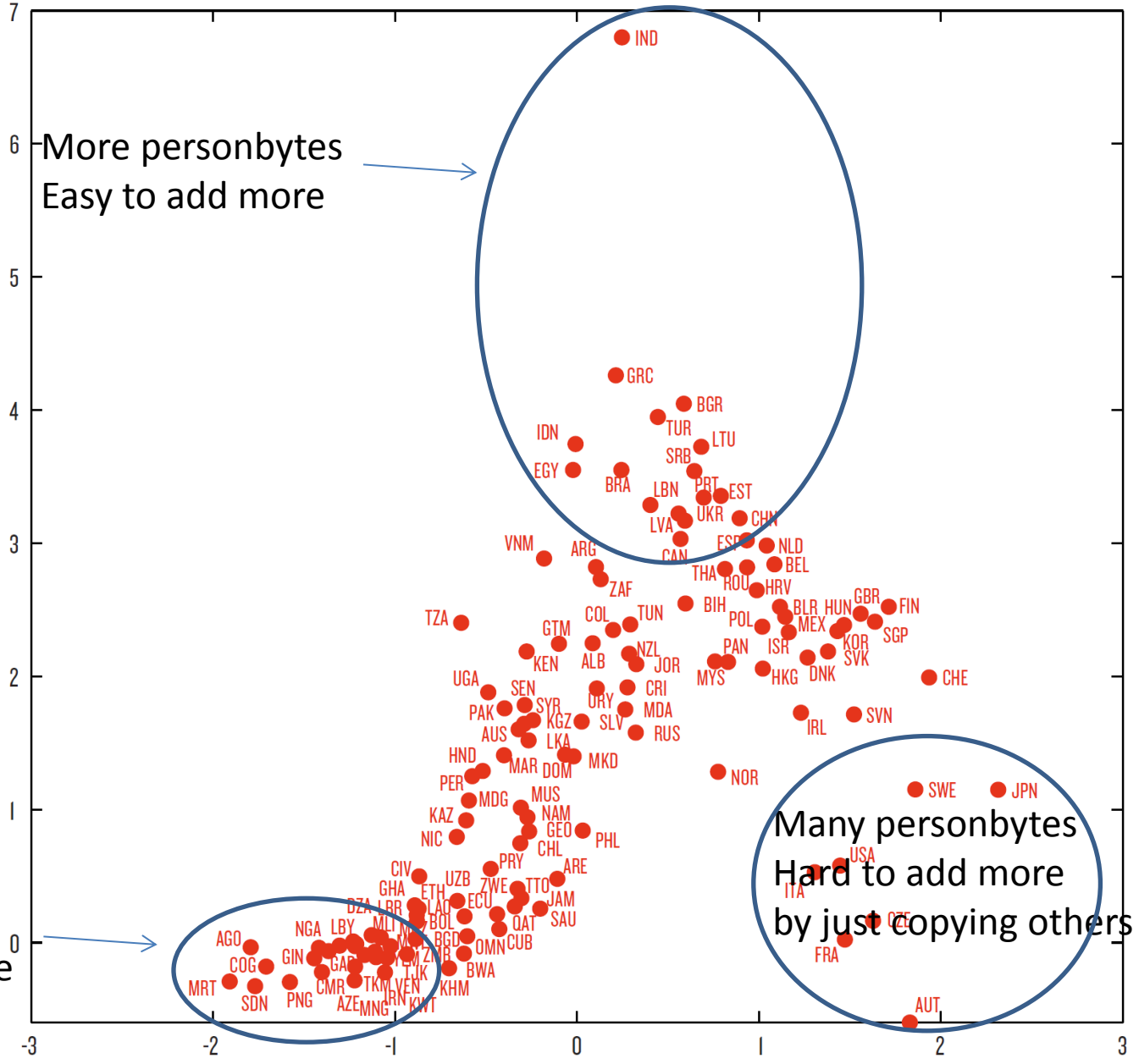
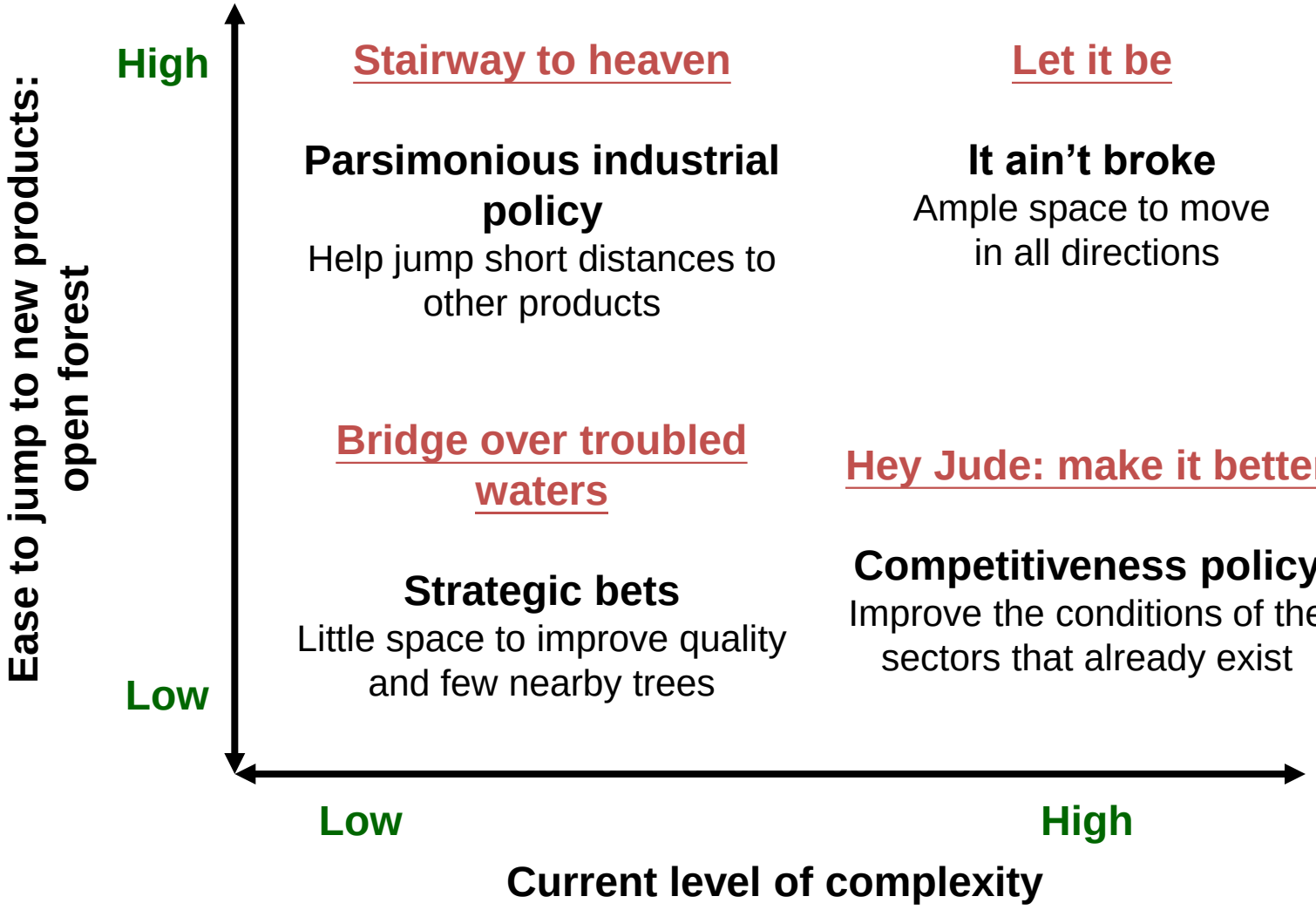
How close are you to other good products?

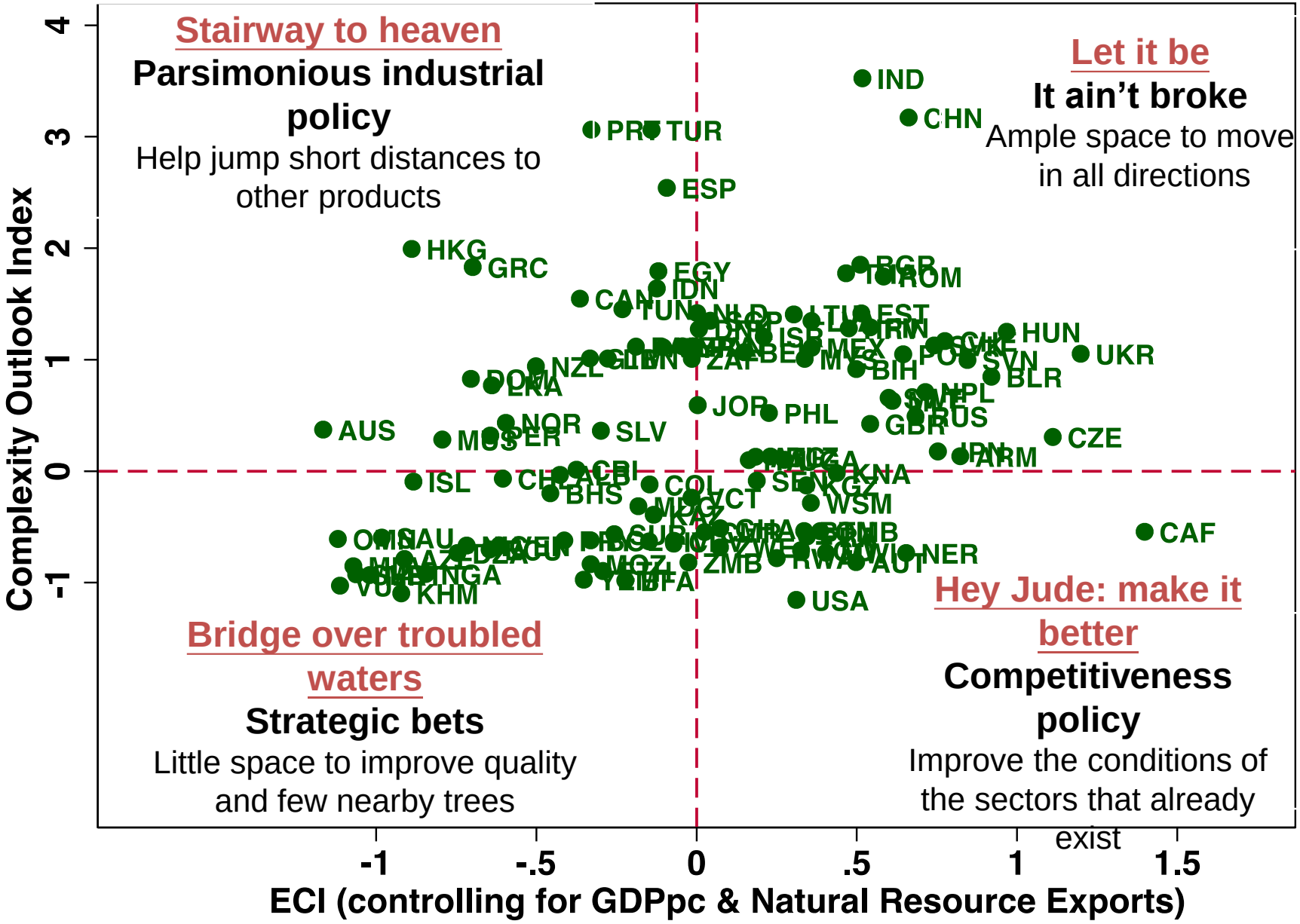


How many personbytes you have?

The strategic setting

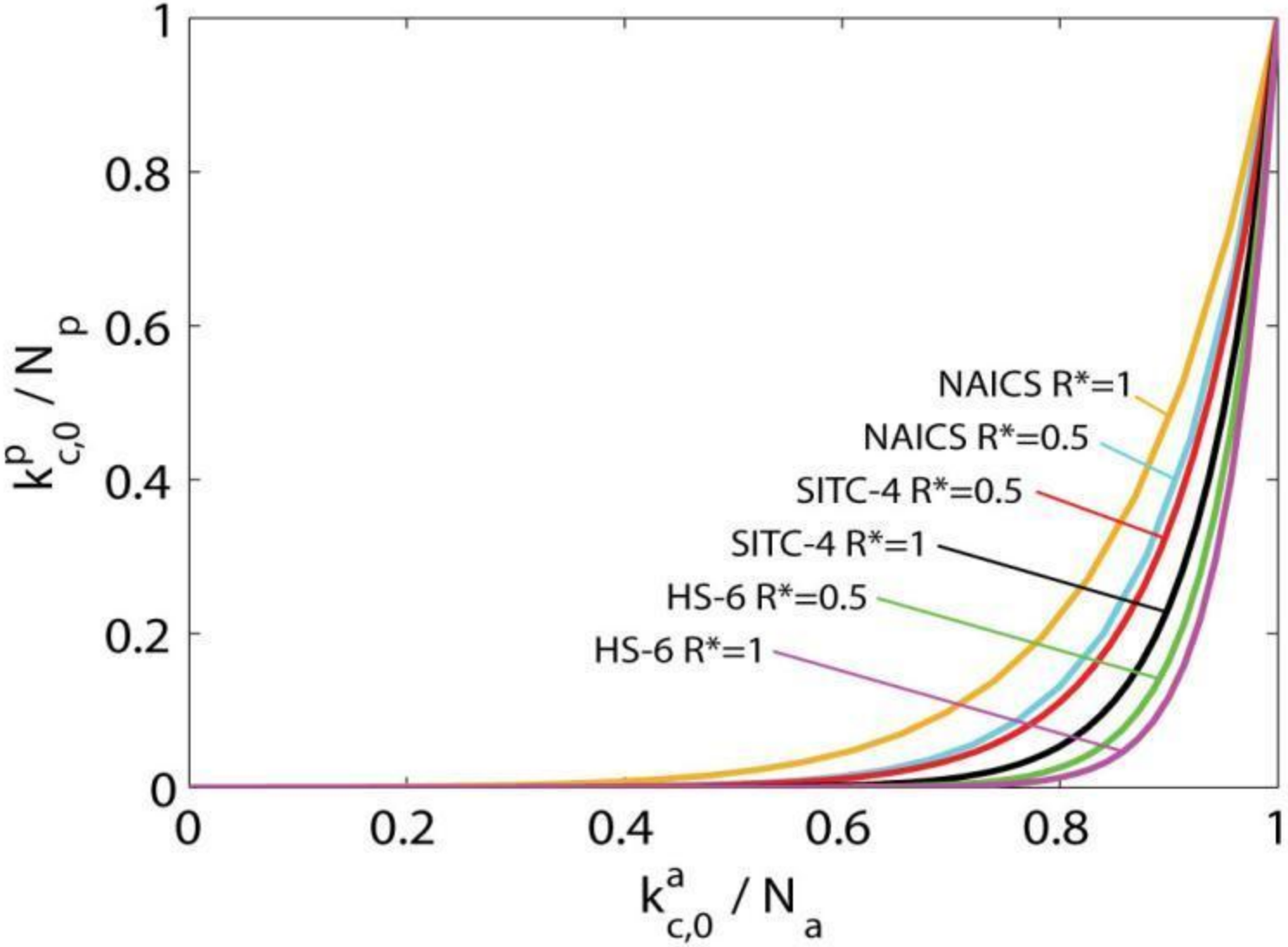


The Strategic Setting: intensive vs. extensive

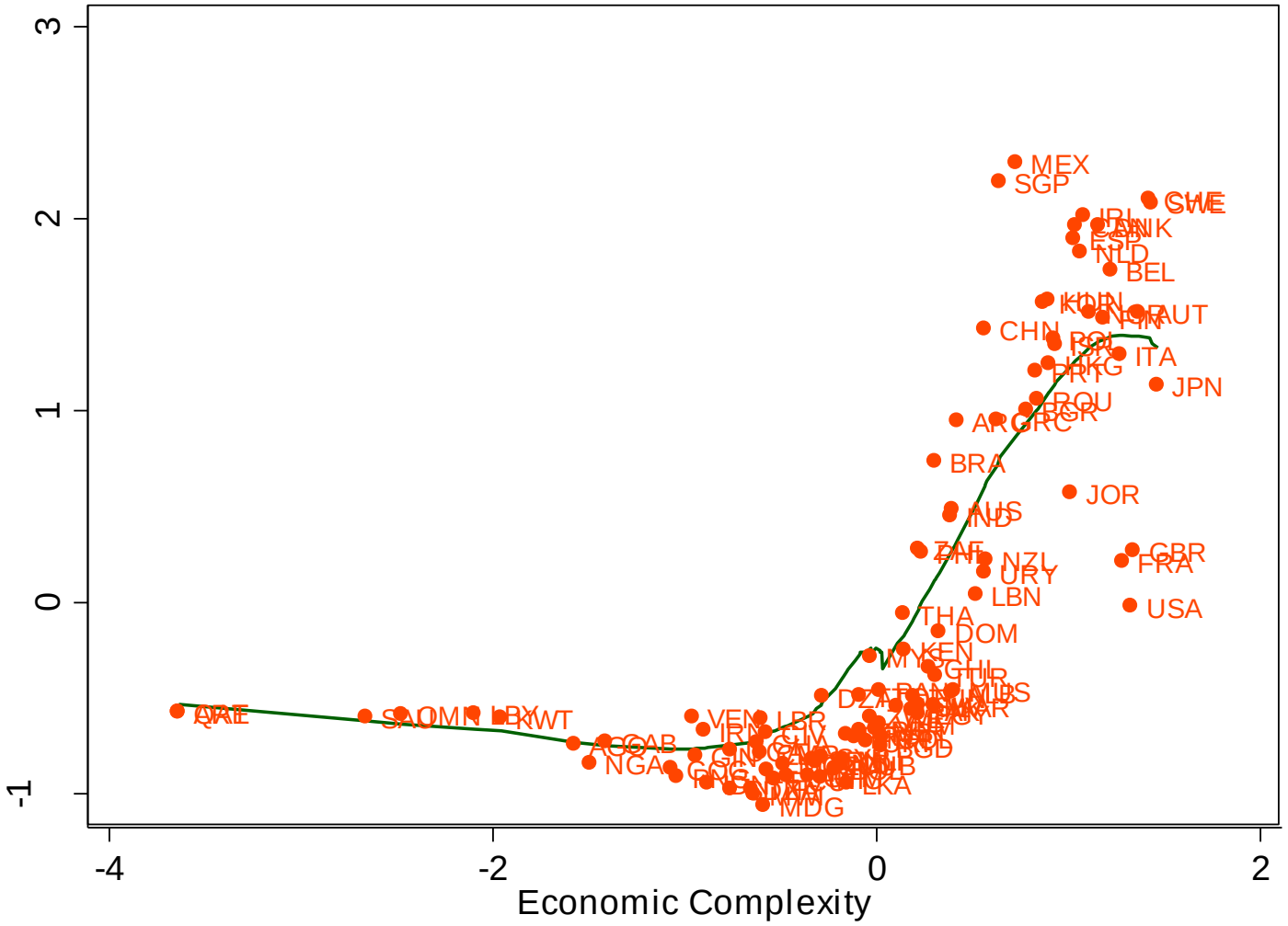


Why divergence then and convergence now?

