Diversification and Structural Transformation for Growth and Stability in Low-Income Countries

Ricardo Hausmann
International Monetary Fund
February 2013

THE ATLAS OF ECONOMIC COMPLEXITY

MAPPING PATHS TO PROSPERITY

Hausmann, Hidalgo et al.

www.cid.harvard.edu/atlas

The Observatory

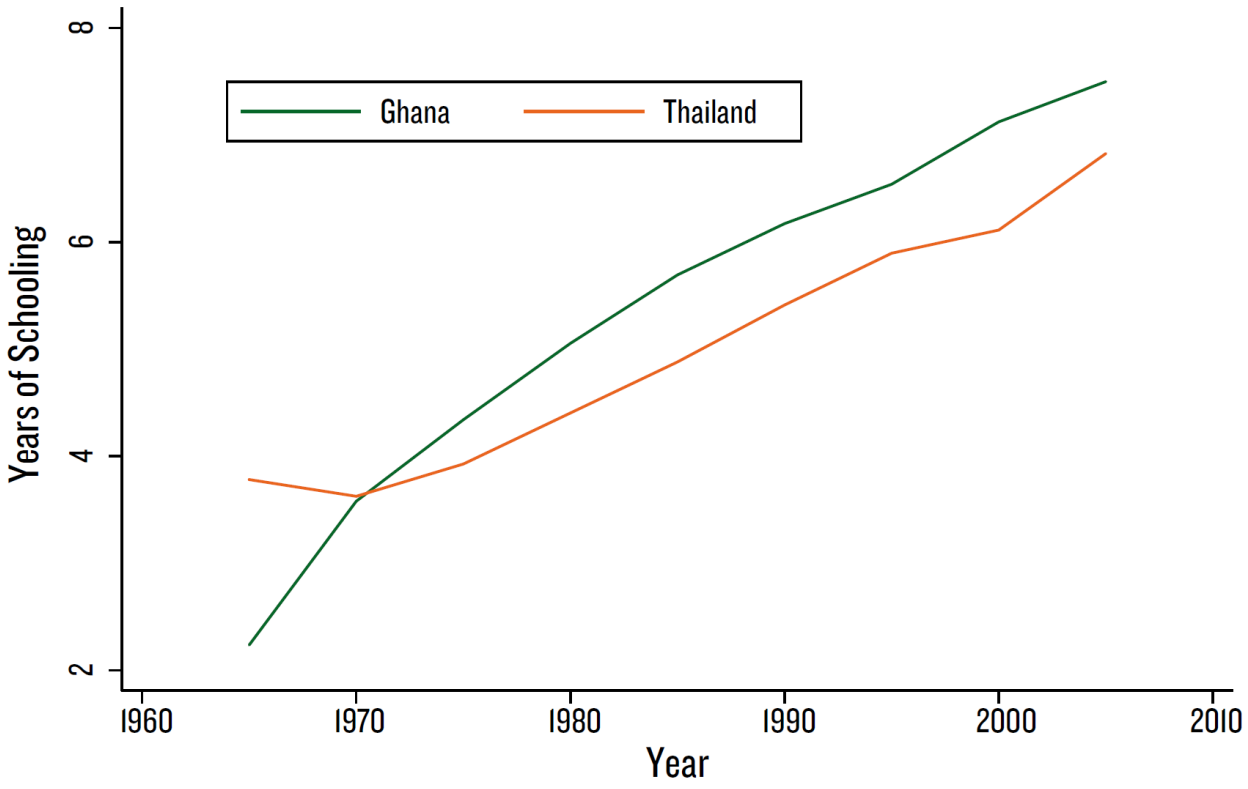
OF ECONOMIC COMPLEXITY

A tale of two countries: Ghana vs. Thailand

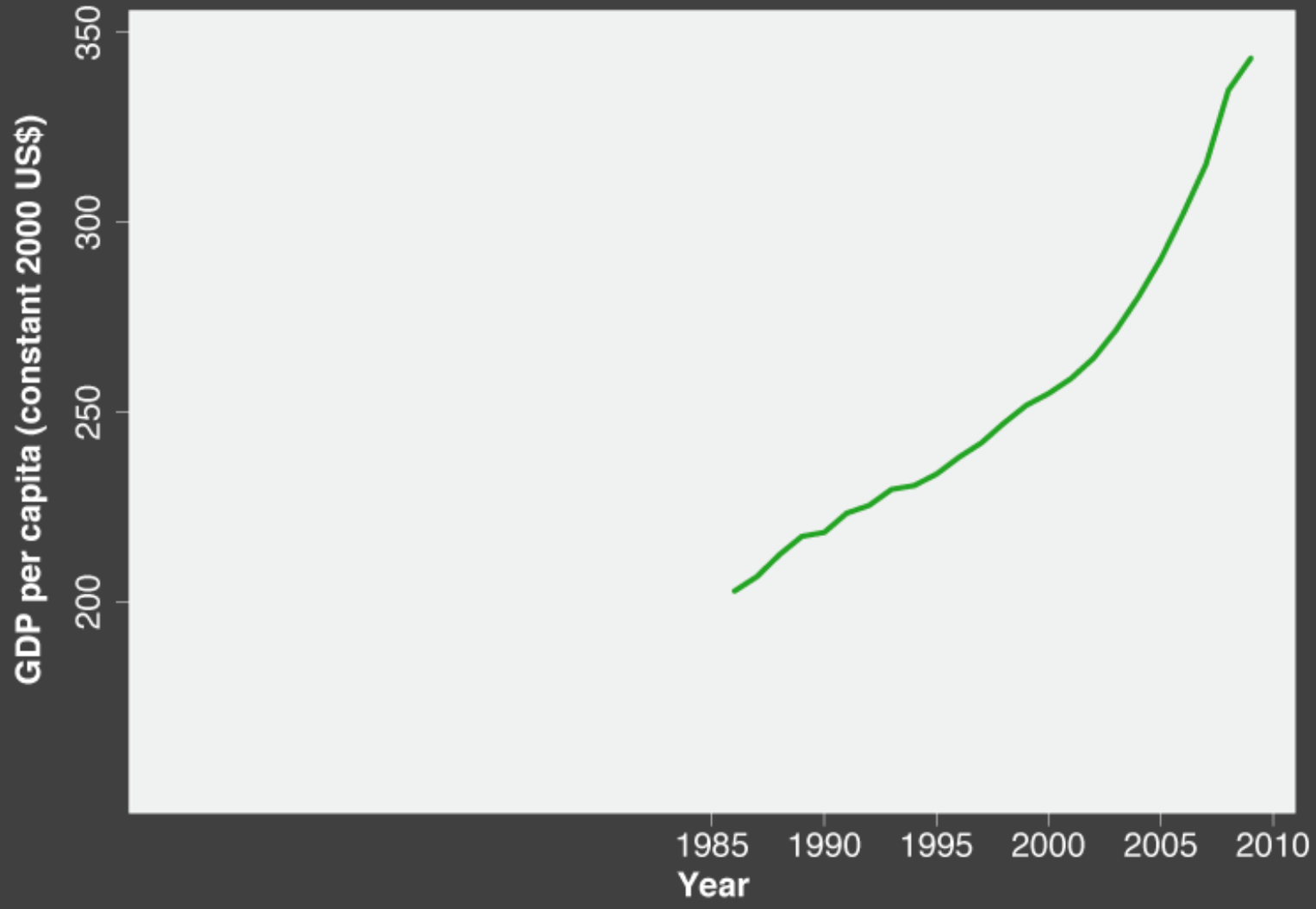
Ghana

...more education than in Thailand

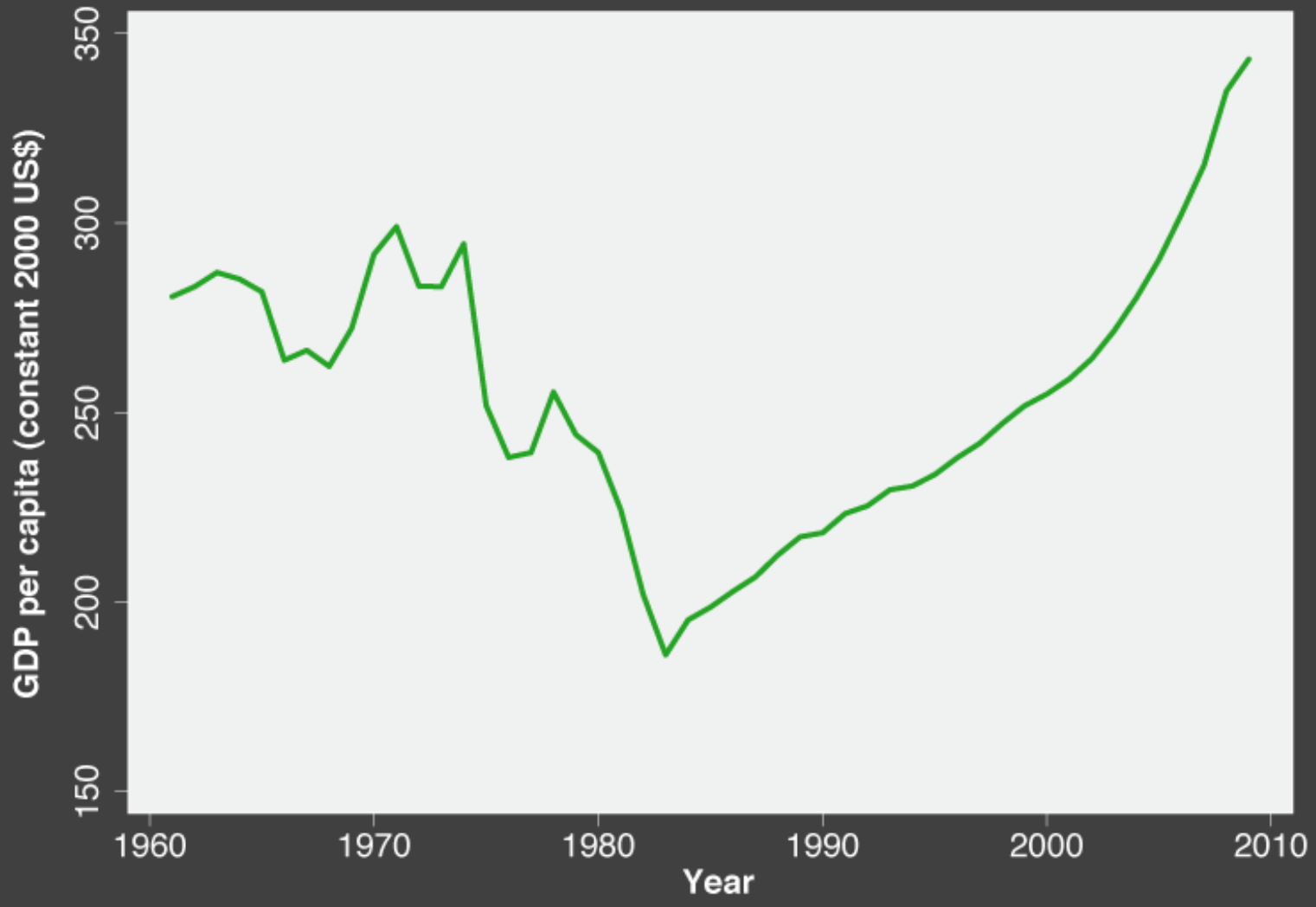
Years of schooling of Thailand and Ghana as a function of time.