The deep cause of the Great Divergence



1978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Economic Complexity
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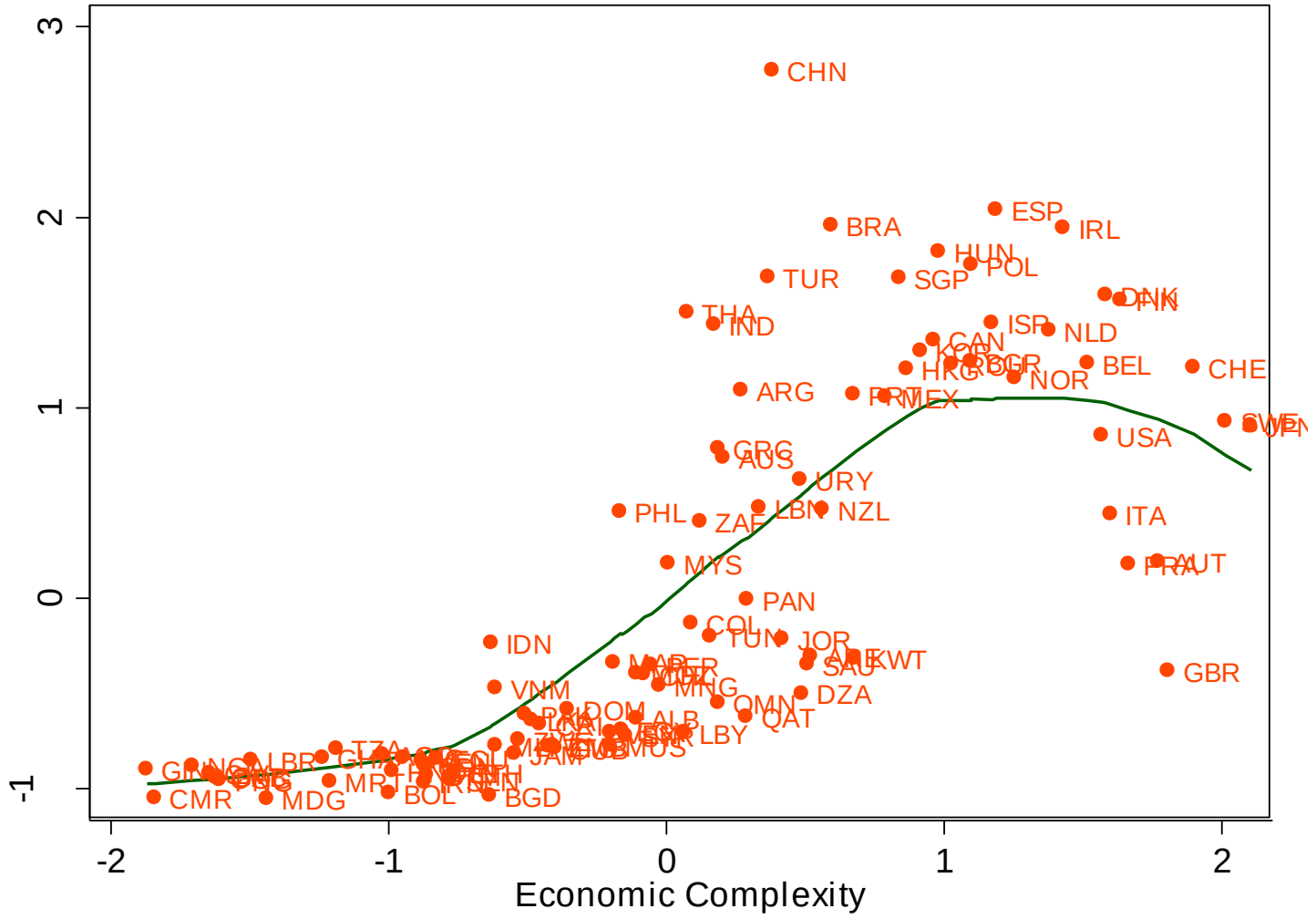
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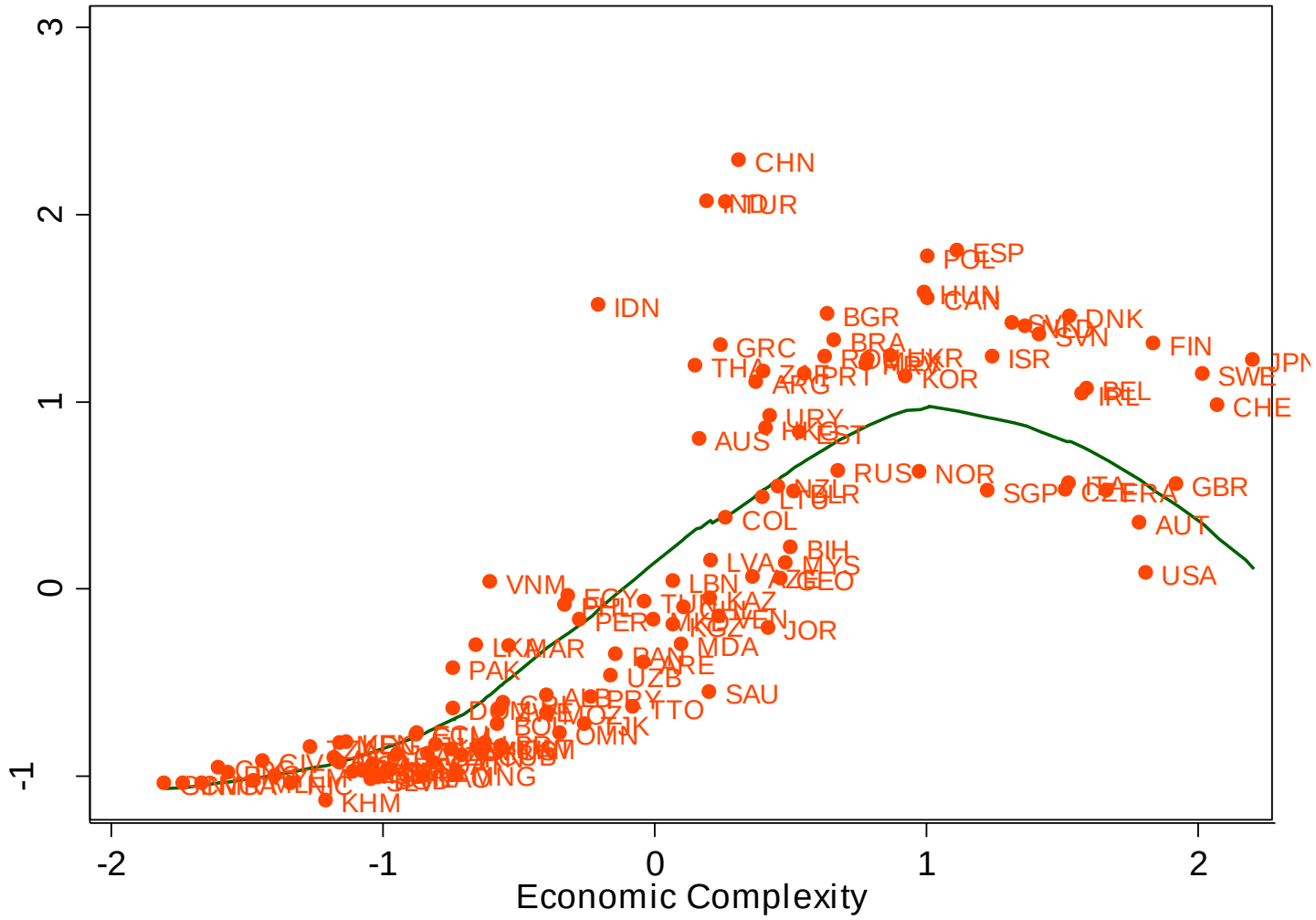
Economic Complexity

1998



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Economic Complexity
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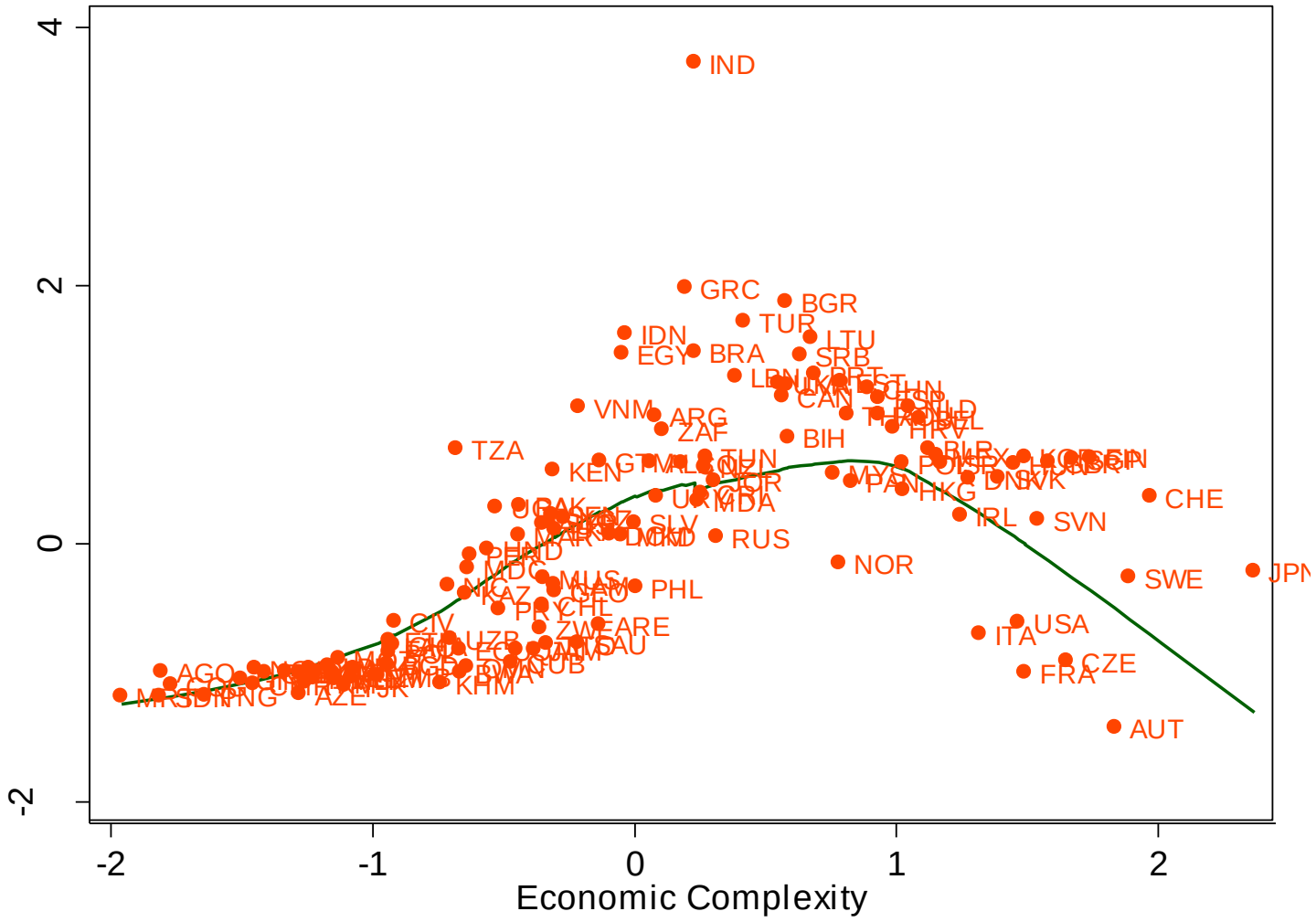
2008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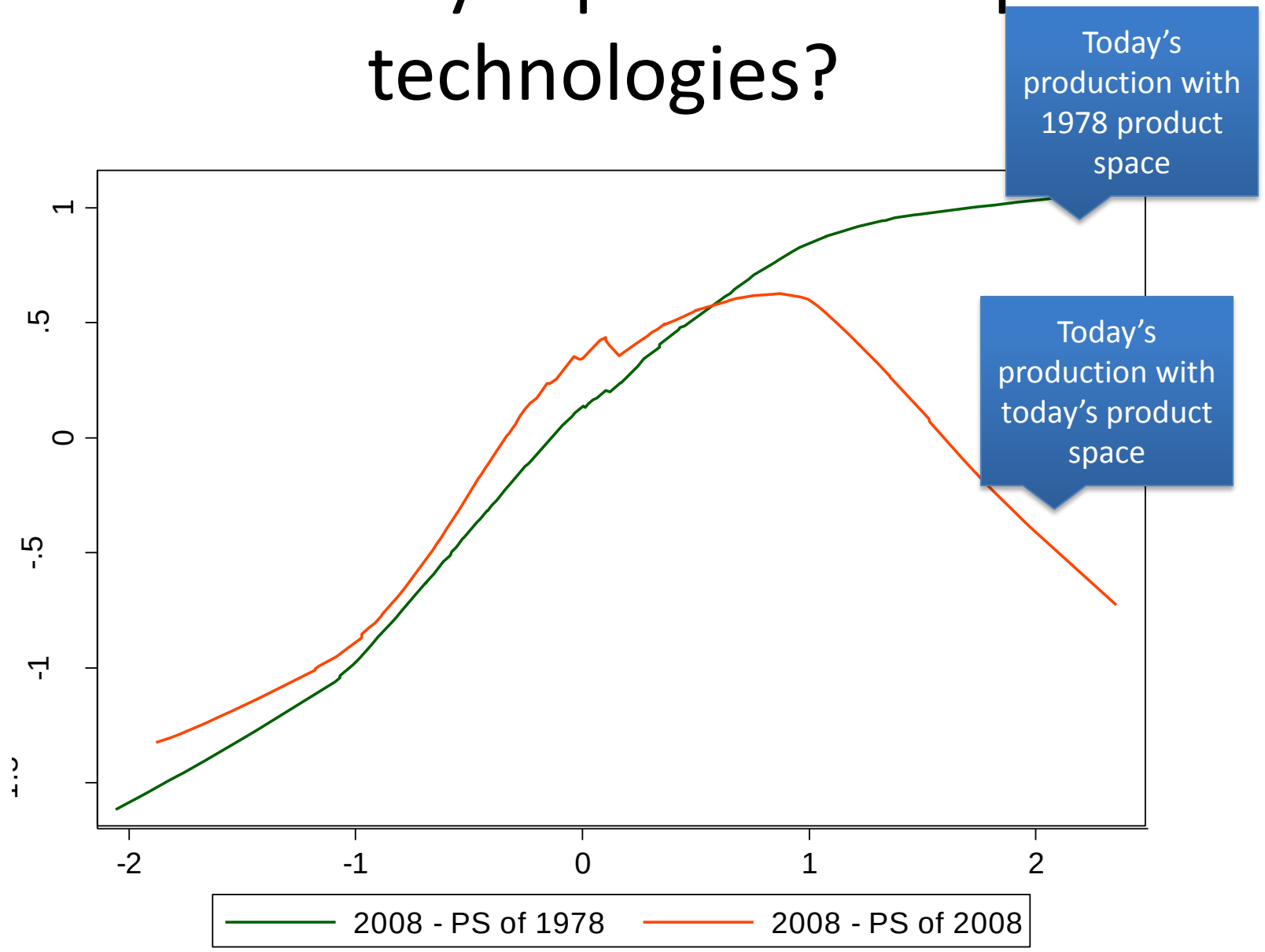
Economic Complexity

IS IT BECAUSE OF THE ACCUMULATION OF COUNTRY CAPABILITIES OR A CHANGE IN PRODUCT TECHNOLOGY?