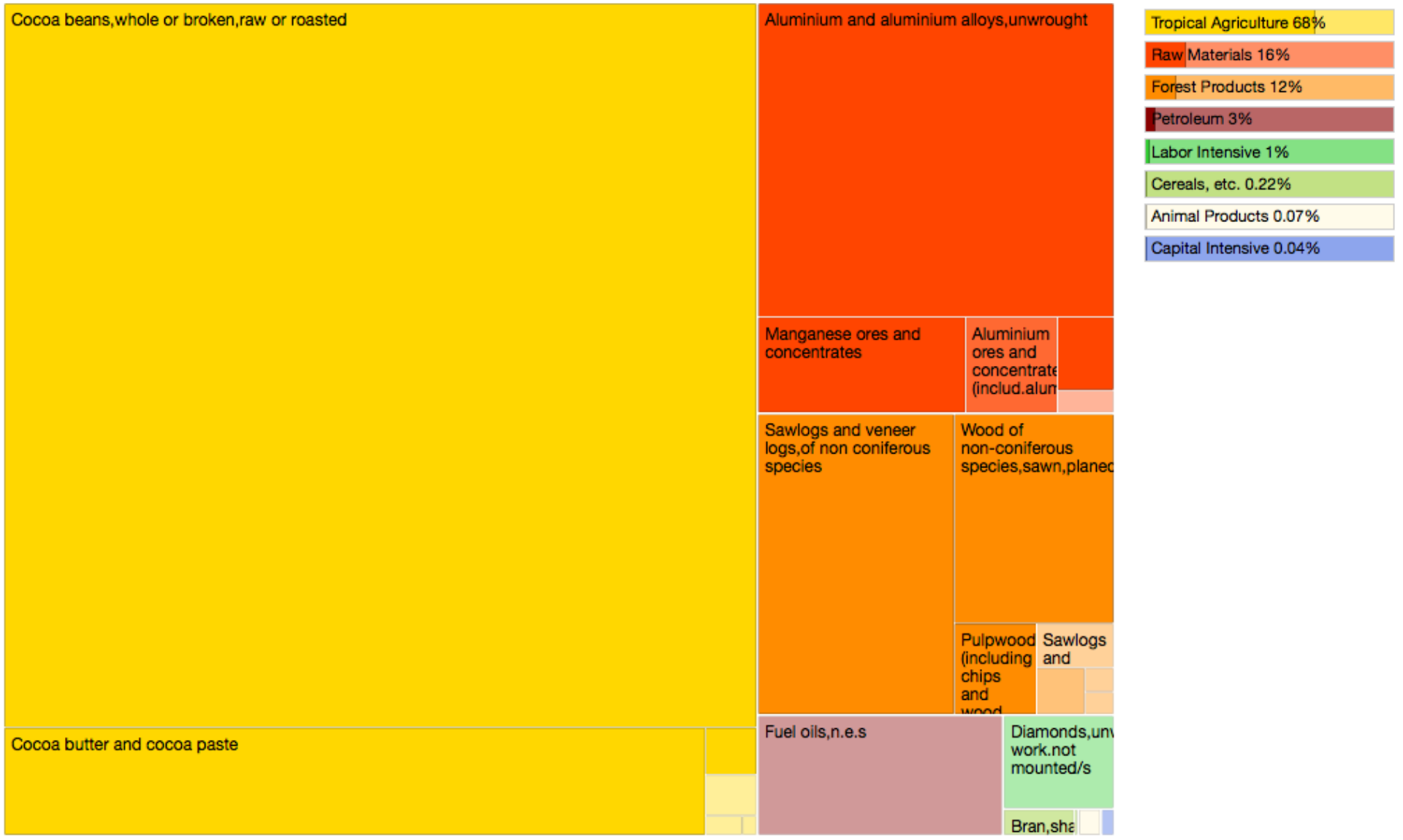


Ghana: a success story?

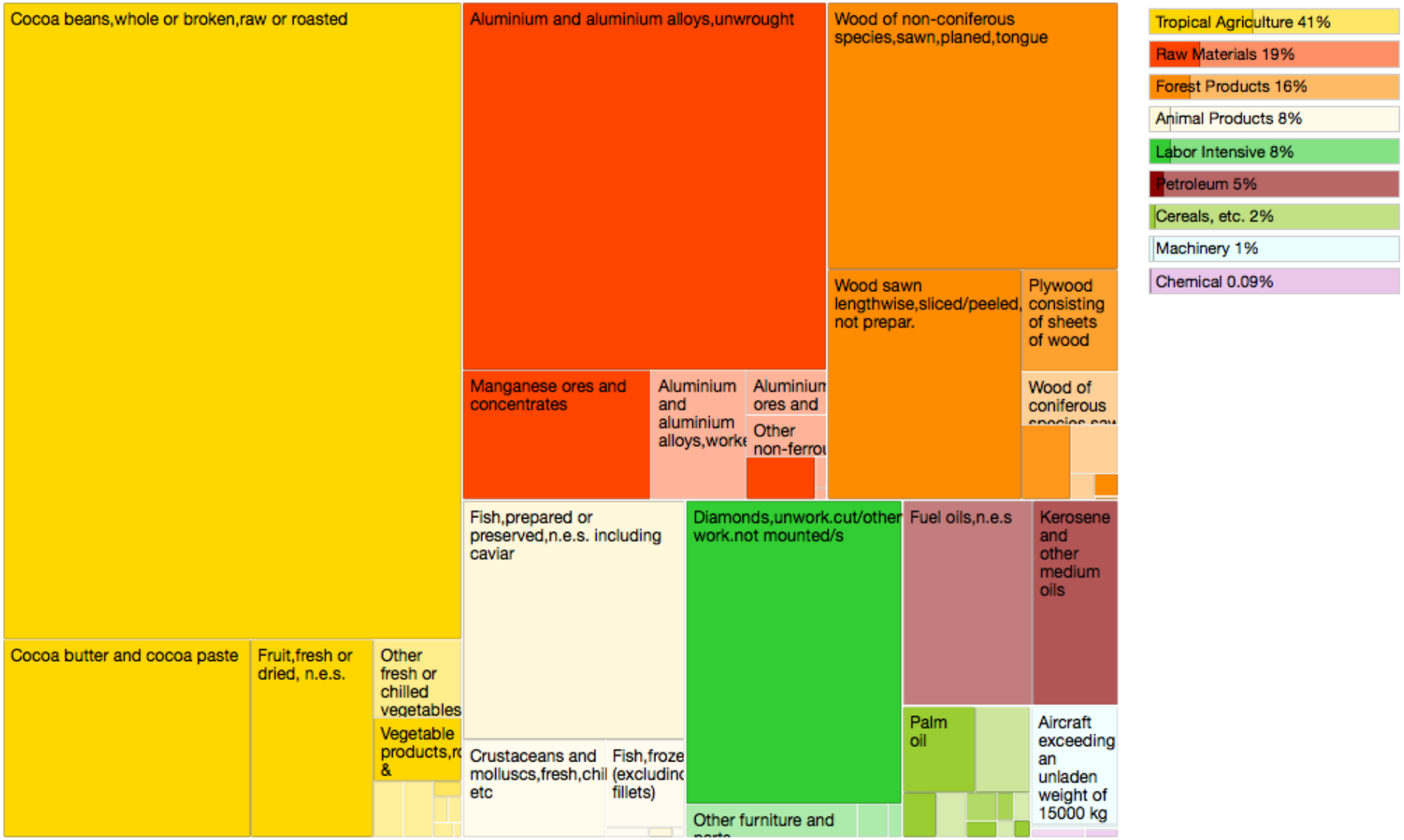


Ghana: a success story?

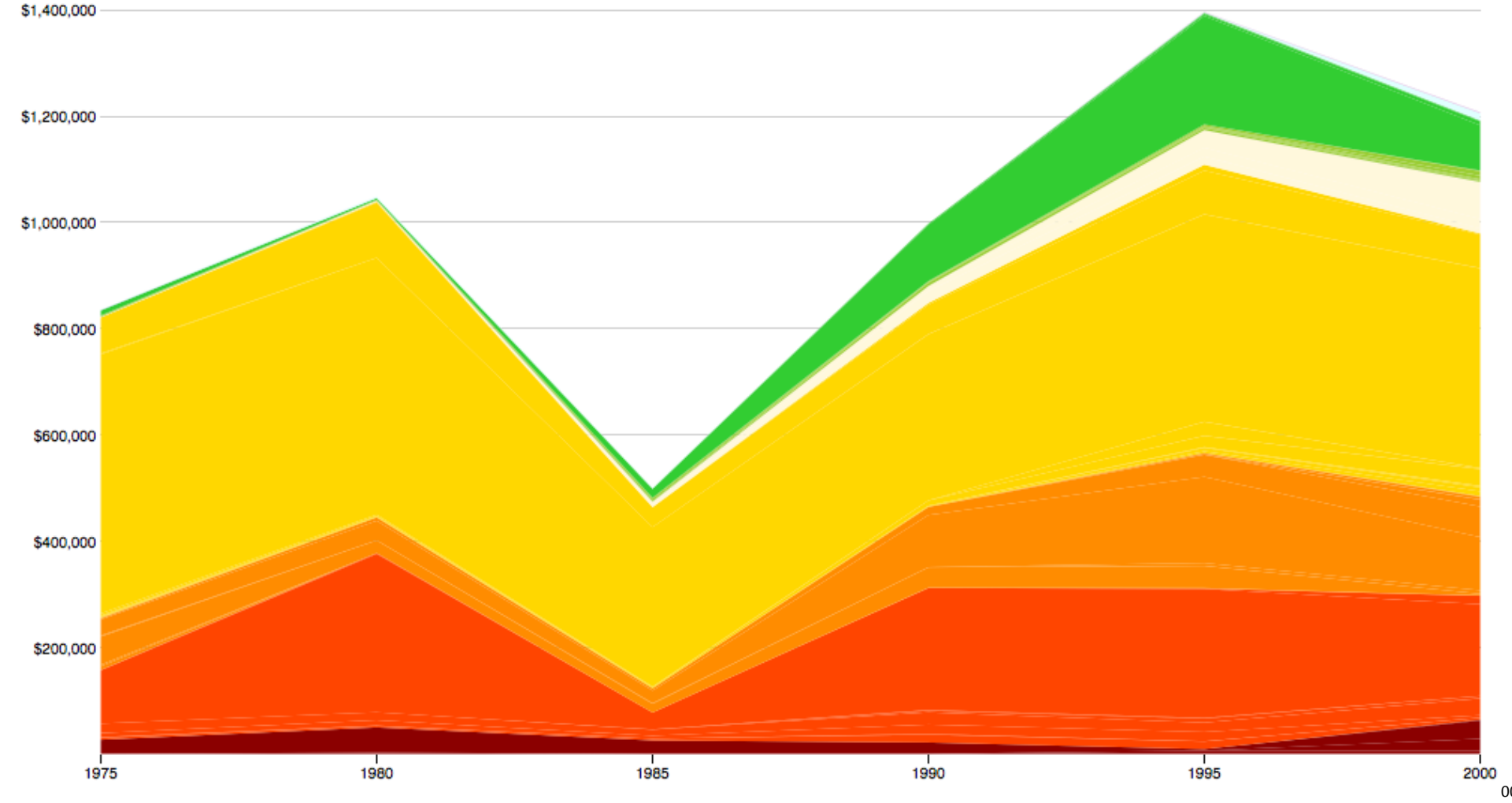



Cocoa beans,whole or broken,raw or roasted
Cocoa butter and cocoa paste
Aluminium and aluminium alloys,unwrought
Manganese ores and concentrates
Aluminium ores and concentrate (includ.alun
Sawlogs and veneer logs,of non coniferous species
Wood of non-coniferous species,sawn,planed
Pulpwood (including chips and
Sawlogs and
Fuel oils,n.e.s
Diamonds,unv work.not mounted/s
Bran,sha
Tropical Agriculture 68%
Raw Materials 16%
Forest Products 12%
Petroleum 3%
Labor Intensive 1%
Cereals, etc. 0.22%
Animal Products 0.07%
Capital Intensive 0.04%