Is it the country capabilities or product technologies?



Some answers to old questions

- Does what you produce matter?
  - Yes, because it affects the amount of inter-industry spillovers you will be able to exploit
  - Contrast Chilean Salmon with Malaysian microwave ovens
- What causes the “resource curse”?
  - The fact that the resource-intensive sectors are in a sparse part of the forest
- What causes growth collapses?
  - Hausmann, Rodriguez and Wagner (2008)
  - A shock to you export sector in countries that are poorly positioned in the product space

Some answers to old questions

- Why has income in the world not converged?
  - Because the distance between products is bigger than the typical size of a monkey's jump
  - Unless they are well positioned or on steroids monkeys cannot reach the central parts of the product space
- What about globalization matters for convergence?
  - Trade in tasks and global production chains save on the number of capabilities that need to be present in a single place
- Does the dictum "add value to your raw materials" make sense? (Hausmann, Klinger and Lawrence, 2008)
  - Not too much: proximity matters but is not I/O related
  - Finish wood
  - Follow the capabilities, not the products

Summing up

- What caused the Great Acceleration?
  - More letters (technologies)
  - More words (products)
- What caused the Great Divergence
  - The alphabet and the words got longer
  - Countries with few letters could not catch up

Summing up (cont'd)

- What is causing the Great Convergence?
  - Globalization of the value chain is making it easier for any location to get into the game
  - Trade in syllables
- But not for all countries
  - Many are still trapped

Summing up

- Development is about the accumulation of productive knowledge at the social level
- Because individuals are limited, this requires the division of knowledge (and labor)
- But this knowledge needs to be re-aggregated through organizations and markets
- The accumulation of productive knowledge is made difficult because of strong complementarities
  - Coordination failures

Summing up (cont'd)

- The heterogeneous nature of the product space affects the intensity of the coordination problem and hence of convergence and growth
- The nature of the obstacles have shifted over the past 35 years, making the accumulation of productive knowledge easier for middle knowledge countries
  - Because of increased tradability of intermediate inputs?
  - Because of increased accumulation of personbytes?

THE ATLAS OF ECONOMIC COMPLEXITY

MAPPING PATHS TO PROSPERITY

Hausmann, Hidalgo et al.

www.cid.harvard.edu/atlas

The Observatory

OF ECONOMIC COMPLEXITY

The role of globalization

- Products may be getting more complex
  - Longer words
- …but value chains are becoming more global
- Each location needs to have fewer capabilities
  - Words are getting shorter
  - Trade in syllables
- Easier to get in
  - Lenovo

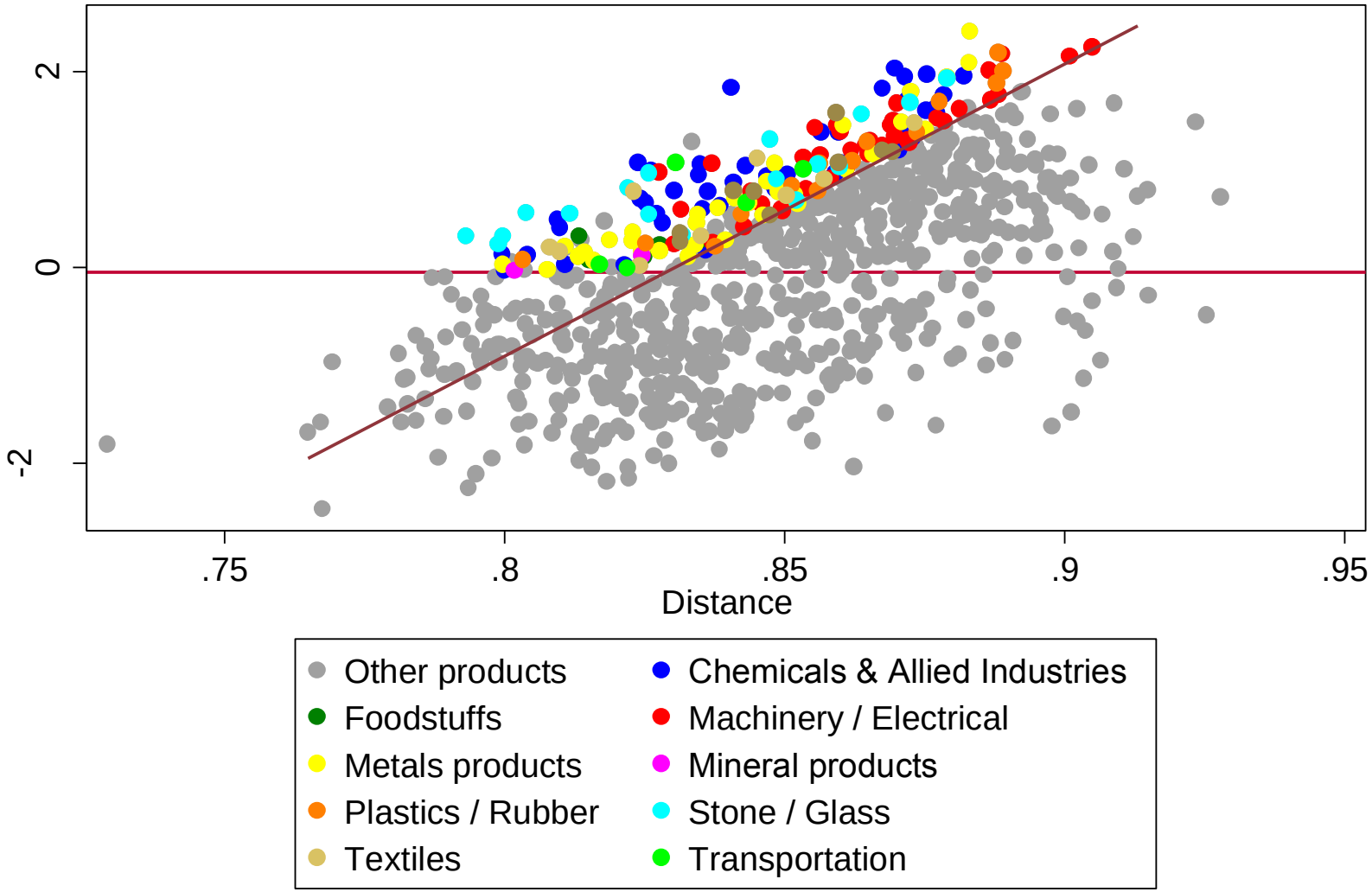
Useful measures

- How far is a certain industry from your current revealed capabilities?
  - A measure of how difficult it will be to develop it
- How complex is the industry?
  - A measure of how profitable, or how high are the wages it would be able to pay
- How strategic is that industry?
  - How connectedness is the industry? How would conquering it make future diversification easier
- The efficient frontier
  - How to balance these criteria?

Two views of the efficient frontier

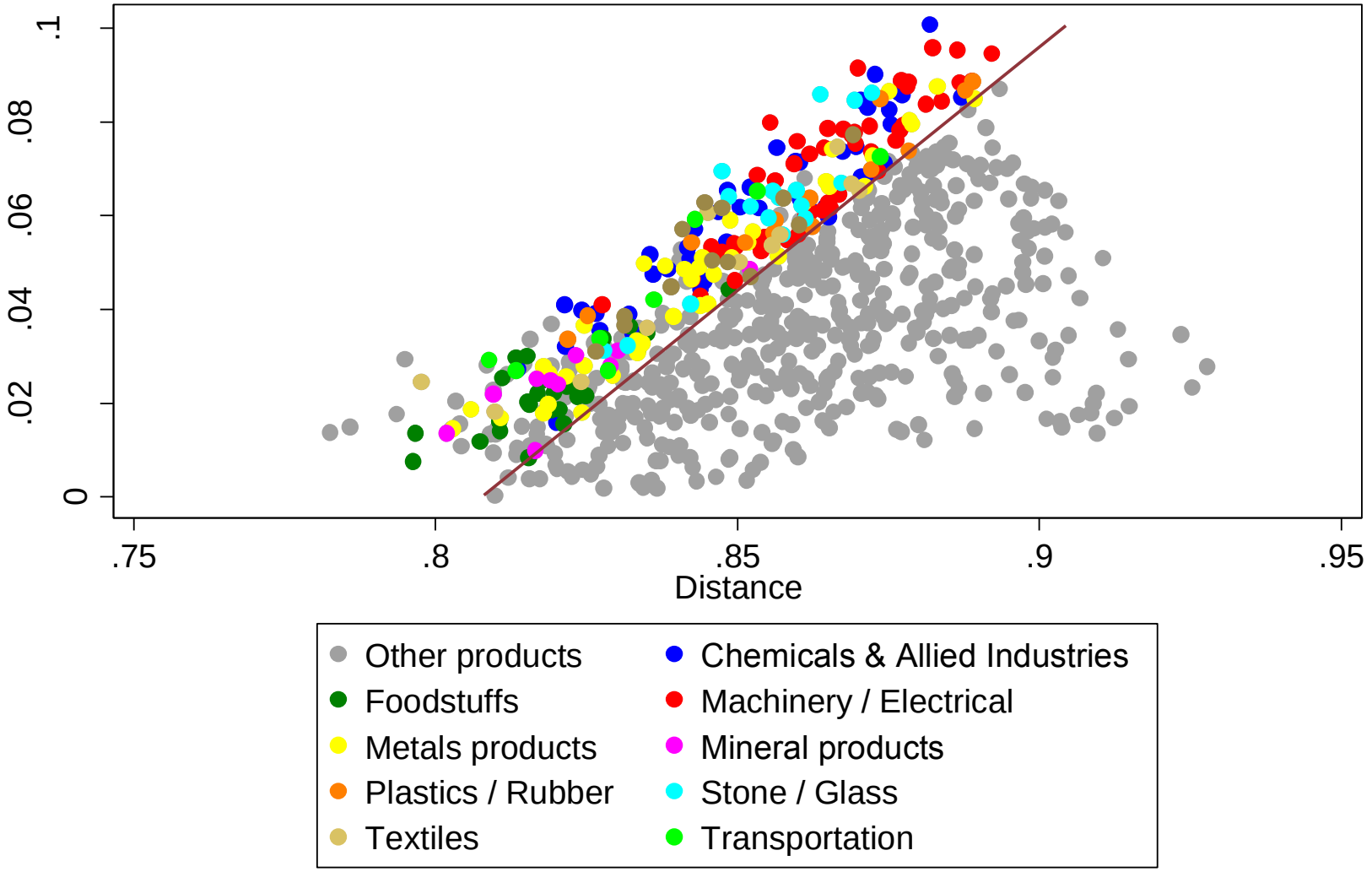
- Distance vs. Complexity
- Distance vs. Opportunity Gain (Strategic Value)

Two views of Saudi Arabia's efficient frontier: Complexity and distance



Note: Colors according to HS Chapters

Two views of Saudi Arabia's efficient frontier: Opportunity gain and distance



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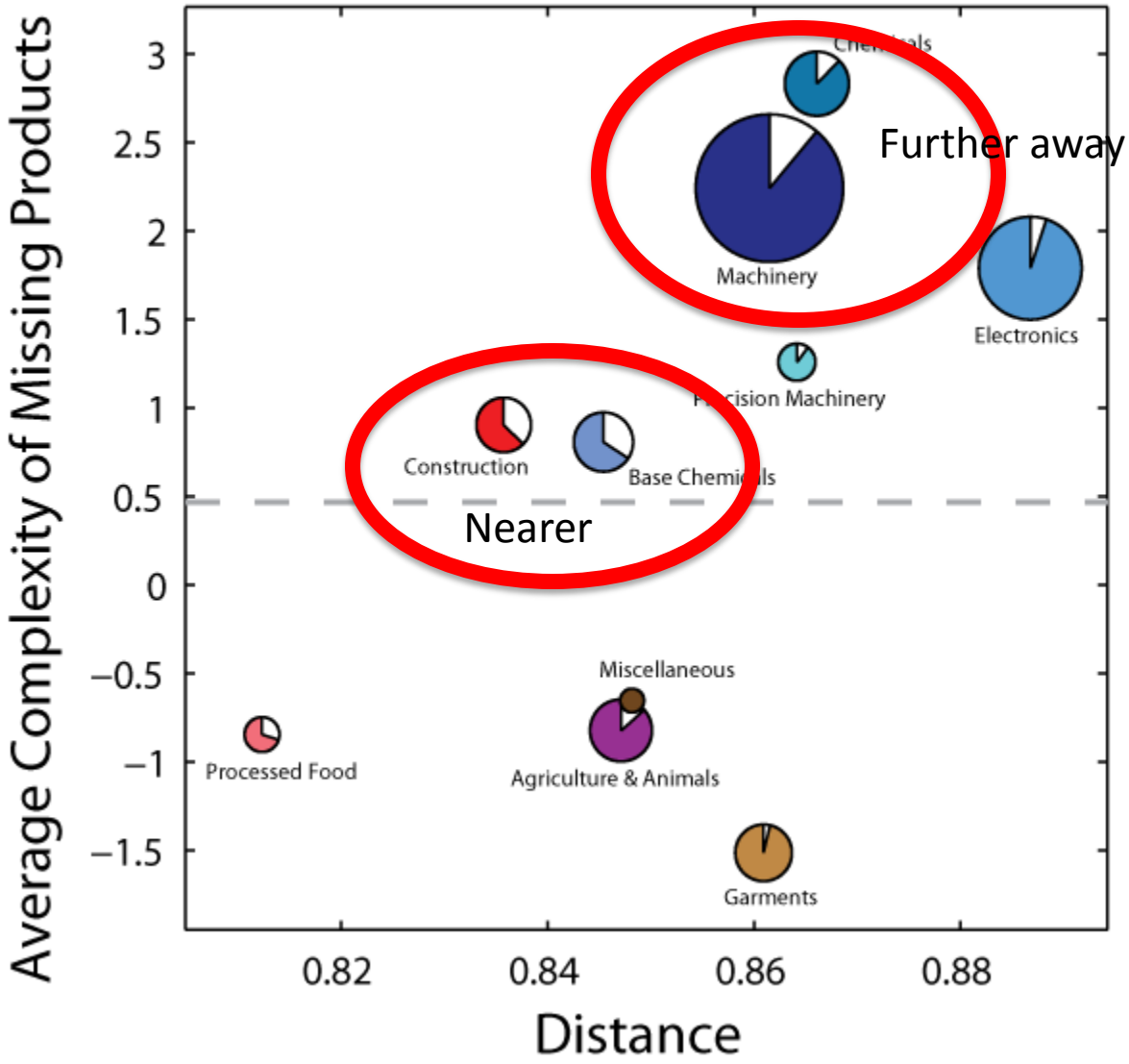
Average Complexity of Missing Products
3
2.5
2
1.5
1
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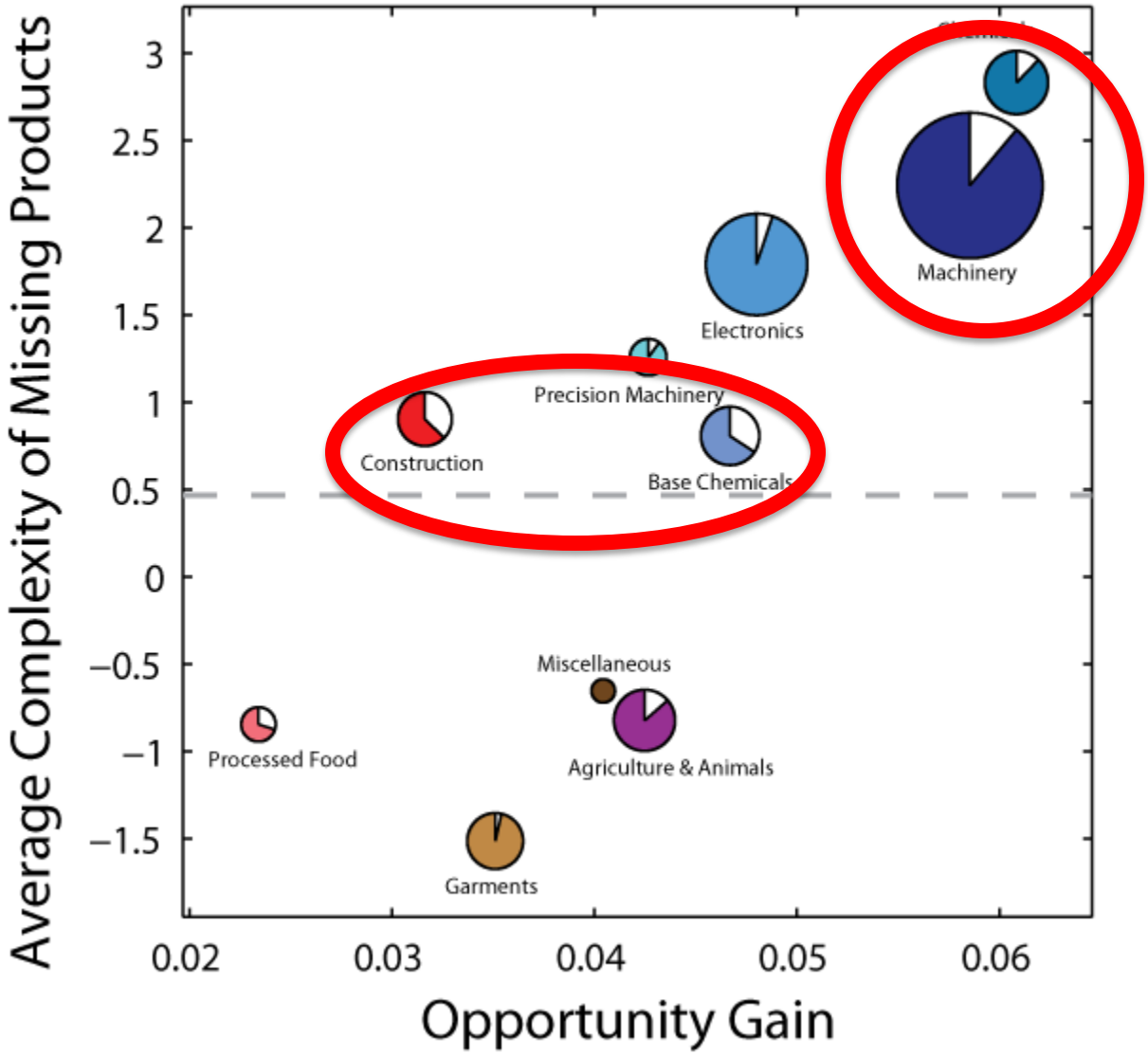
−0.5
−1
−1.5
0.82
0.84
0.86
0.88
Distance
Further away
Nearer
Machinery
Electronics
Construction
Miscellaneous
Processed Food
Agriculture & Animals
Garments