1975


Cocoa beans,whole or broken,raw or roasted
Aluminium and aluminium alloys,unwrought
Wood of non-coniferous species,sawn,planed,tongue
Wood sawn lengthwise,sliced/peeled, not prepar.
Plywood consisting of sheets of wood
Manganese ores and concentrates
Aluminium and aluminium alloys,worke
Aluminium ores and
Other non-ferrou
Wood of coniferous
Fish,prepared or preserved,n.e.s. including caviar
Diamonds,unwork.cut/other work.not mounted/s
Fuel oils,n.e.s
Kerosene and other medium oils
Cocoa butter and cocoa paste
Fruit,fresh or dried, n.e.s.
Other fresh or chilled vegetables
Vegetable products,r &
Crustaceans and molluscs,fresh,chil etc
Fish,froze (excludinc fillets)
Palm oil
Aircraft exceeding an unladen weight of 15000 kg
Other furniture and
Tropical Agriculture 41%
Raw Materials 19%
Forest Products 16%
Animal Products 8%
Labor Intensive 8%
Petroleum 5%
Cereals, etc. 2%
Machinery 1%
Chemical 0.09%

2000

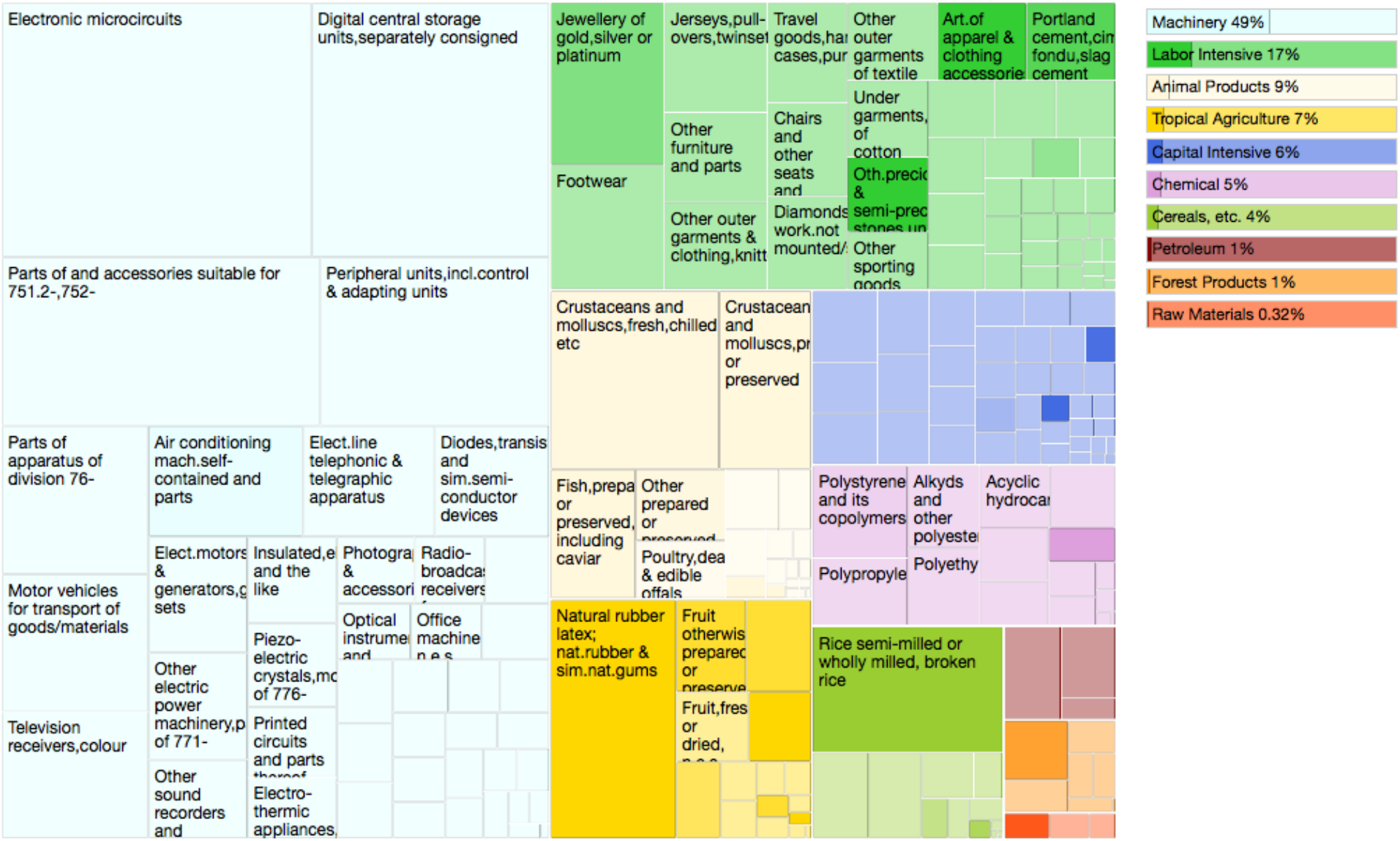

$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
1975
1980
1985
1990
1995
2000

Value

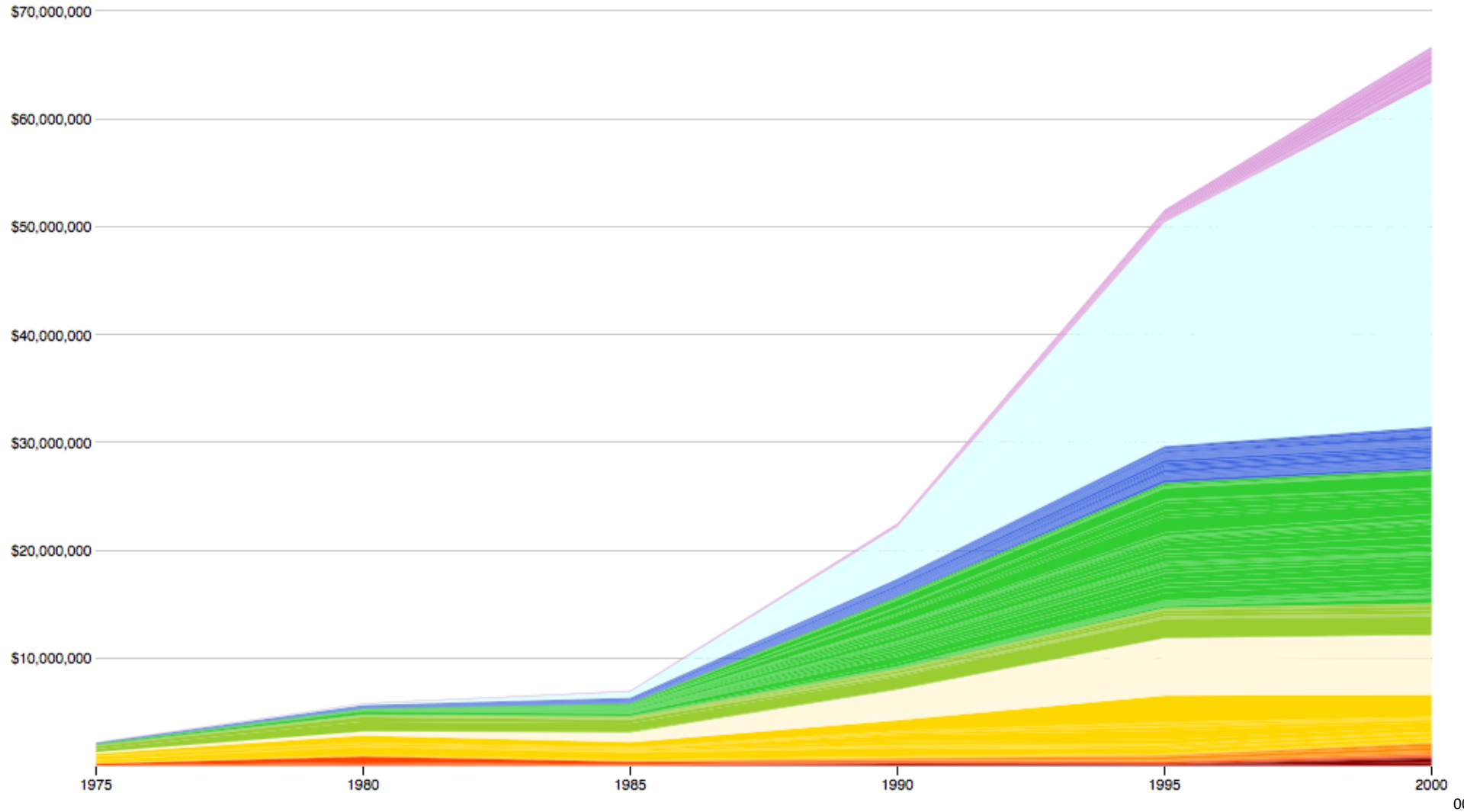
Thailand


Sugars,beet and cane,raw,solid
Maize (corn),unmilled
Rice semi-milled or wholly milled, broken rice
Vegetable products,roots & tubers,for human food
Natural rubber latex; nat.rubber & sim.nat.gums
Jute & other textile bast fibres,nes,rav
Buckwhea seed,grain sorghum etc
Cereal grains,wo (breakfas foods)
Rice in the
Tin and tin alloys,unwrought
Crustaceans and molluscs,fresh,chilled etc
Wood of non-coniferou species,sawn,
Manufactures of wood for domestic/deco
Sacks and bags,of textile
Twine,cord &
Refined sugars and other prod. of ref. beet/cane
Molasses,w or not decolourize
Beans,peas & other leguminous vegetables
Fruit otherwise prepared or preserved
Quartz,mi & chiolite
Zinc ores and
Oth.precious & semi-precious stones,unwork.cut etc
Portland cement,ciment fondu,slag cement etc.
Cotton fabrics,wo
Tropical Agriculture 42%
Cereals, etc. 31%
Raw Materials 8%
Animal Products 6%
Labor Intensive 5%
Forest Products 3%
Capital Intensive 2%
Chemical 1%
Machinery 0.55%