Average Complexity of Missing Products
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0.5
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−0.5
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0.02
0.03
0.04
0.05
0.06
Opportunity Gain
Machinery
Electronics
Precision Machinery
Construction
Base Chemicals
Miscellaneous
Agriculture & Animals
Processed Food
Garments

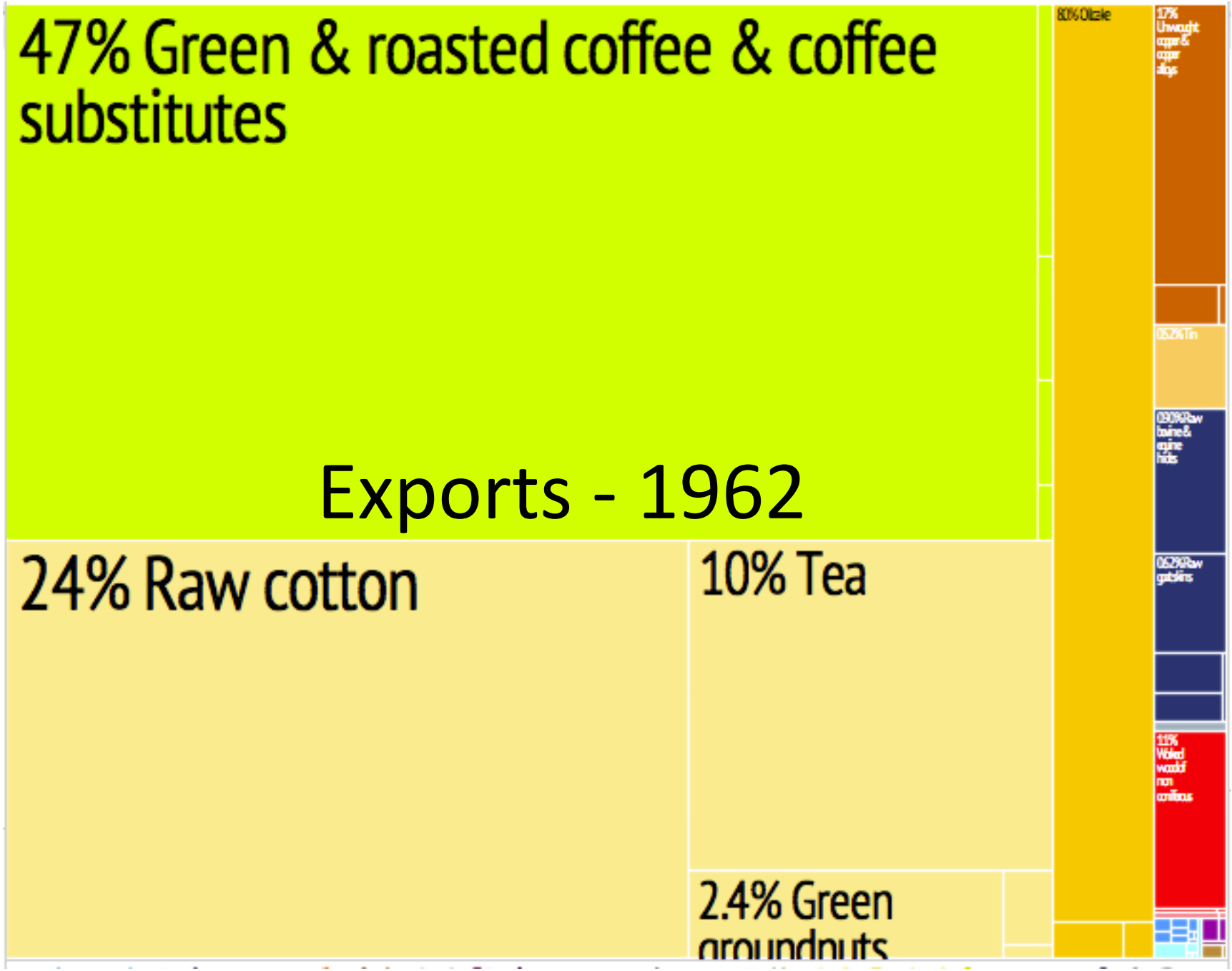
Summary

Product communities	Number of products	Complexity target range (only)	Opp. Gain target range (only)	Both	Sum	sum as share of number of products
Base Chemicals	33	10	11	10	31	94%
Chemicals	84	18	14	22	54	64%
Construction	51	15	5	14	34	67%
Machinery	183	15	39	52	106	58%
Agriculture and	108		45	4	49	45%
Electronics	51	2	1	2	5	10%
Garments	71	1	1		2	3%
Miscellaneous	23		8		8	35%
Not Classified	117	12	16	7	35	30%
Precision Machin	16				0	0%
Processed Food	27		15	1	16	59%
Raw Materials /	102	4	25	8	37	36%
Total	866	77	180	120	377	44%

Recommended product communities

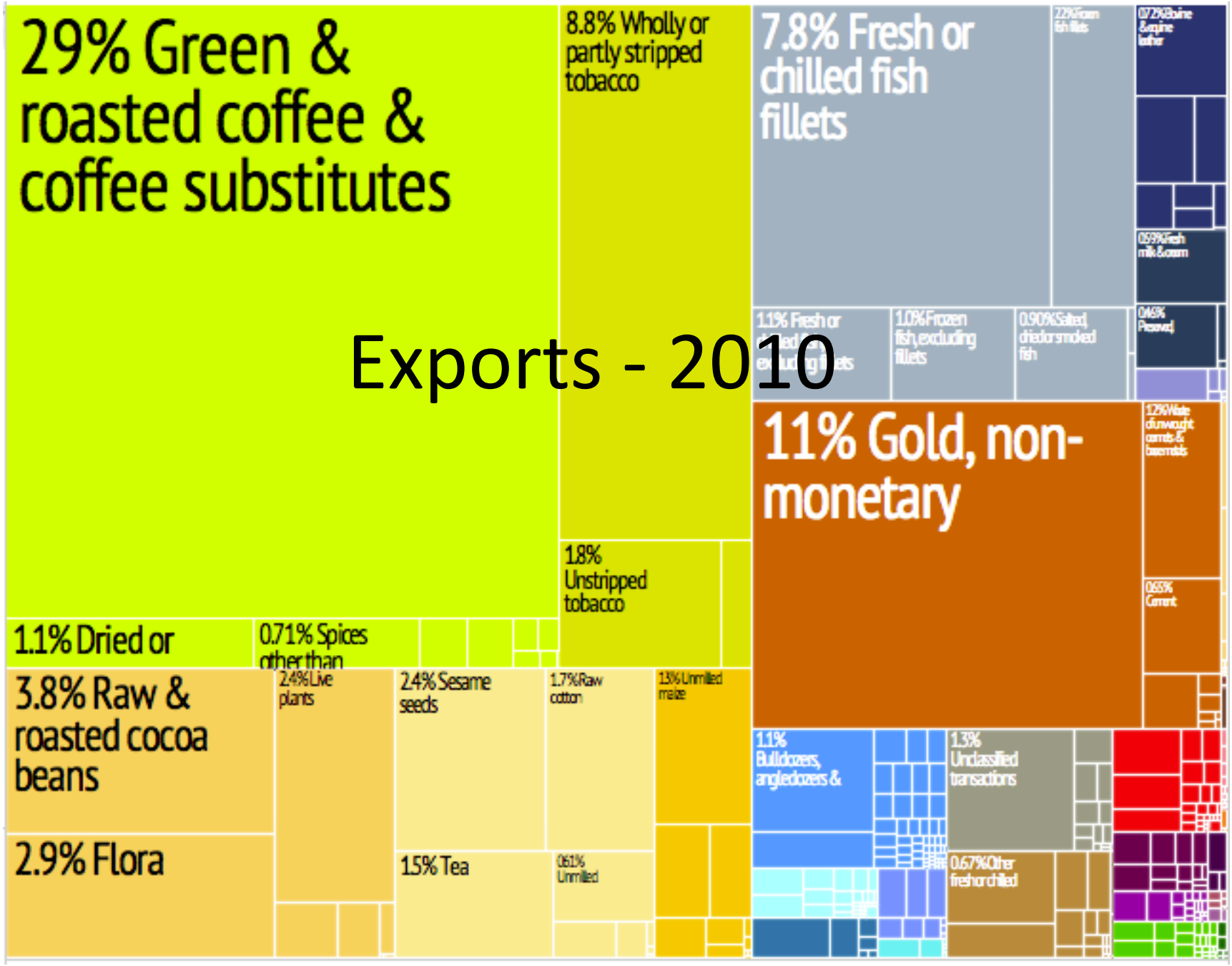
Other

So how does Uganda look in the Product space?

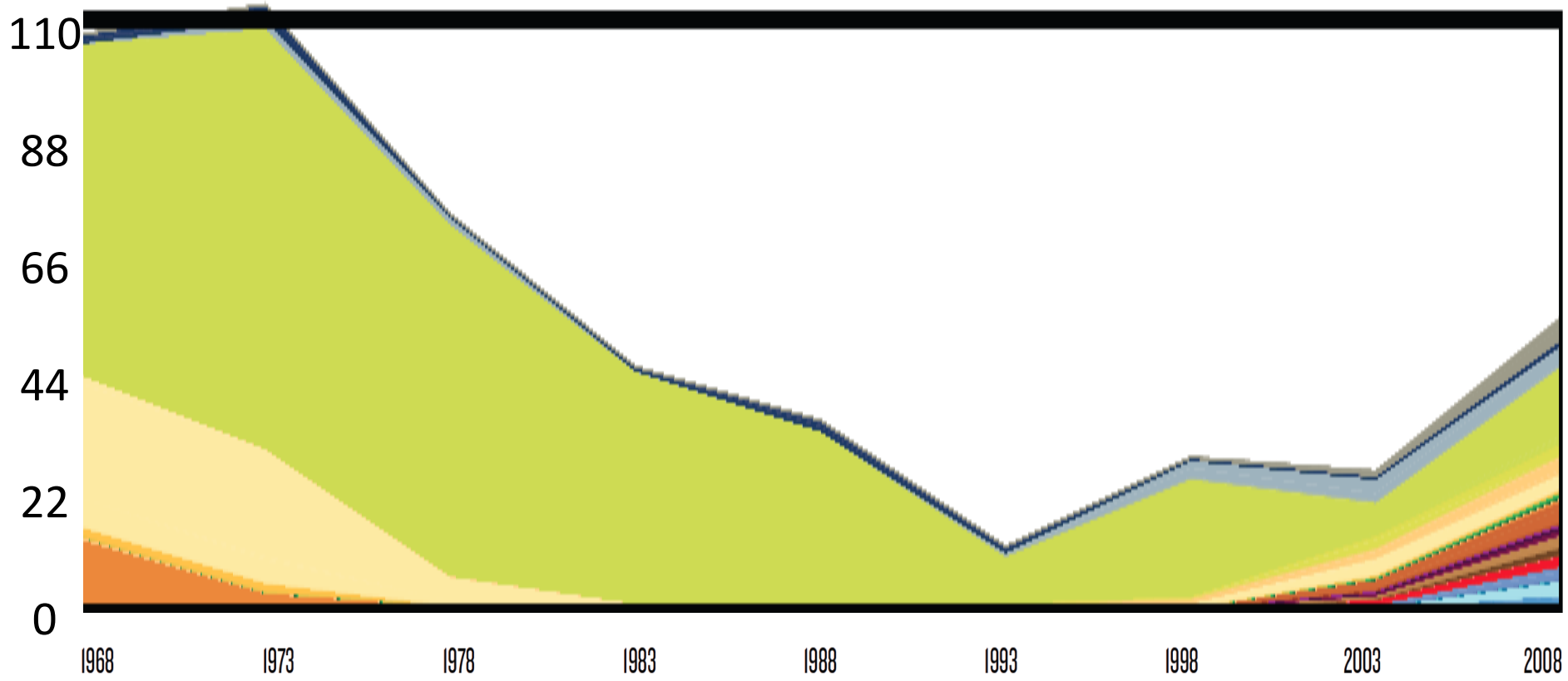

47% Green & roasted coffee & coffee substitutes
Exports - 1962
24% Raw cotton
10% Tea
2.4% Green groundnuts
80% Oilcake
17% Unwought copper & copper alloys
0.52% Tin
0.90% Raw bovine & equine hides
0.62% Raw goatskins
1.1% Worked wood of non coniferous