1975

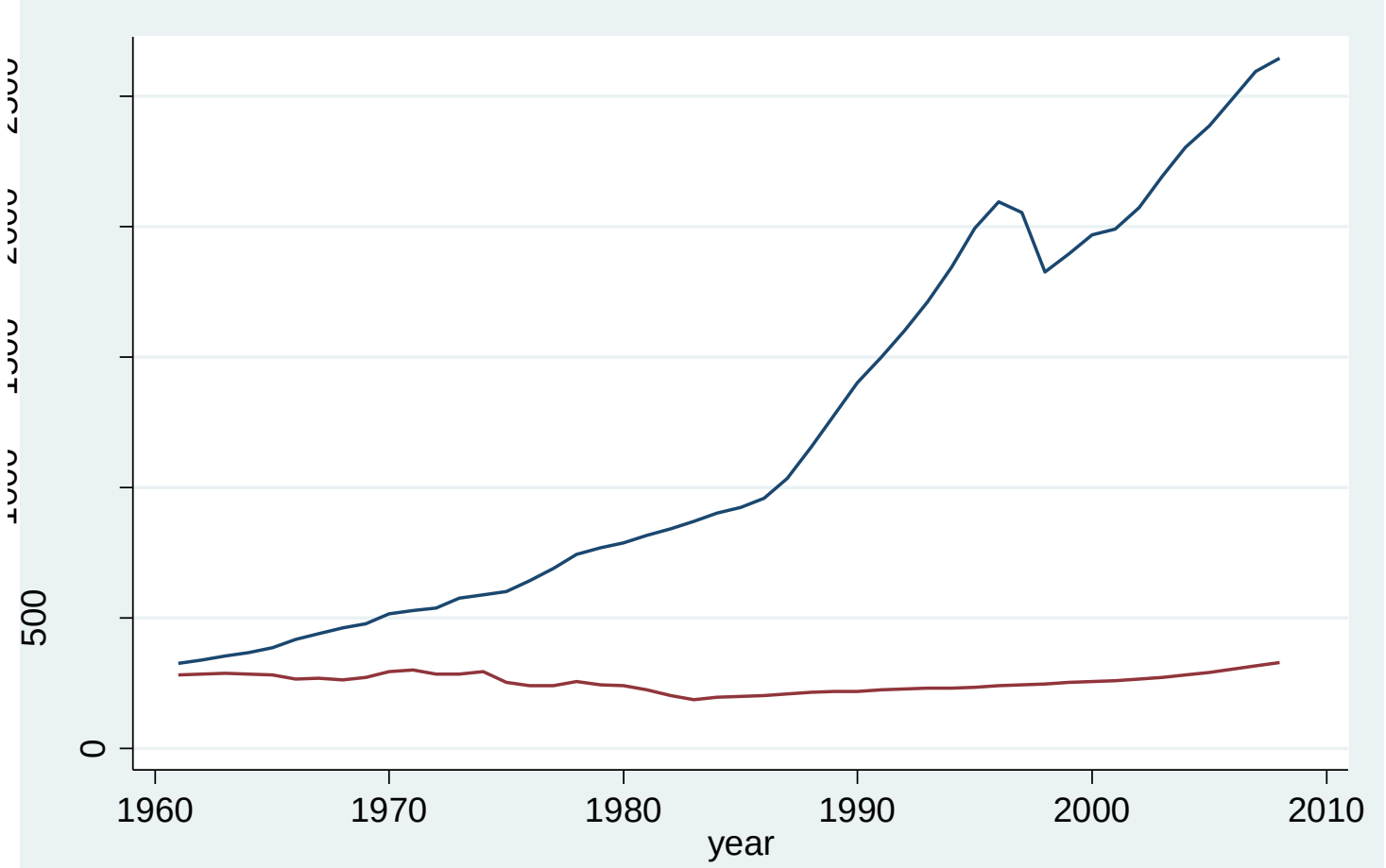

Electronic microcircuits
Digital central storage units,separately consigned
Parts of and accessories suitable for 751.2-,752-
Peripheral units,incl.control & adapting units
Parts of apparatus of division 76-
Air conditioning mach.self-contained and parts
Elect.line telephonic & telegraphic apparatus
Diodes,transis and sim.semi-conductor devices
Elect.motors & generators,g sets
Insulated,e and the like
Photogra & accessori
Radio-broadca receivers
Motor vehicles for transport of goods/materials
Optical instrume and
Office machine n.e.s.
Piezo-electric crystals,mc of 776-
Other electric power machinery,p of 771-
Printed circuits and parts thereof
Television receivers,colour
Other sound recorders and
Electro-thermic appliances,
Jewellery of gold,silver or platinum
Jerseys,pull-overs,twinset
Travel goods,ha cases,pur
Other outer garments of textile
Art.of apparel & clothing accessorie
Portland cement,cin fondu,slag cement
Under garments, of cotton
Chairs and other seats and
Other furniture and parts
Oth.precio & semi-prec stones un
Footwear
Diamonds work.not mounted/
Other outer garments & clothing,knitt
Other sporting goods
Crustaceans and molluscs,fresh,chilled etc
Crustacean and molluscs,pr or preserved
Fish,prepa or preserved, including caviar
Other prepared or
Poultry,dea & edible offals
Polystyrene and its copolymers
Alkyds and other polyeste
Acyclic hydroca
Polypropyle
Polyethy
Natural rubber latex; nat.rubber & sim.nat.gums
Fruit otherwis preparec or preserve
Fruit,fres or dried,
Rice semi-milled or wholly milled, broken rice
Machinery 49%
Labor Intensive 17%
Animal Products 9%
Tropical Agriculture 7%
Capital Intensive 6%
Chemical 5%
Cereals, etc. 4%
Petroleum 1%
Forest Products 1%
Raw Materials 0.32%

2000


$70,000,000
$60,000,000
$50,000,000
$40,000,000
$30,000,000
$20,000,000
$10,000,000
1975
1980
1985
1990
1995
2000

Value

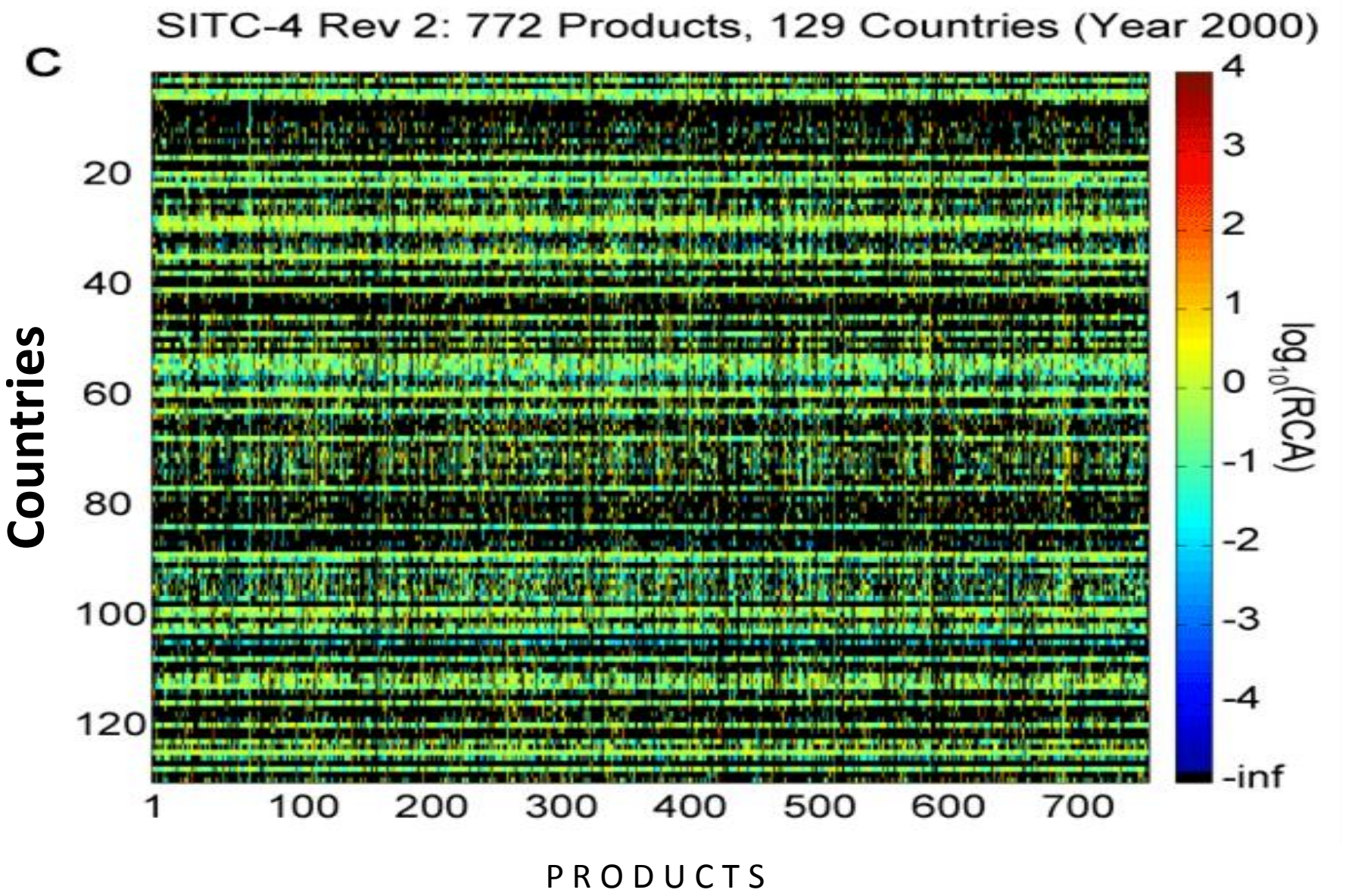
Thailand vs Ghana

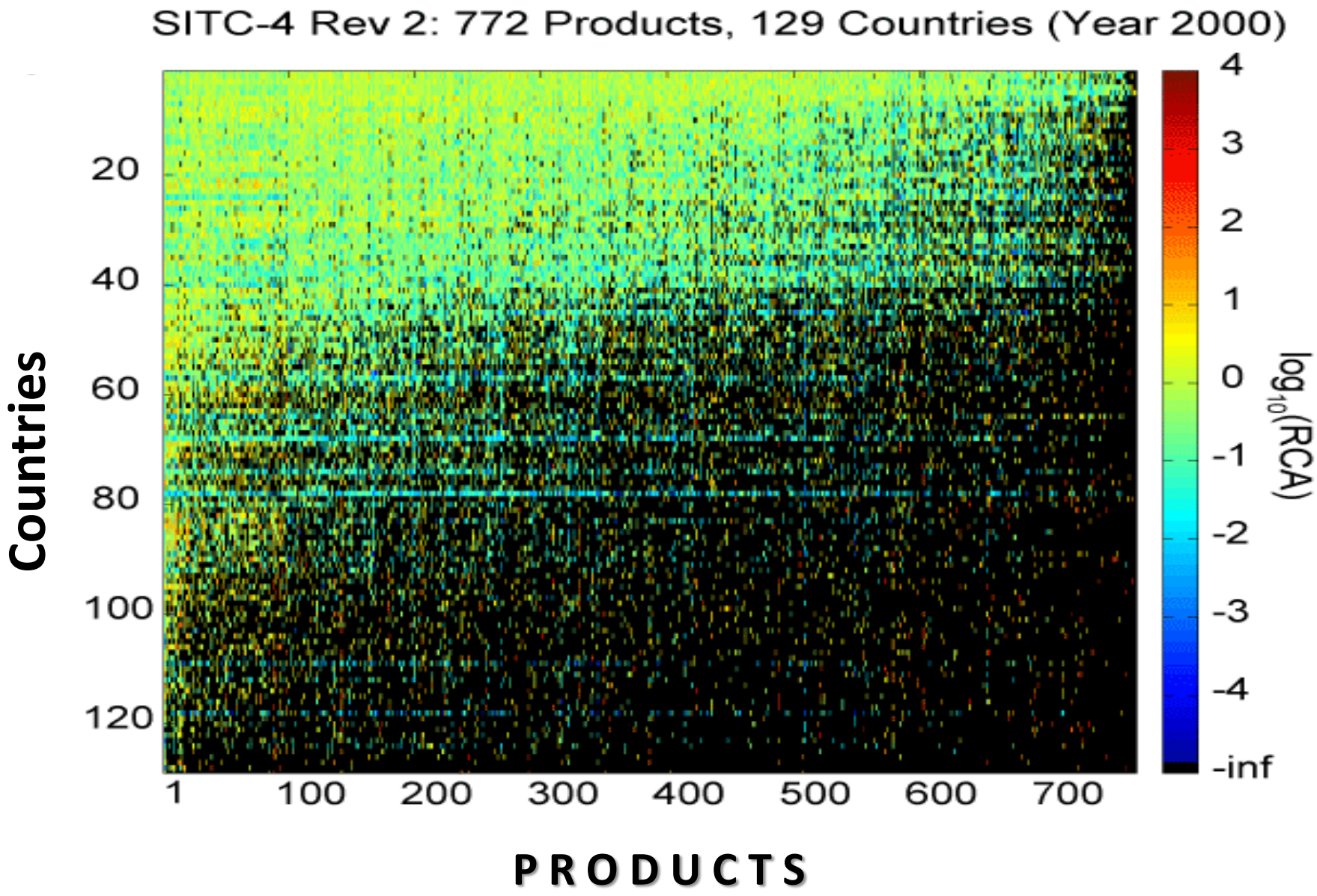


DIVERSIFICATION AND STRUCTURAL TRANSFORMATION

- Rich countries are more stable and more diversified than poor countries
- Is there anything causal about this relationship? Does diversification cause growth?
- Is there a trade-off between growth and diversification for stability
  - Developing less productive activities for the sake of stability
  - Like in choosing a lower risk and return portfolio
- Are there market failures in diversification and structural transformation that require policy action?

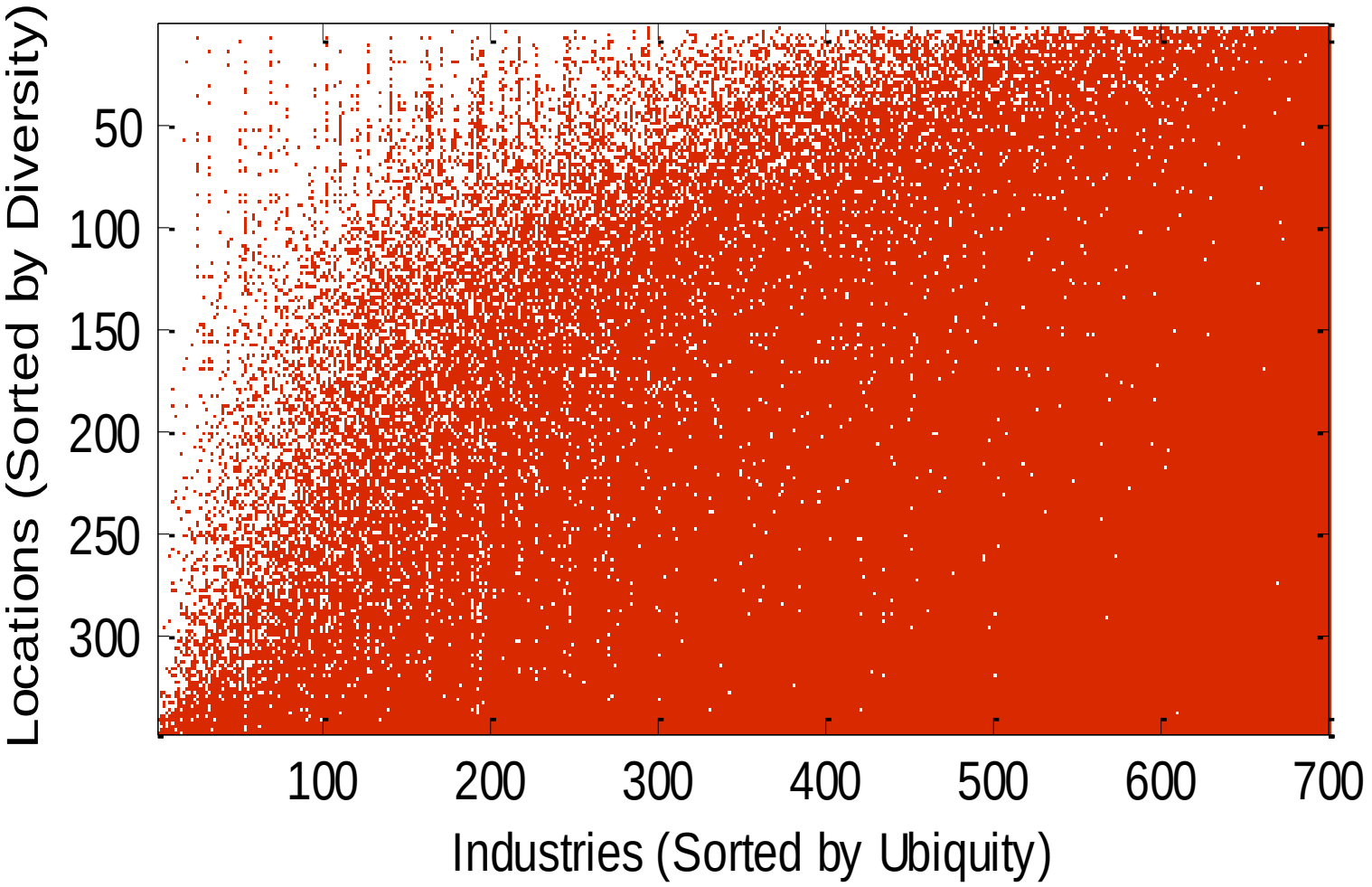
The shape of the world


C
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)

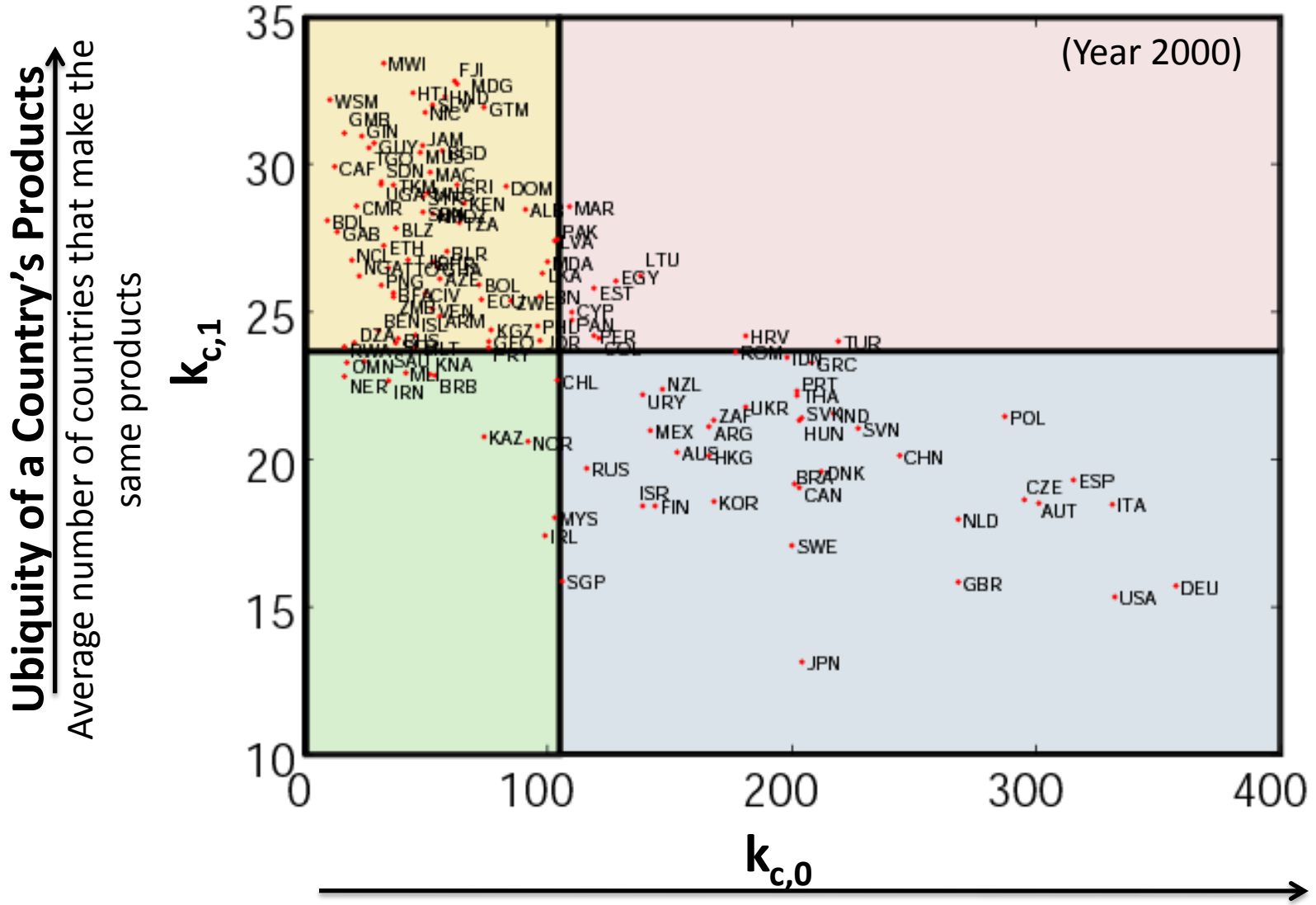

SITC-4 Rev 2: 772 Products, 129 Countries (Year 2000)
Countries
20
40
60
80
100
120
1
100
200
300
400
500
600
700
PRODUCTS
4
3
2
1
0
-1
-2
-3
-4
-inf
log10(RCA)

Happens within countries too:

Chile

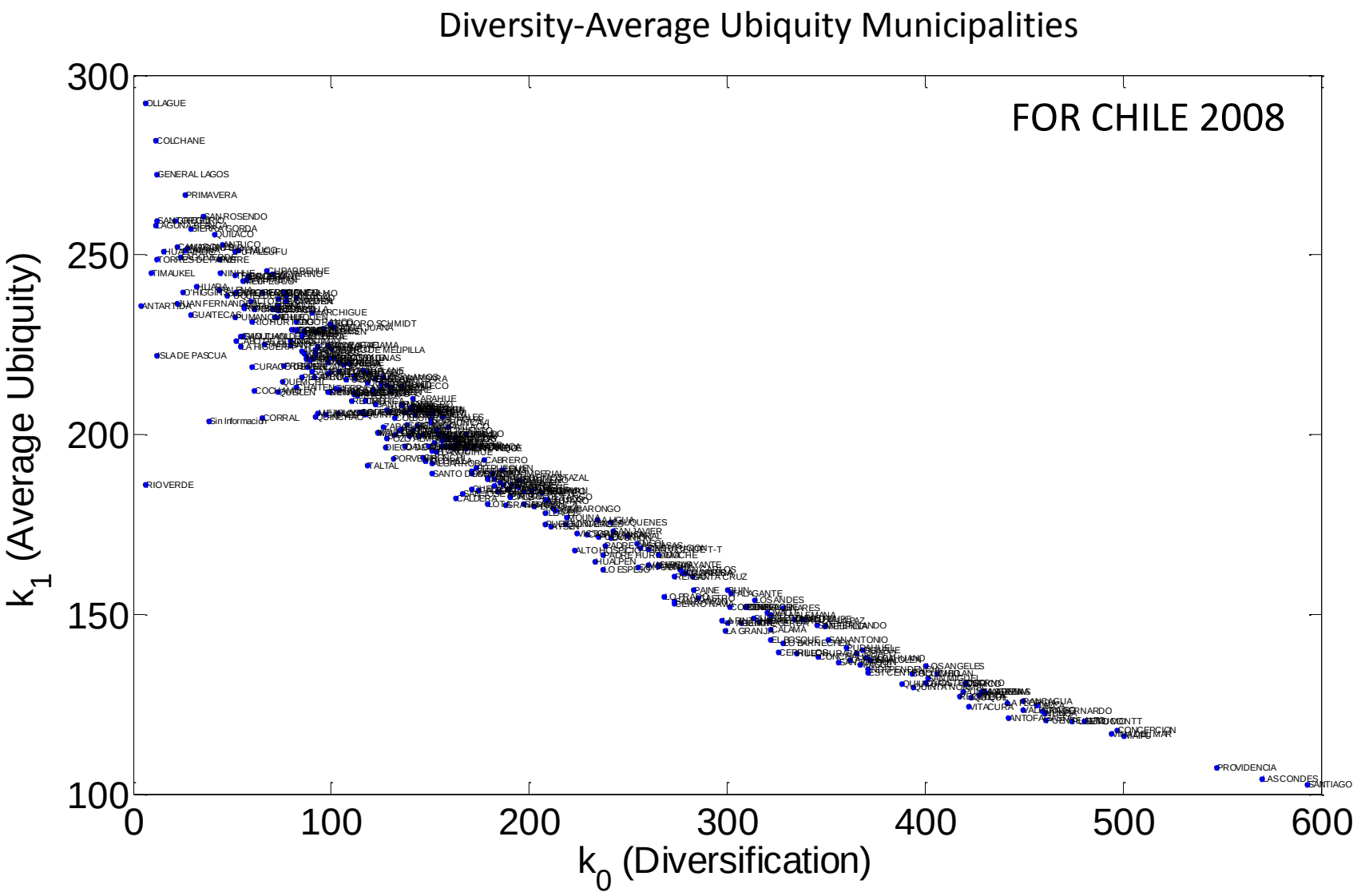


Evidence of the Connection between the diversity of inputs and that of outputs

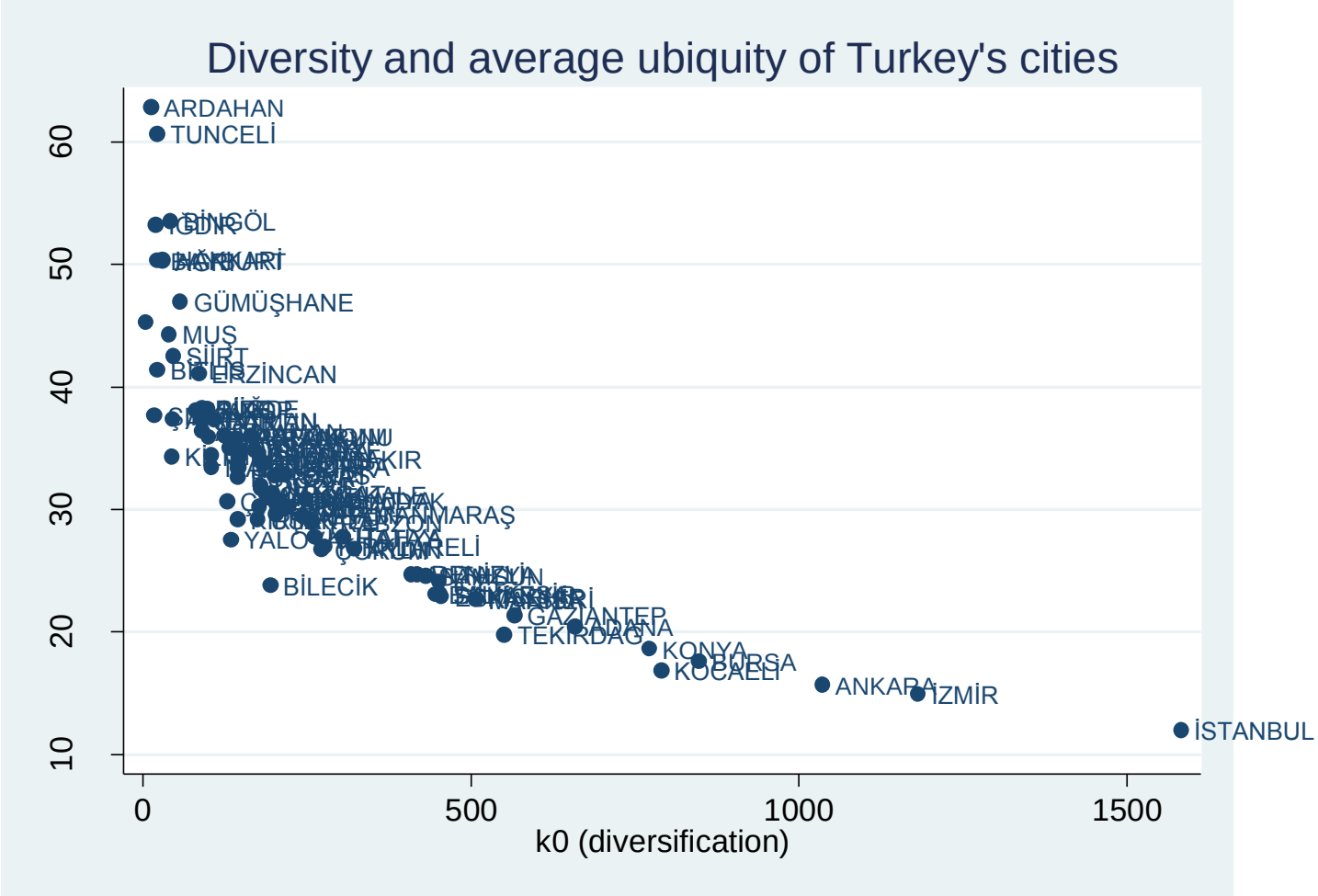


Hidalgo, Hausmann (2009)
PNAS 106(**26**):10570-10575

It also works within countries: Chile



…and Turkey


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

How to account for these features of the world?

- To produce a particular good you need a varying number of non-tradable intermediate inputs (call them capabilities)
  - Specific human skills
  - Non-tradable goods and services
  - Public goods or other types of public inputs
- They are highly complementary
- There is a fixed costs to developing new types of capabilities
- Products differ in the vector of capabilities they require
- Countries or regions differ in the vector of capabilities they have

INTUITION

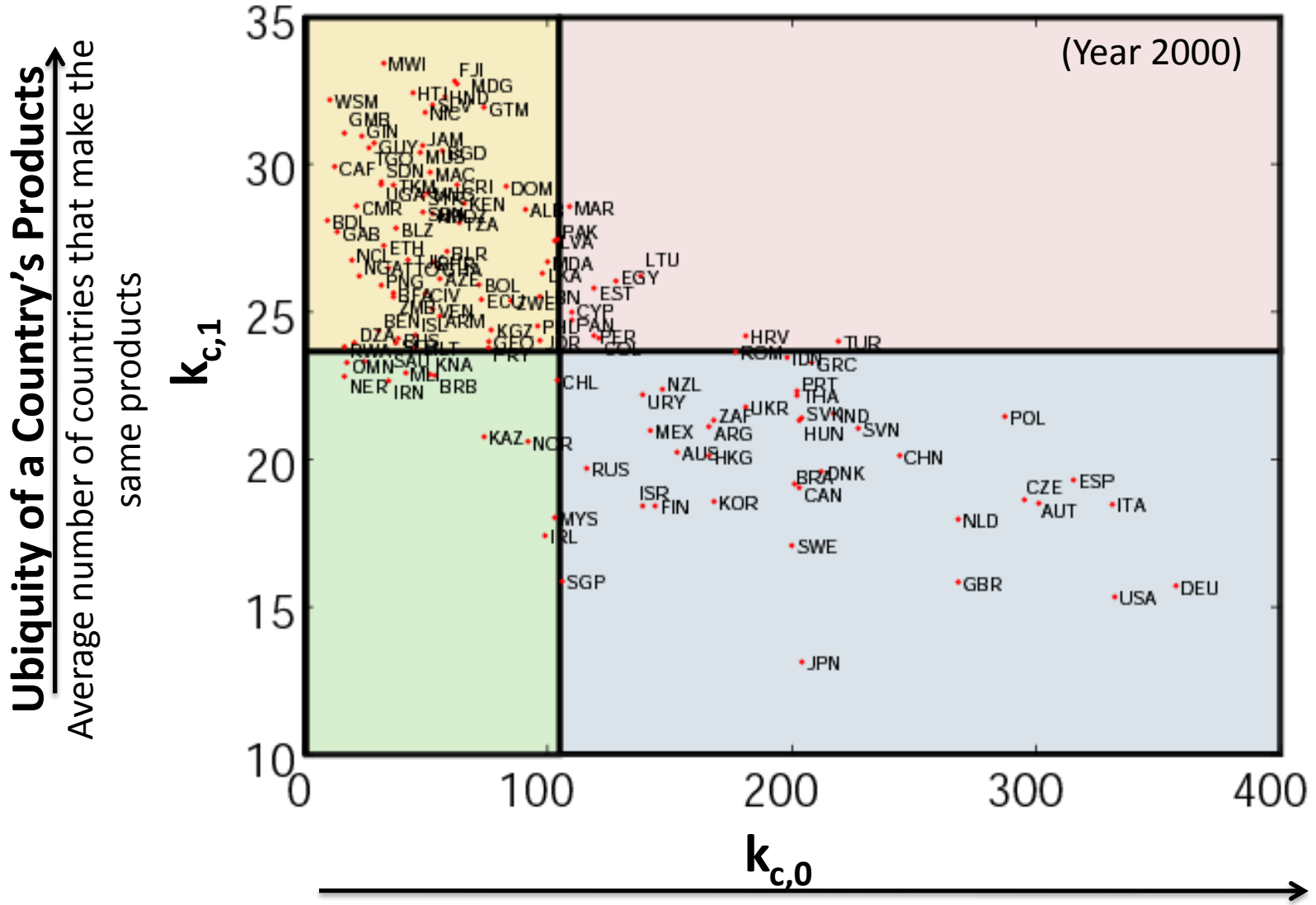
- Countries that have more capabilities will be able to make more products
  Countries would be more diversified

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

- Countries that have more capabilities will be able to make products that require more capabilities
- I.e. products that are less ubiquitous