84% Green & roasted coffee & coffee substitutes

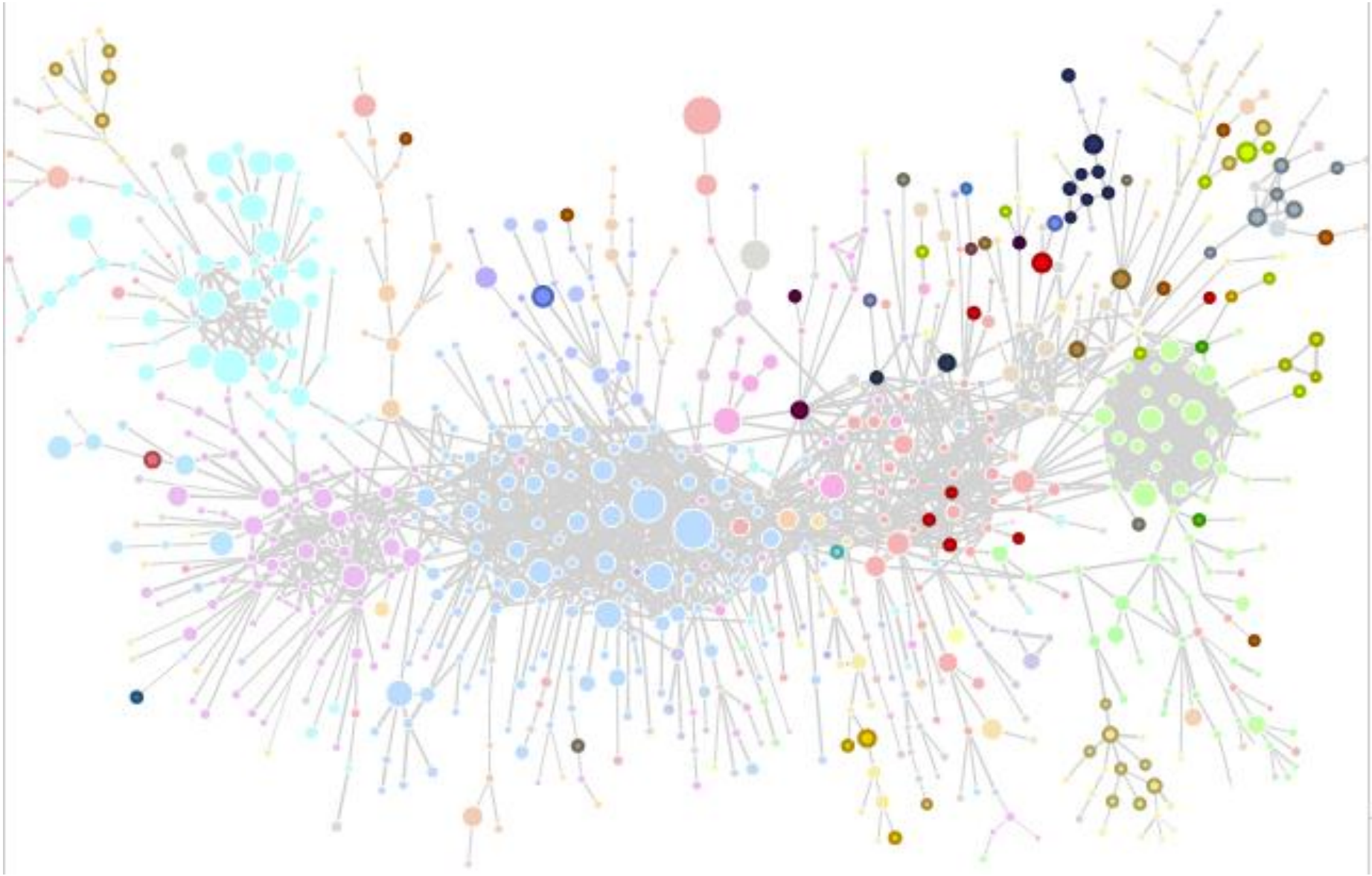
Exports - 1990

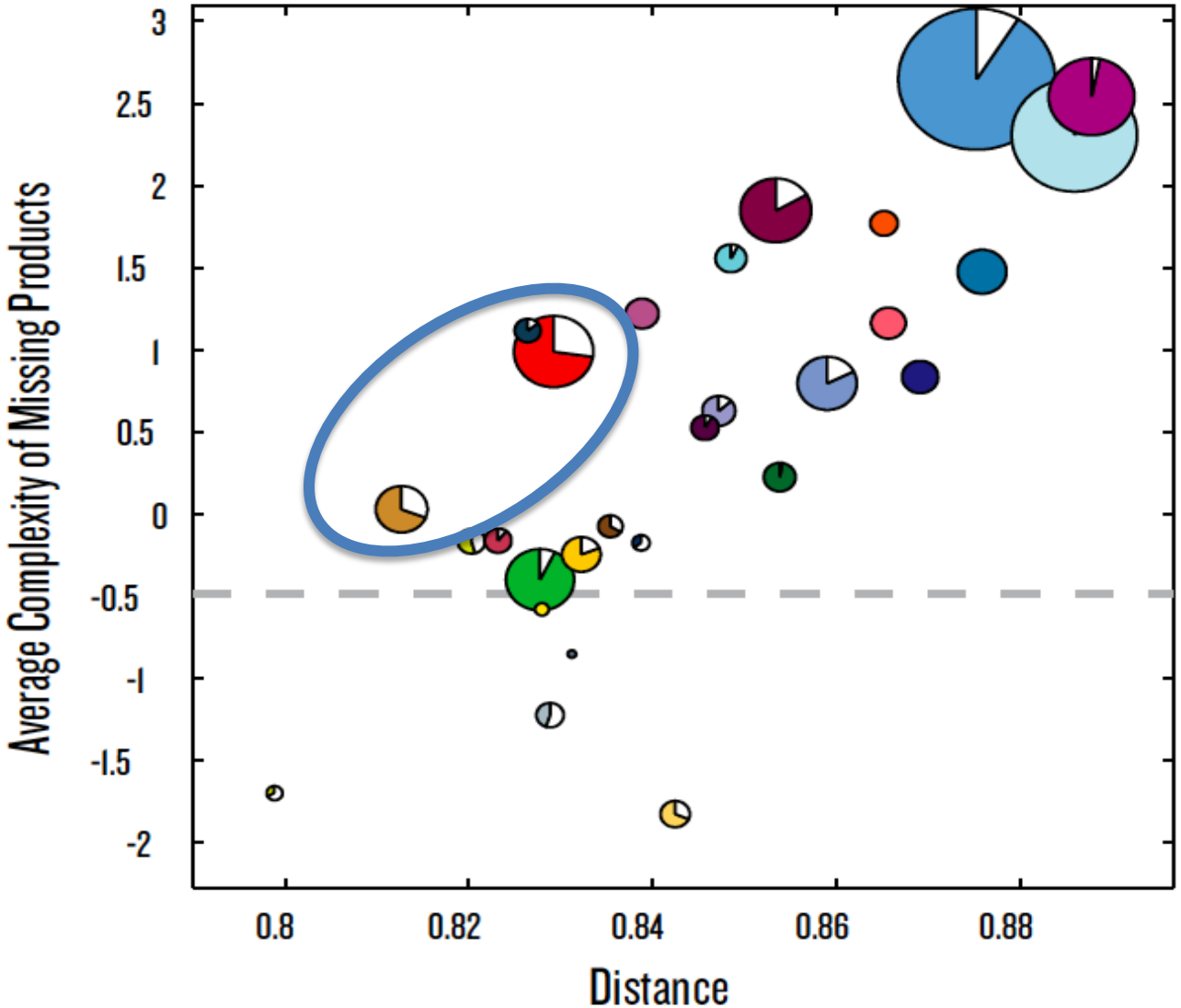

29% Green & roasted coffee & coffee substitutes
8.8% Wholly or partly stripped tobacco
7.8% Fresh or chilled fish fillets
Exports - 2010
11% Gold, non-monetary
1.8% Unstripped tobacco
1.1% Dried or
0.71% Spices other than
3.8% Raw & roasted cocoa beans
2.4% Live plants
2.4% Sesame seeds
1.7% Raw cotton
1.3% Unmilled maize
2.9% Flora
1.5% Tea
0.61% Unmilled
1.1% Bulldozers, angledozers &
1.3% Unclassified transactions
0.67% Other fresh or chilled
0.65% Cement

Evolution of Uganda's exports per capita



Uganda in the product space - 2010




Average Complexity of Missing Products
3
2.5
2
1.5
1
0.5
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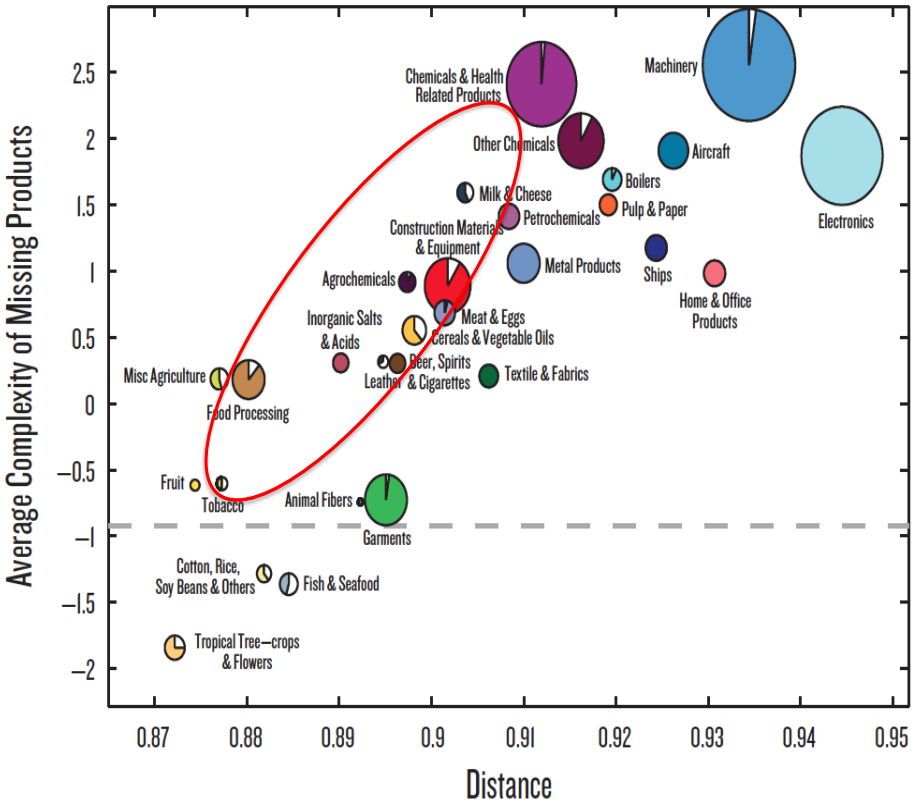
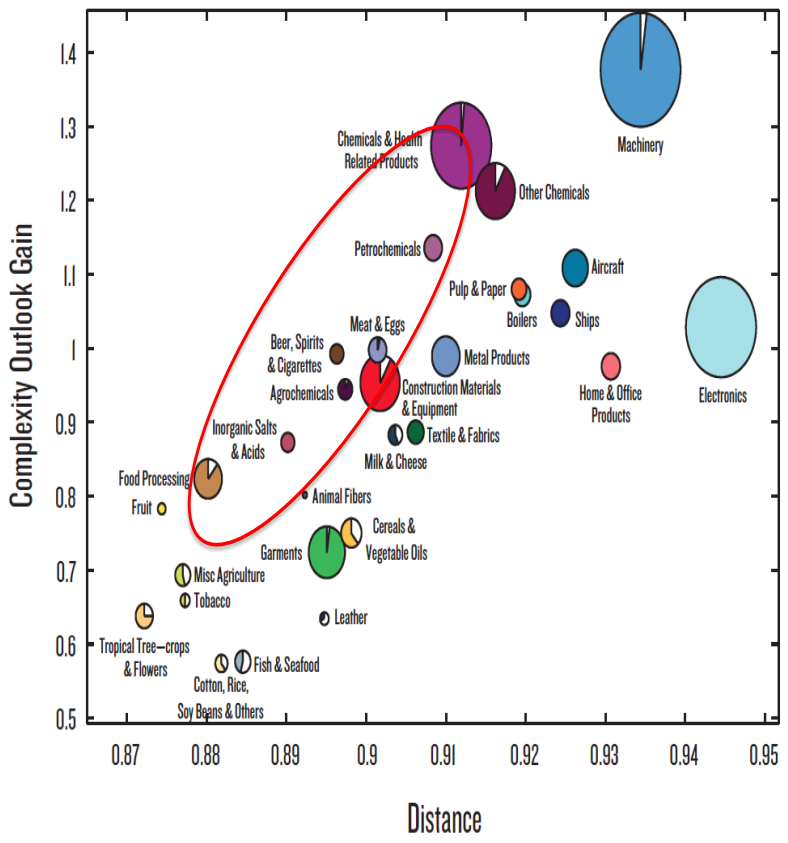
-1
-1.5
-2
0.8
0.82
0.84
0.86
0.88
Distance