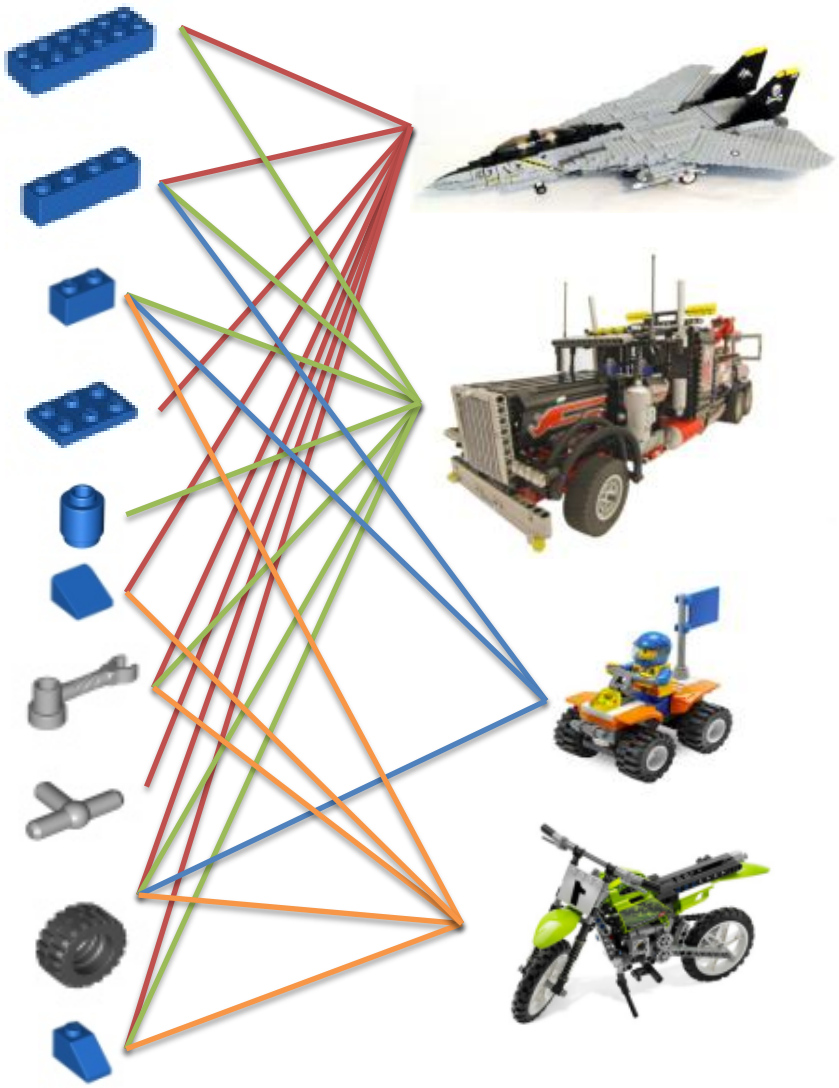
- Countries with more capabilities should thus be more diversified and able to make less ubiquitous products

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

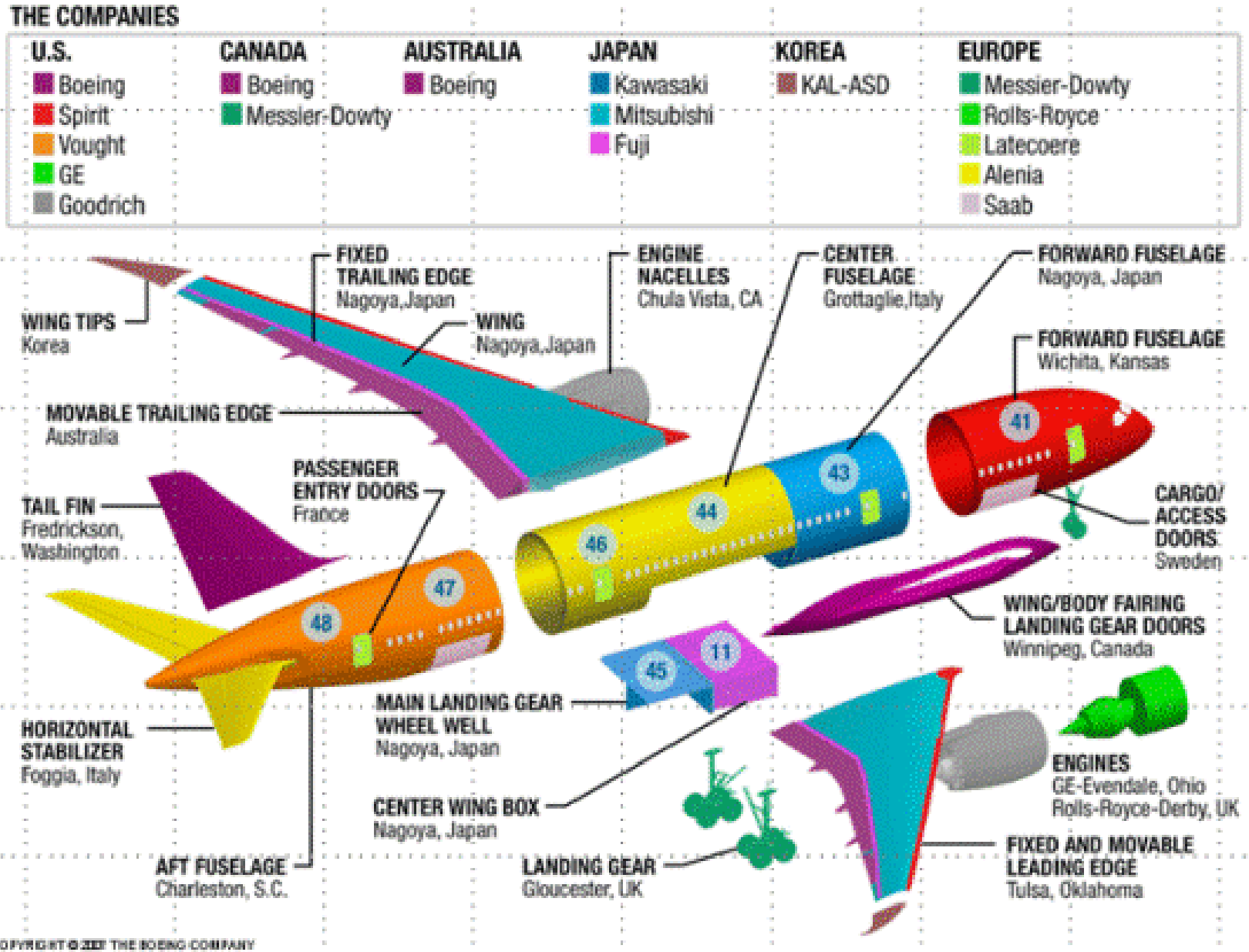


Hidalgo, Hausmann (2009)
PNAS 106(**26**):10570-10575

Products differ in the set of capabilities they require



Nikon
D200
D200
CASHIER
デジタル一眼レフ
LUMIX
Nikon
Nikon
D70s
ヨドバシカメラ
タイムバーゲン
D70S
¥83,800
Yodobashi-Camera