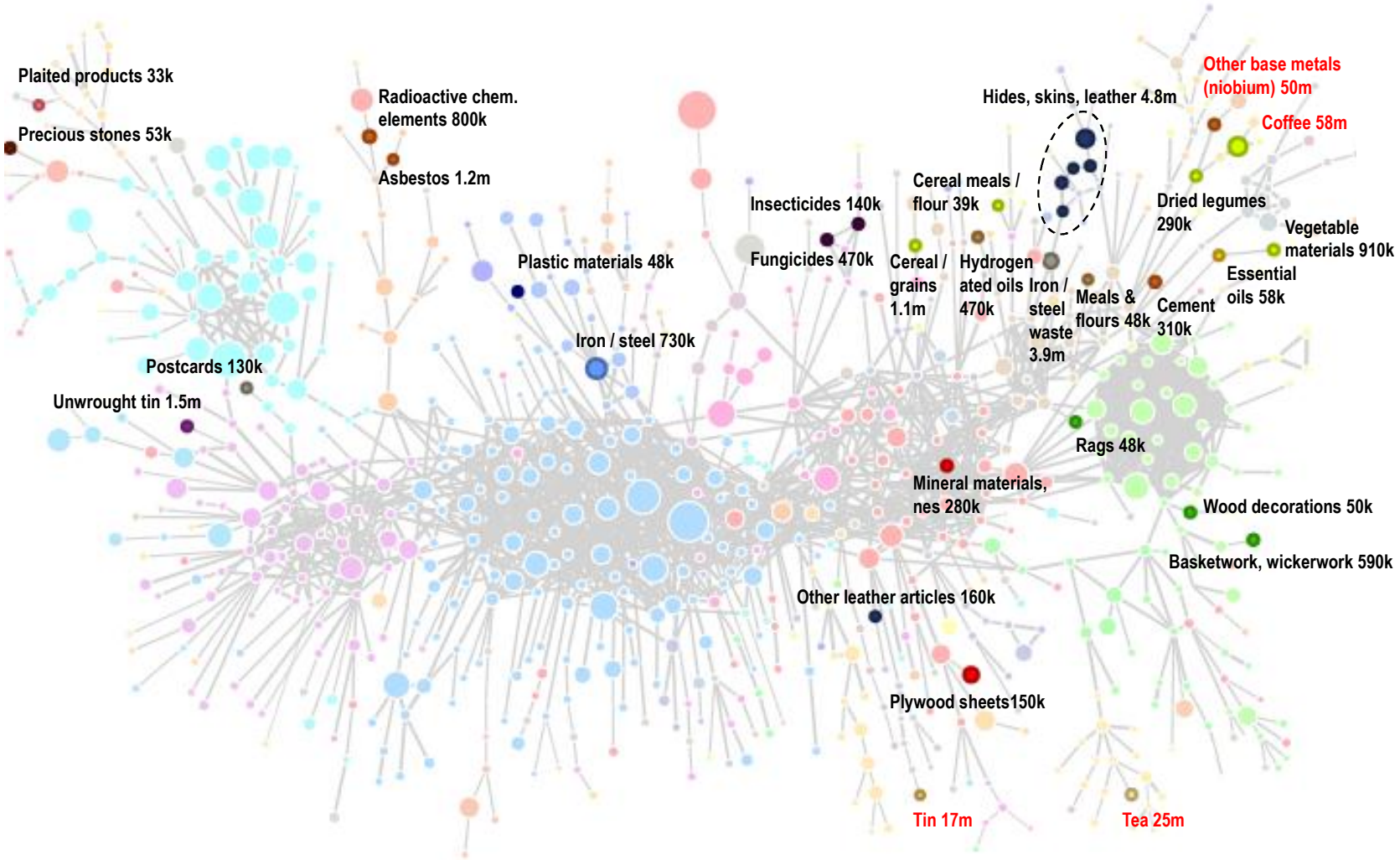
UGANDA'S EFFICIENT FRONTIER



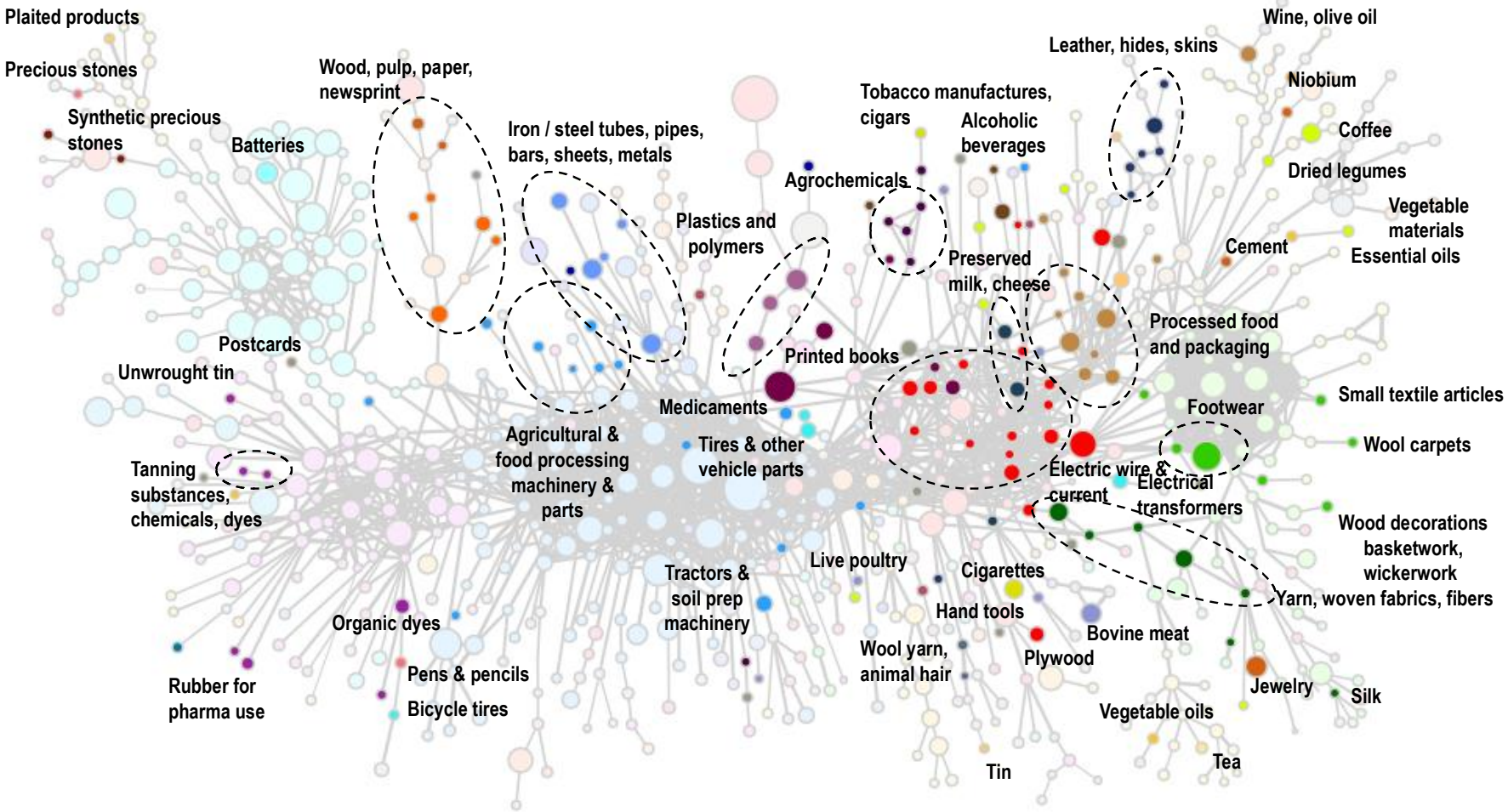


Rwanda

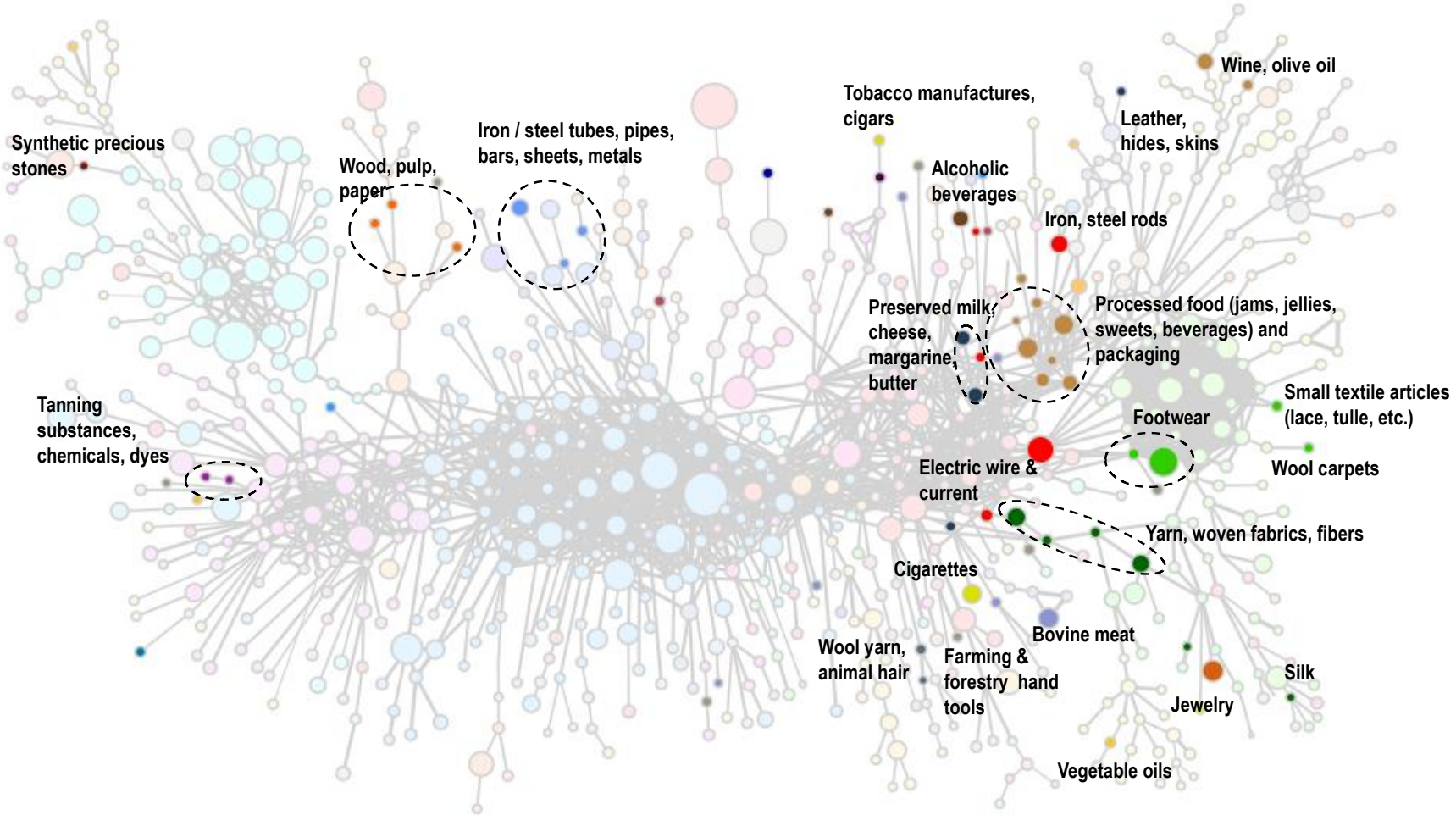
Rwanda in the Product Space



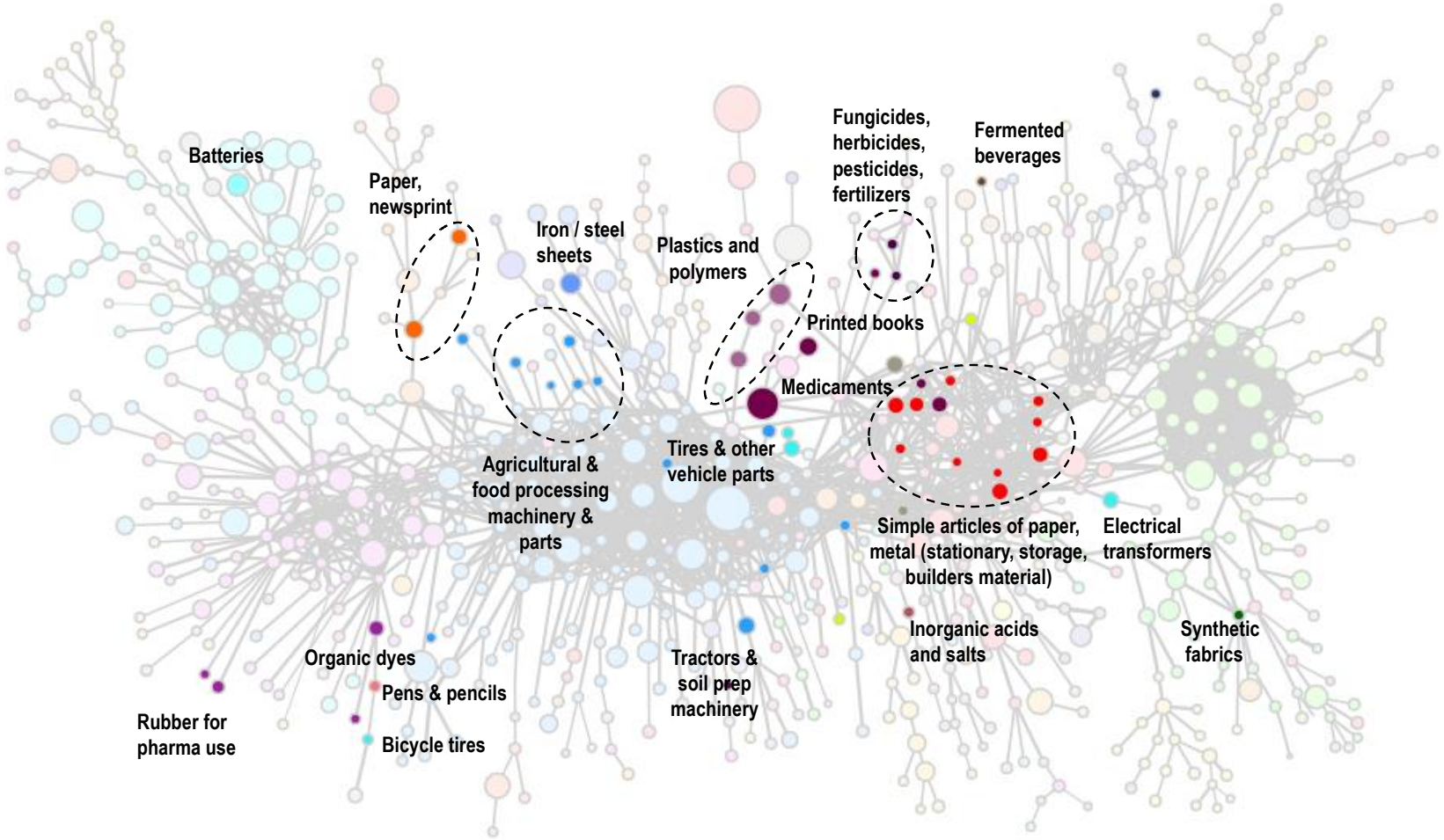
Rwanda's potential future exports



Rwanda's future outside of Africa



Rwanda's future exports to the region



LONG VS SHORT JUMPS?
WHY NOT BOTH?

China 1980-1985

N	Community	Change in RCA
1	Electronics	1.23
2	Garments	0.80
3	Textile & Fabrics	0.54
4	Cotton, rice, soy beans and others	0.38
5	Cereals and vegetable oils	0.15
6	Misc. Chemicals	0.14
7	Leather	0.13
8	Processed minerals	0.11
9	Coal	0.03
10	Milk & cheese	0.02

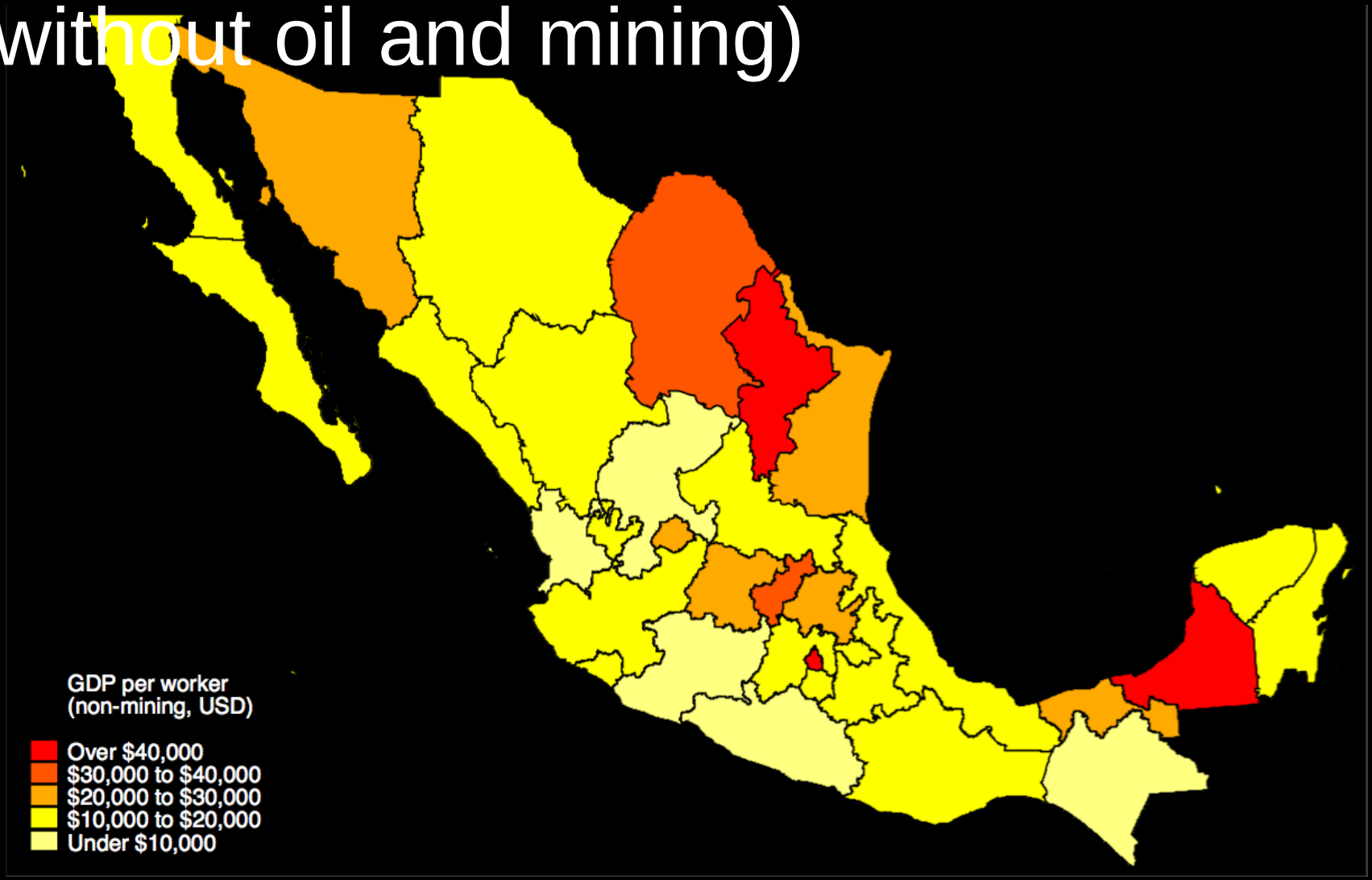
N	Community	New products	Presence
1	Textile & Fabrics	12	72%
2	Garments	8	90%
3	Cereals and vegetable oils	5	38%
4	Electronics	4	15%
5	Cotton, rice, soy beans and others	4	61%
6	Chemicals and health related products	4	13%
7	Processed minerals	2	33%
8	Coal	2	33%
9	Home and office products	2	74%
10	Misc. Chemicals	1	29%

Korea 1985-1990

N	Community	Change in RCA
1	Machinery	3.33
2	Textile & Fabrics	0.78
3	Chemicals and health related products	0.28
4	Food Processing	0.06
5	Misc. Chemicals	0.05
6	Leather	0.03
7	Misc Agriculture	0.03
8	Coal	0.02
9	Oil	0.02
10	Heavy Metals	0.01

N	Community	New products	Presence
1	Electronics	9	60%
2	Machinery	8	14%
3	Textile & Fabrics	7	72%
4	Chemicals and health related products	5	13%
5	Food Processing	3	19%
6	Not classified	3	38%
7	Garments	3	79%
8	Leather	2	21%
9	Home and office products	2	43%
10	Construction materials and equipment	2	16%

Productivity per worker, 2009 (without oil and mining)



note

Source: Employment by industry and federal entity, 2009 Economic Census

What can explain those differences?

1. **Regional effect.** Top regions are just more efficient. Whatever they do, they do it better.
2. **Ricardian effect.** Top regions specialize in those economic activities in which they are relatively better than other regions.
3. **Composition effect**. Top performing regions have larger shares of employment in industries that have higher average productivities everywhere.

What can explain those differences?

- Using a method of variance decomposition, we are able to isolate the three effects and analyze which one can better explain the observed differences in productivity.

$$\Delta \text{ productivity} = + \Delta \text{ Composition effect}$$
$$+ \Delta \text{ Regional effect}$$
$$+ \Delta \text{ Ricardian effect}$$

The composition effect dominates

- Preliminary results indicate that the **composition effect** explains the largest share of the observed differences in productivity in Mexico.

- At the state level, **55%** of productivity differences are explained by composition, **25%** by the regional effect, **20%** by the Ricardian effect.

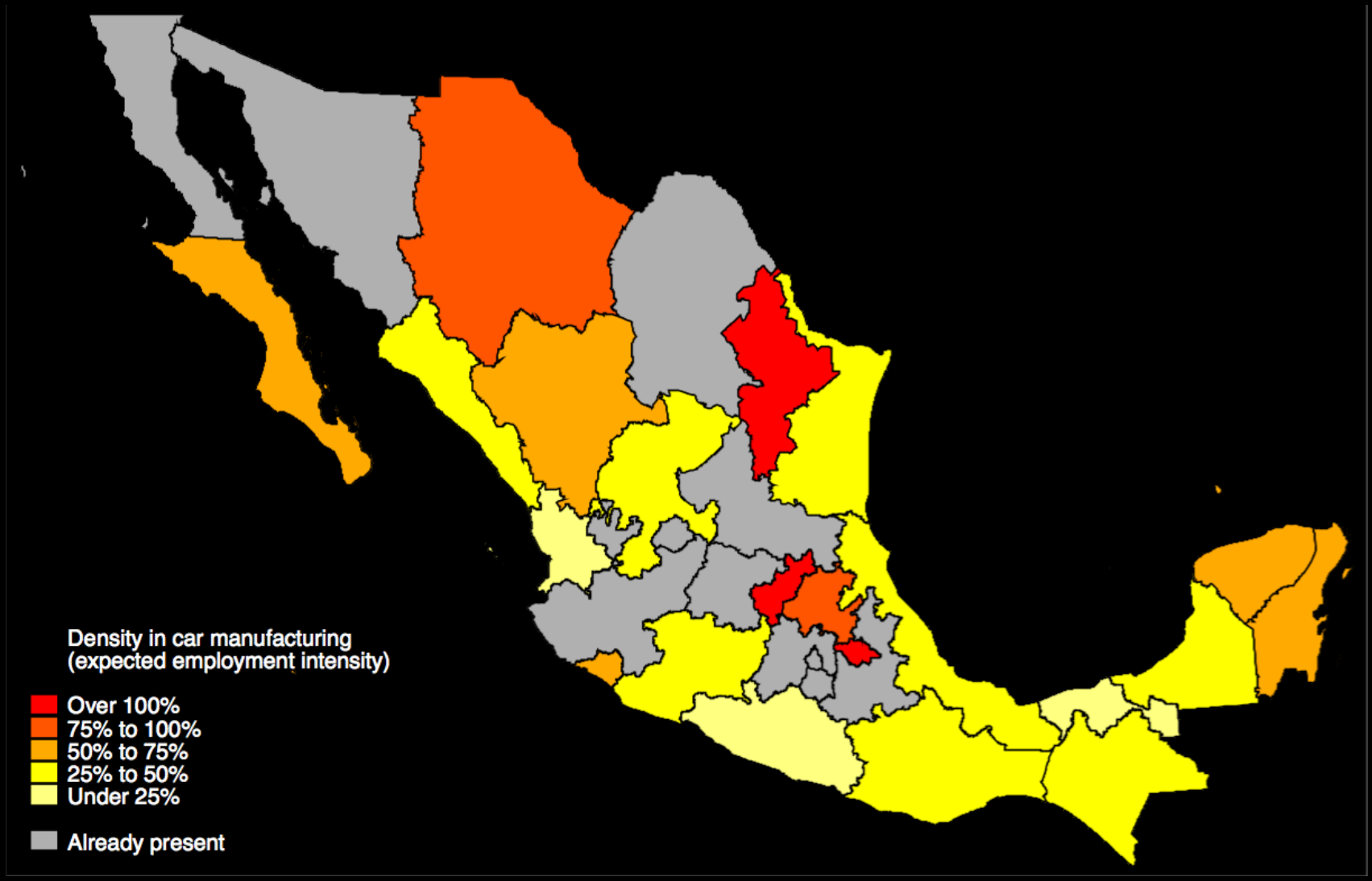
- At the city level, **55%** of productivity differences are explained by composition, **5%** by the regional effect, **40%** by the Ricardian effect.

EMPLOYMENT IN THE AUTO INDUSTRY

note

Source: Total employment by industry and federal entity, 2009 Economic Census

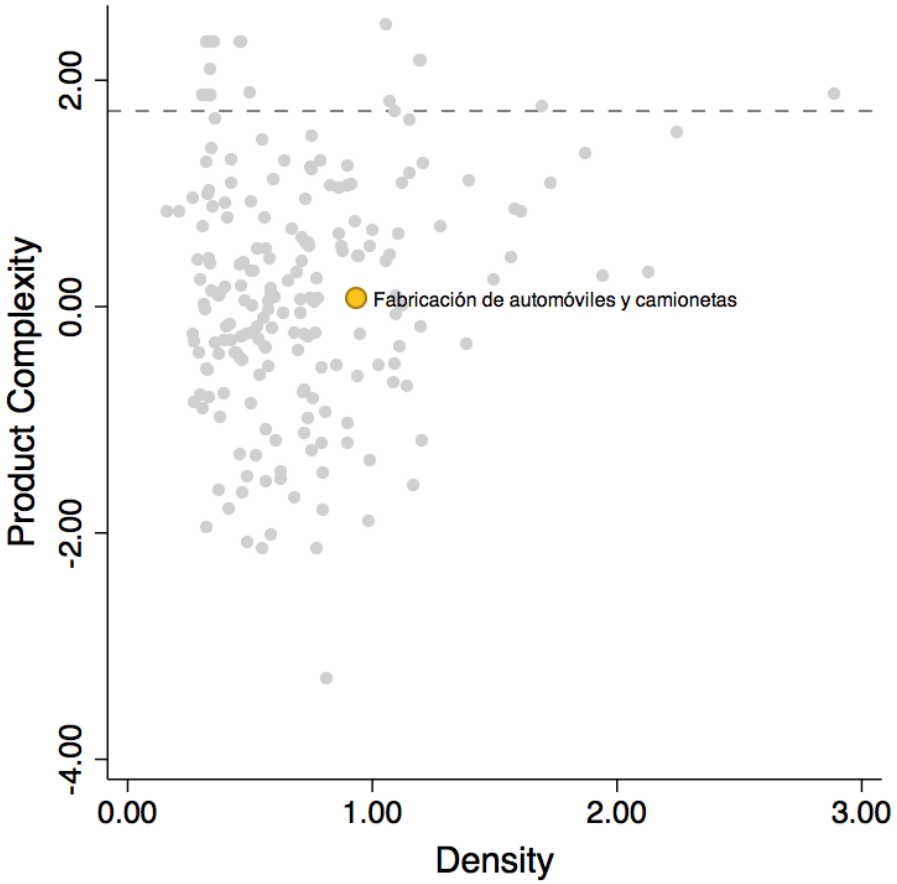
Density in the auto industry

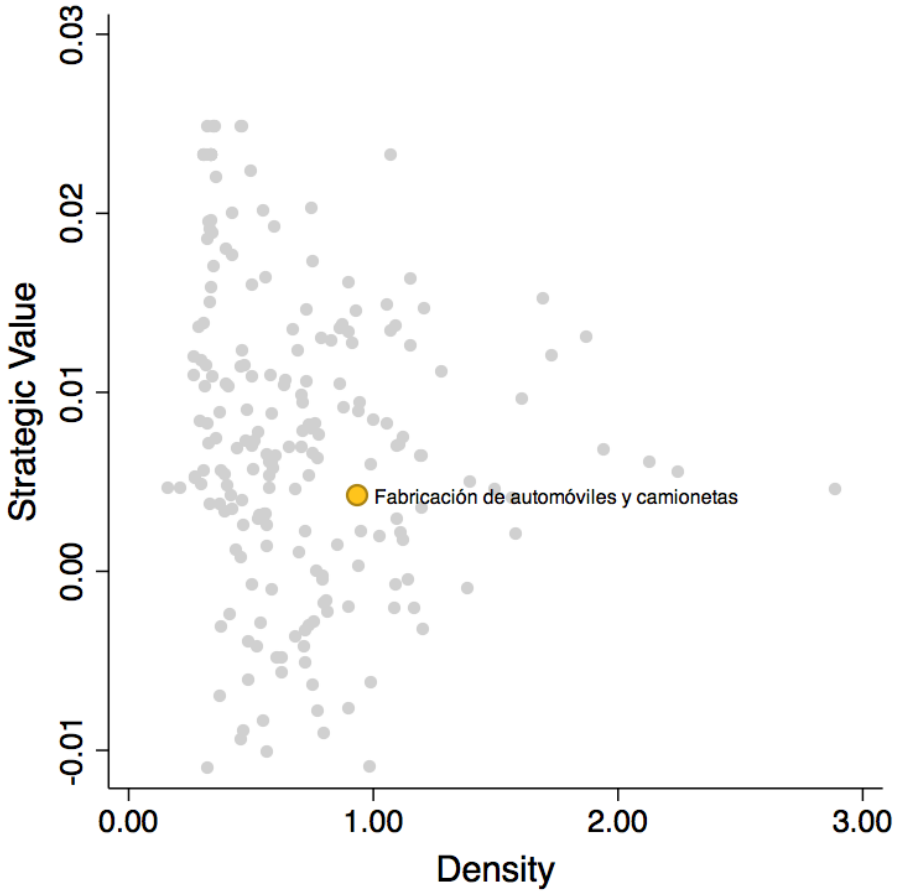


note

Source: Total employment by industry and federal entity, 2009 Economic Census

Chihuahua: how feasible and attractive are autos?





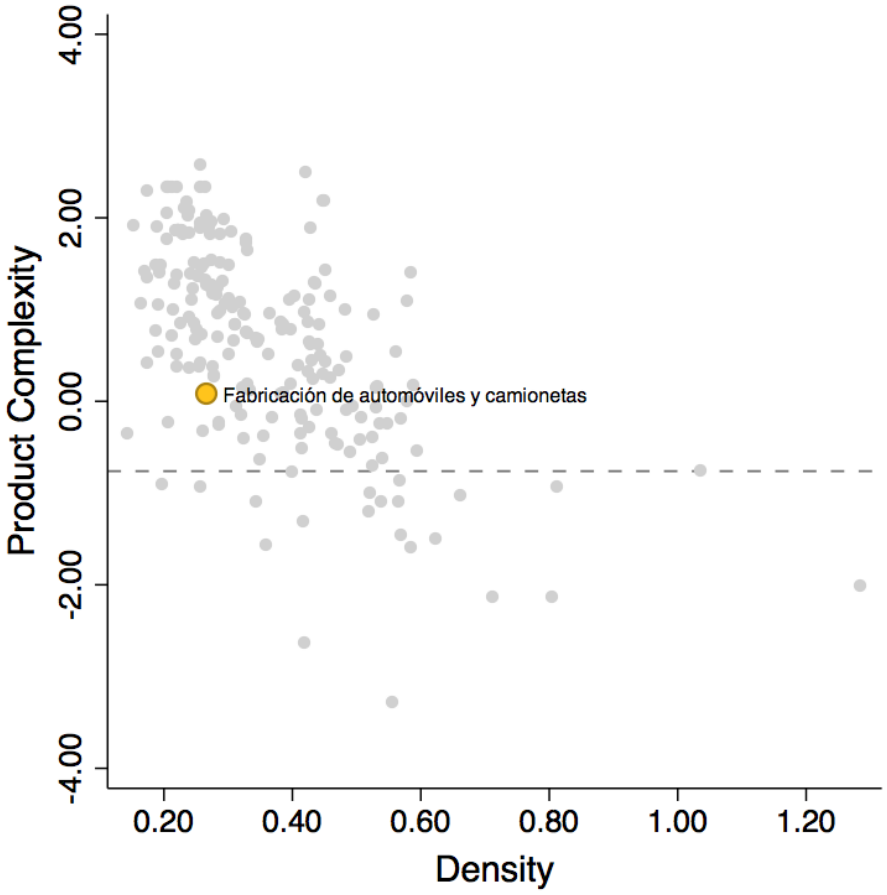
…the related industries are already there

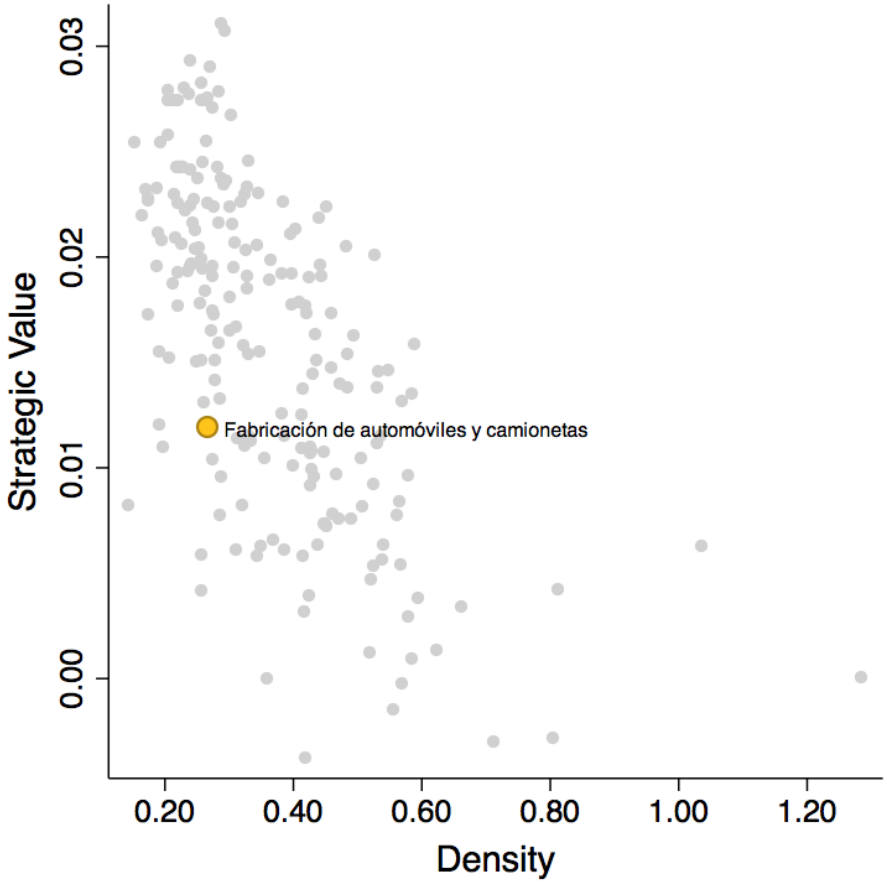
Employment of industries in Equipo de Transporte subsector, Chihuahua 2009

SCIAN6 code	Industry	Similarity to Autos	Employment	Employment intensity	Density
336110	Automóviles y camionetas	100%	0	0%	94%
336310	Motores de gasolina para automoviles	79%	1,727	145%	167%
336370	Piezas metálicas troqueladas para automoviles	73%	35	8%	69%
336340	Partes de sistemas de frenos para automoviles	73%	1,160	253%	186%
336360	Asientos y accesorios interiores para automoviles	72%	21,362	1113%	527%
336330	Sistemas de dirección y suspensión para automoviles	69%	505	125%	157%
336350	Sistemas de transmisión para vehículos automotores	68%	360	64%	156%
336120	Camiones y tractocamiones	67%	0	0%	90%
336210	Carrocerías y remolques	65%	455	72%	121%
336410	Equipo aeroespacial	64%	1,868	557%	433%
336320	Equipo para vehículos automotores	60%	67,666	1202%	508%
336390	Otras partes para automoviles	60%	15,070	546%	398%
336510	Equipo ferroviario	58%	0	0%	79%
336999	Otro equipo de transporte	56%	0	0%	43%
336991	Motocicletas	50%	630	853%	537%
336992	Bicicletas y triciclos	46%	0	0%	35%
336610	Embarcaciones	43%	0	0%	139%

Source: Censo Económico de 2009

Veracruz: less feasible but more strategic





How to get there?

Agricultural, forestry machinery for soil preparation

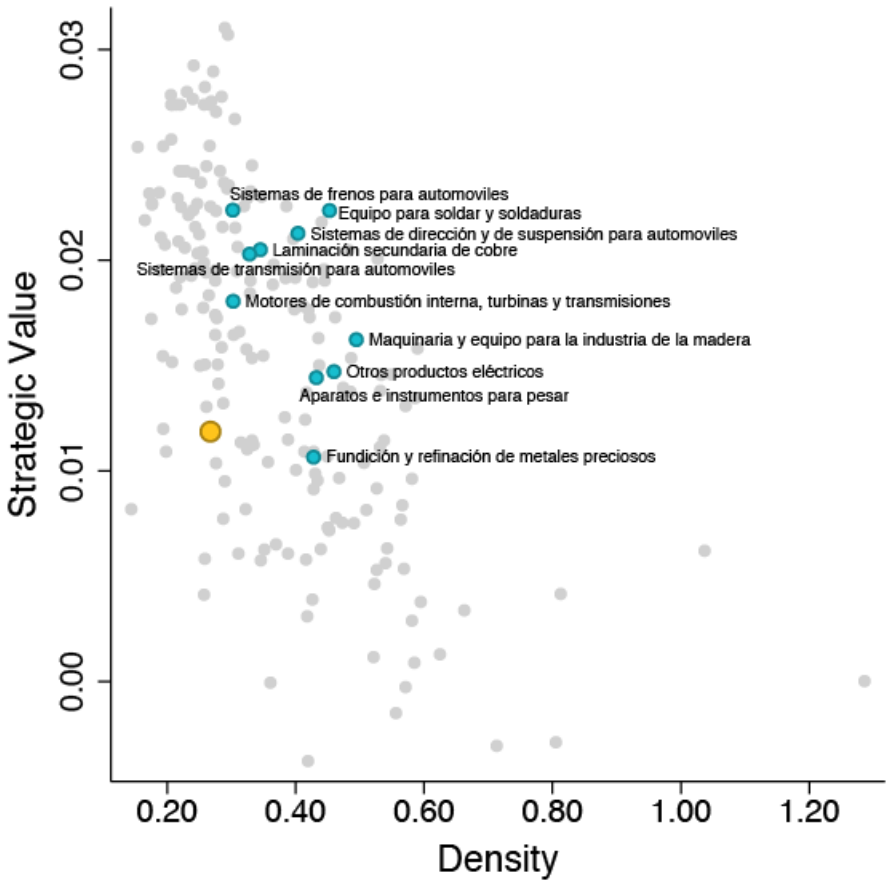
Code	8432
Current	$2.16M
Complexity	0.59
Distance	0.95
RCA	0.07
World Trade	$7.63B

Primary Connections

- Electrical energy
- Packing cases, boxes, crates, drums of wood
- Slag wool, rock wool and similar mineral wools
- Aluminum structures (bridges, towers etc)
- Other articles of iron or steel
- Parts of railway locomotives
- Trailers and semi-trailers
- Machinery for working earth, stone, and other mineral substances
- Electrical insulators of any material
- Other furniture and parts thereof
- Plaster articles
- Parts for use with hoists and excavation machinery

Trees to conquer before autos

Industry		Similarity to Autos	Density
336110	Automóviles y camionetas	100%	26.7%
336340	Sistemas de frenos para automoviles	73%	30.2%
336330	Sistemas de dirección y de suspensión para automoviles	69%	40.4%
333210	Maquinaria y equipo para la industria de la madera	68%	49.5%
331412	Fundición y refinación de metales preciosos	68%	42.8%
333610	Motores de combustión interna, turbinas y transmisiones	68%	30.3%
336350	Sistemas de transmisión para automoviles	68%	32.8%
333991	Equipo para soldar y soldaduras	68%	45.3%
333993	Aparatos e instrumentos para pesar	67%	43.2%
335999	Otros productos eléctricos	67%	46.0%
331420	Laminación secundaria de cobre	66%	34.5%



WHAT CAN YOU DO WITH OCCUPATION DATA (BRAZIL)

What human resources are needed for electrical machinery and which are available in Bahia?

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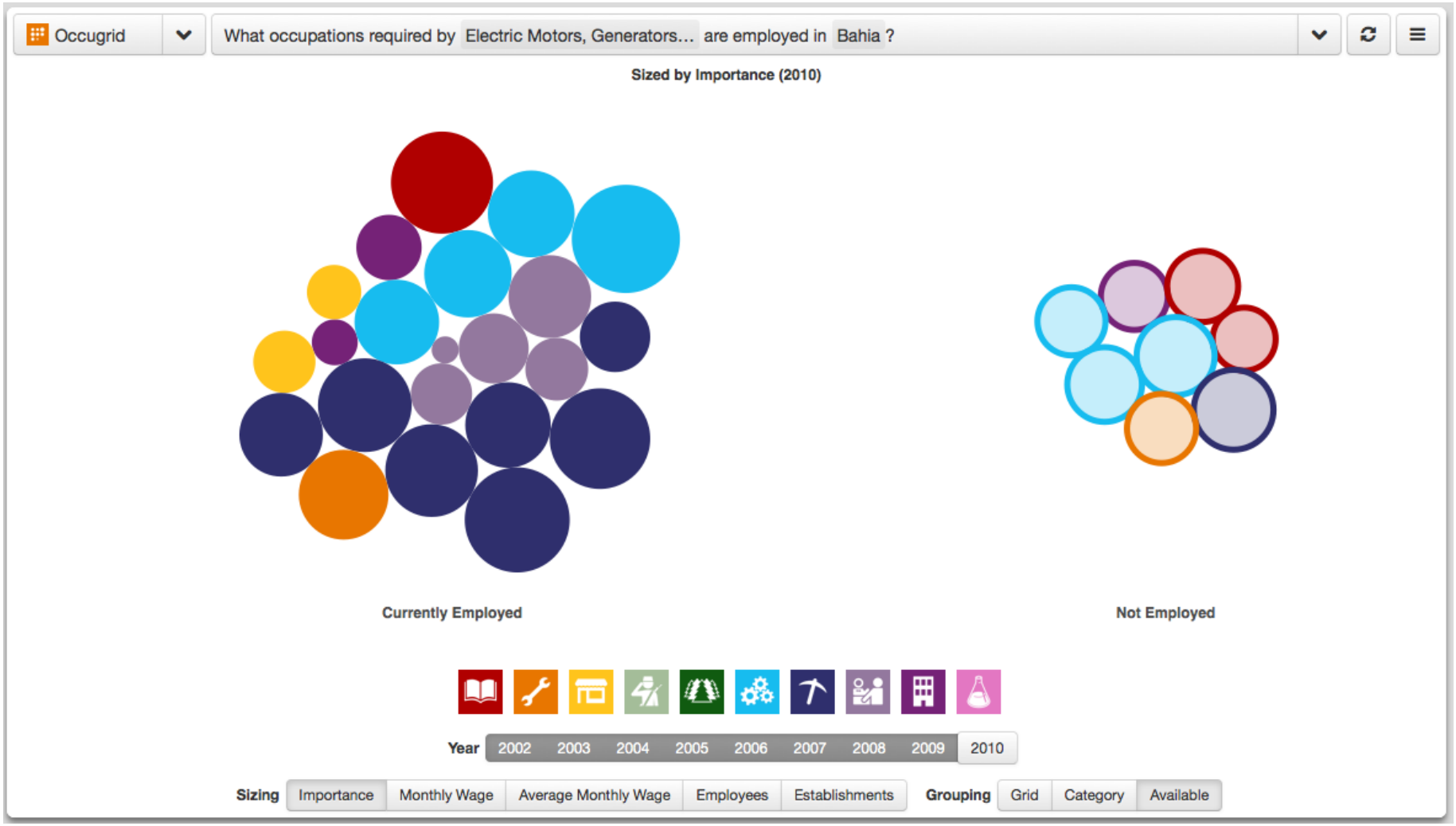


THE ATLAS OF ECONOMIC COMPLEXITY

MAPPING PATHS TO PROSPERITY

Hausmann, Hidalgo et al.

www.atlas.cid.harvard.edu

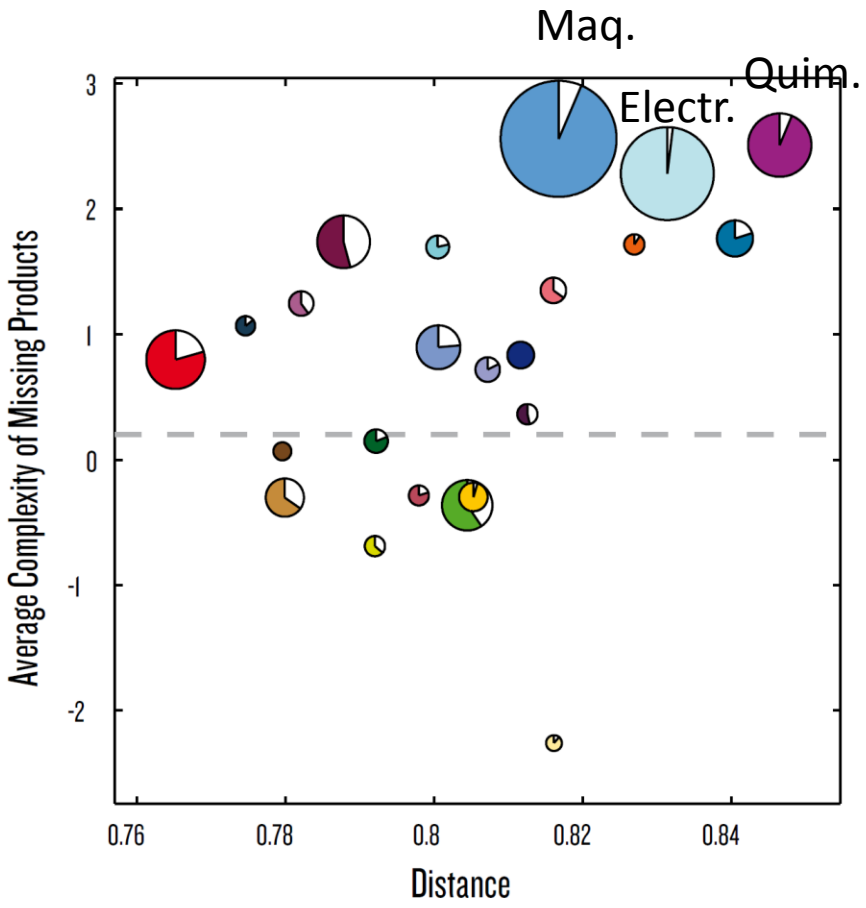
The Observatory

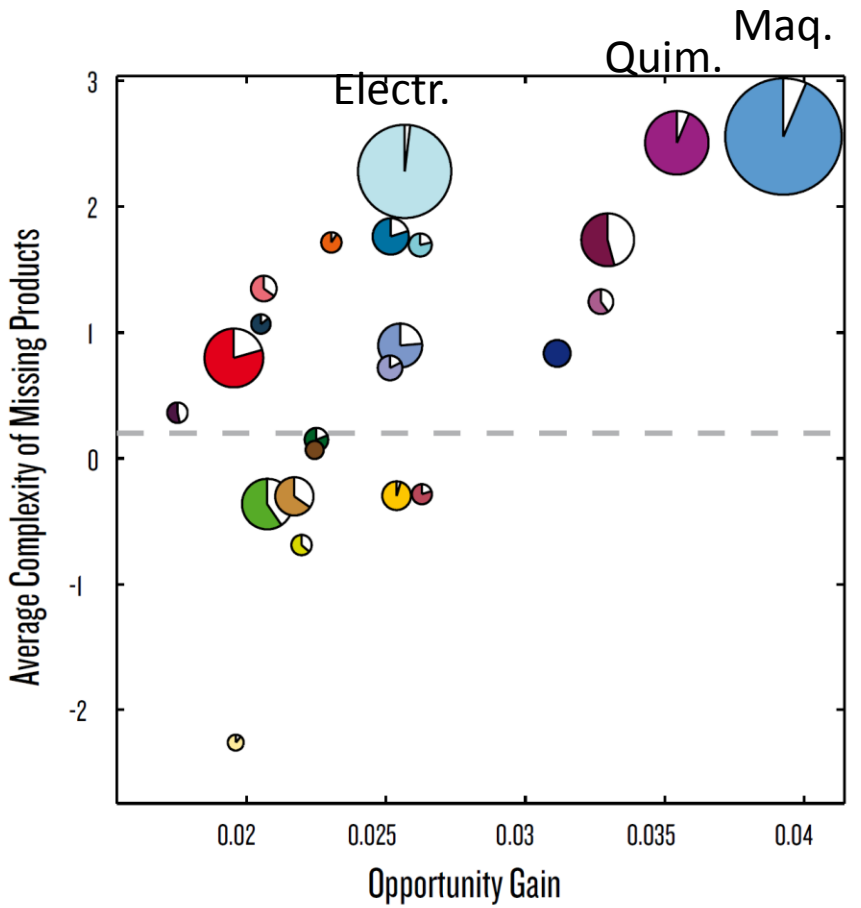
OF ECONOMIC COMPLEXITY

Useful measures

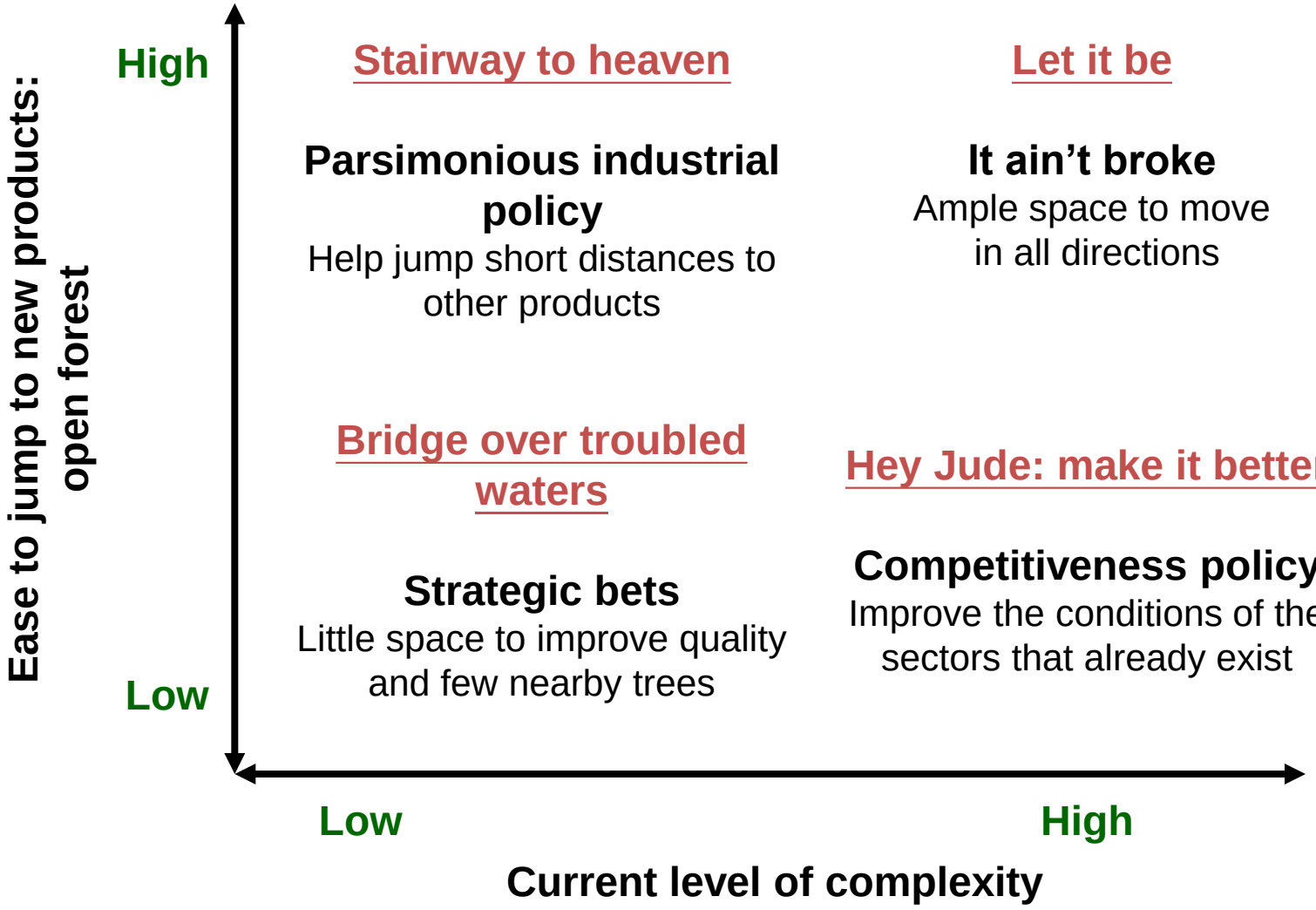
- How far is a certain industry from your current revealed capabilities?
- How attractive is that industry in terms of its revealed level of sophistication?
  - Product complexity
  - Level of income of competitors
- How strategic is that industry in terms of its proximity to other attractive industries?
  - Connectedness to other products

Distance, complexity and opportunity gain





The strategic setting



China 1980-1985

N	Community	Change in RCA
1	Electronics	1.23
2	Garments	0.80
3	Textile & Fabrics	0.54
4	Cotton, rice, soy beans and others	0.38
5	Cereals and vegetable oils	0.15
6	Misc. Chemicals	0.14
7	Leather	0.13
8	Processed minerals	0.11
9	Coal	0.03
10	Milk & cheese	0.02

N	Community	New products	Presence
1	Textile & Fabrics	12	72%
2	Garments	8	90%
3	Cereals and vegetable oils	5	38%
4	Electronics	4	15%
5	Cotton, rice, soy beans and others	4	61%
6	Chemicals and health related products	4	13%
7	Processed minerals	2	33%
8	Coal	2	33%
9	Home and office products	2	74%
10	Misc. Chemicals	1	29%

Korea 1985-1990

N	Community	Change in RCA
1	Machinery	3.33
2	Textile & Fabrics	0.78
3	Chemicals and health related products	0.28
4	Food Processing	0.06
5	Misc. Chemicals	0.05
6	Leather	0.03
7	Misc Agriculture	0.03
8	Coal	0.02
9	Oil	0.02
10	Heavy Metals	0.01

N	Community	New products	Presence
1	Electronics	9	60%
2	Machinery	8	14%
3	Textile & Fabrics	7	72%
4	Chemicals and health related products	5	13%
5	Food Processing	3	19%
6	Not classified	3	38%
7	Garments	3	79%
8	Leather	2	21%
9	Home and office products	2	43%
10	Construction materials and equipment	2	16%