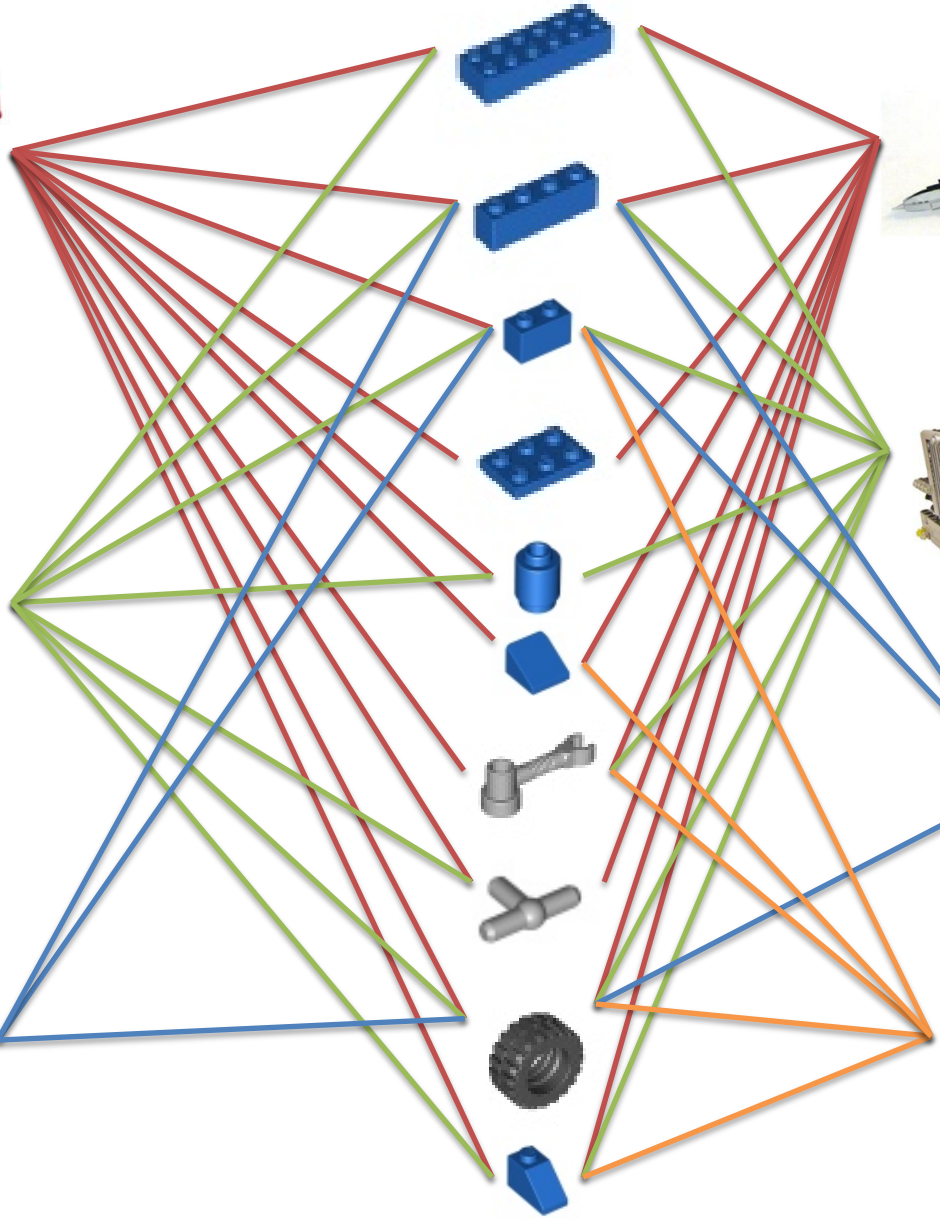


Countries differ in the set of capabilities they have

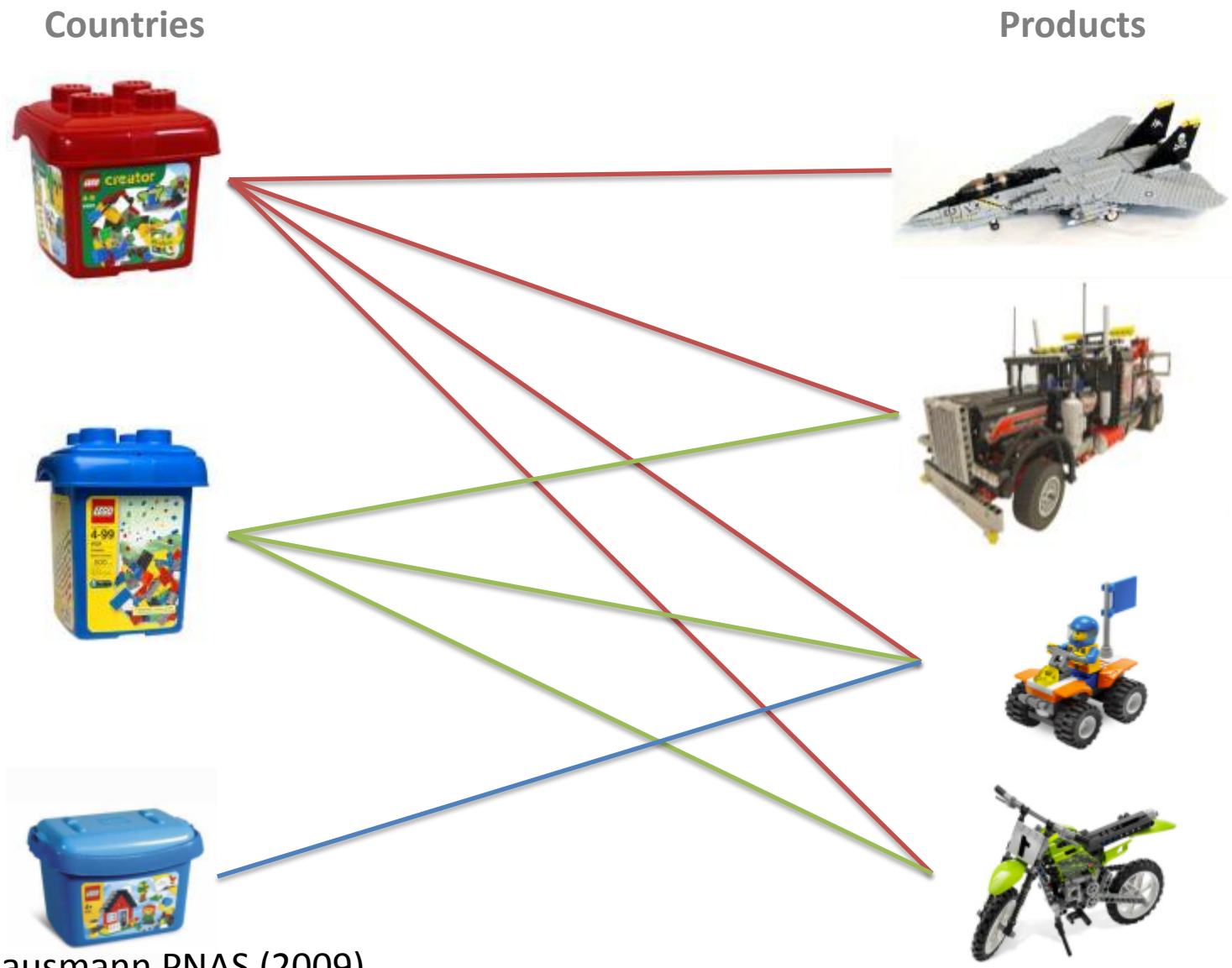
Countries

capabilities

Products



What we can observe



Hidalgo, Hausmann PNAS (2009)

The diversification that matters is at the level of capabilities.

It is expressed in the variety and complexity of the products that countries are able to put together

How can we measure a country's capabilities?

Calculating productive knowledge

$$Diversity = k_{c,0} = \sum_{p} M_{cp} \quad (1)$$

$$Ubiquity = k_{p,0} = \sum_{c} M_{cp} \quad (2)$$

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} \cdot k_{p,N-1} \quad (3)$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_{c} M_{cp} \cdot k_{c,N-1} \quad (4)$$

$$k_{c,N} = \sum_{c'} \widetilde{M}_{cc'} k_{c',N-2} \quad (7)$$

where

$$\widetilde{M}_{cc'} = \sum_{p} \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}} \quad (8)$$

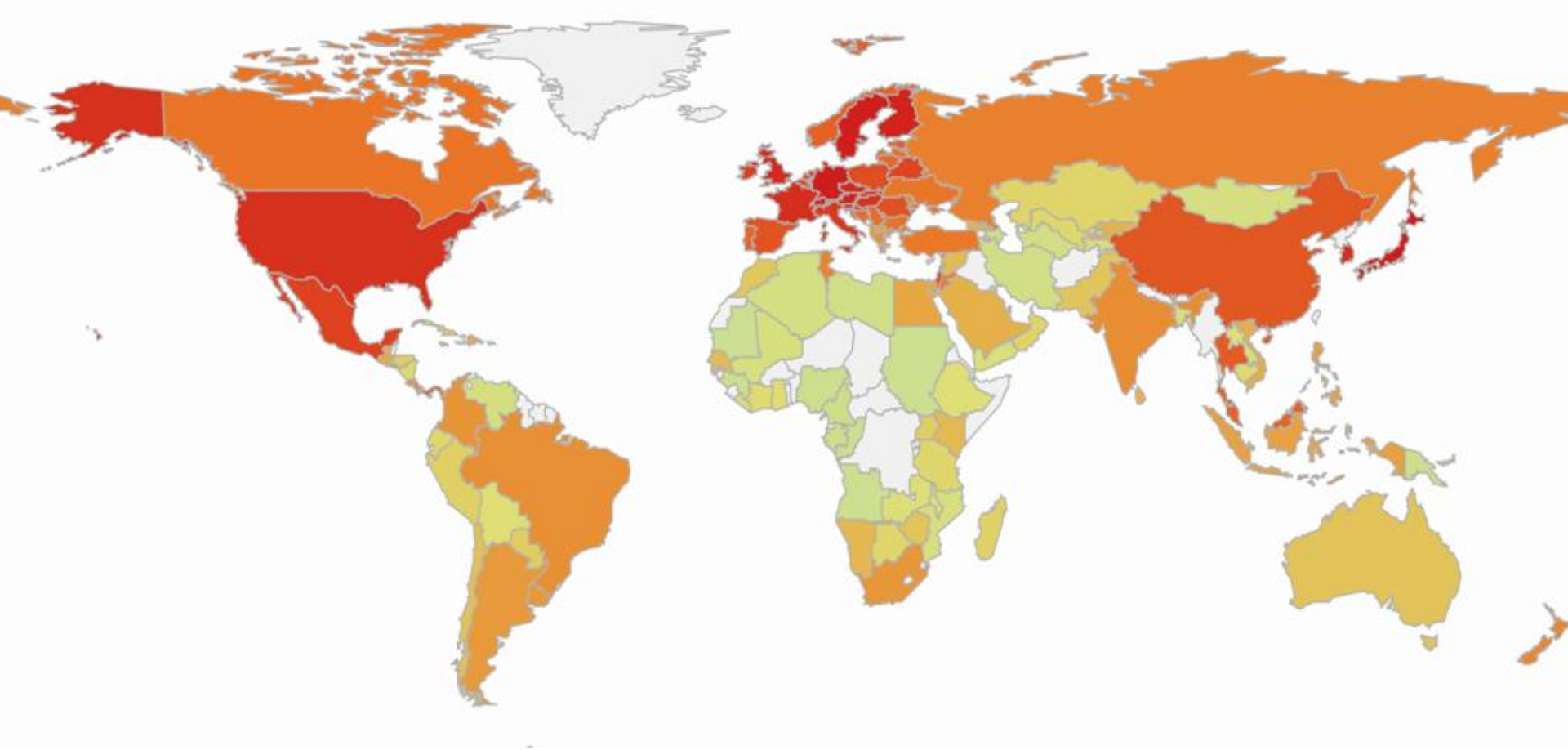
We calculate the second eigenvector
We can do the same for products

Another stab at the logic

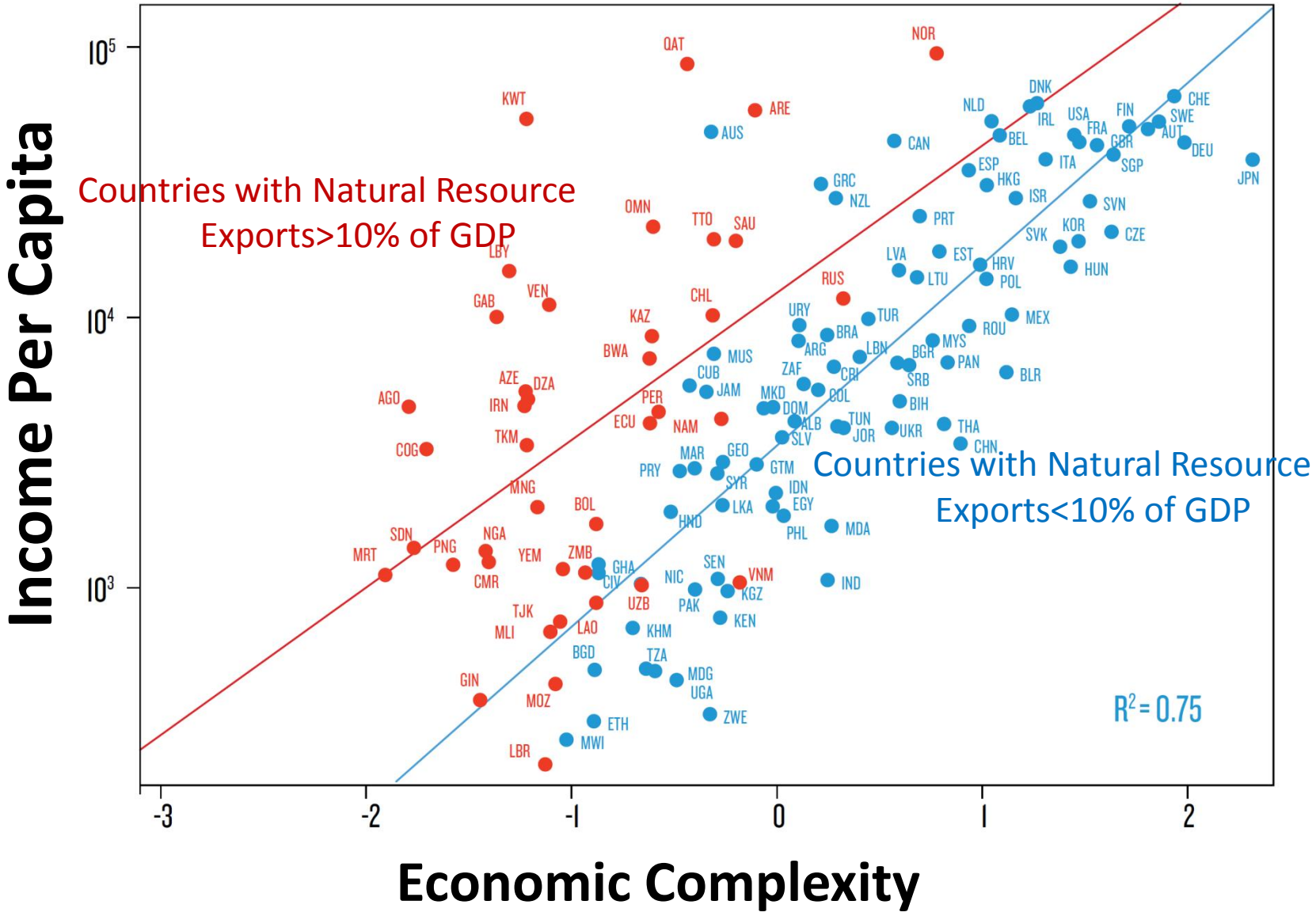
$$M_{c,p} = C_{c,a} \ddot{A} P_{p,a}$$

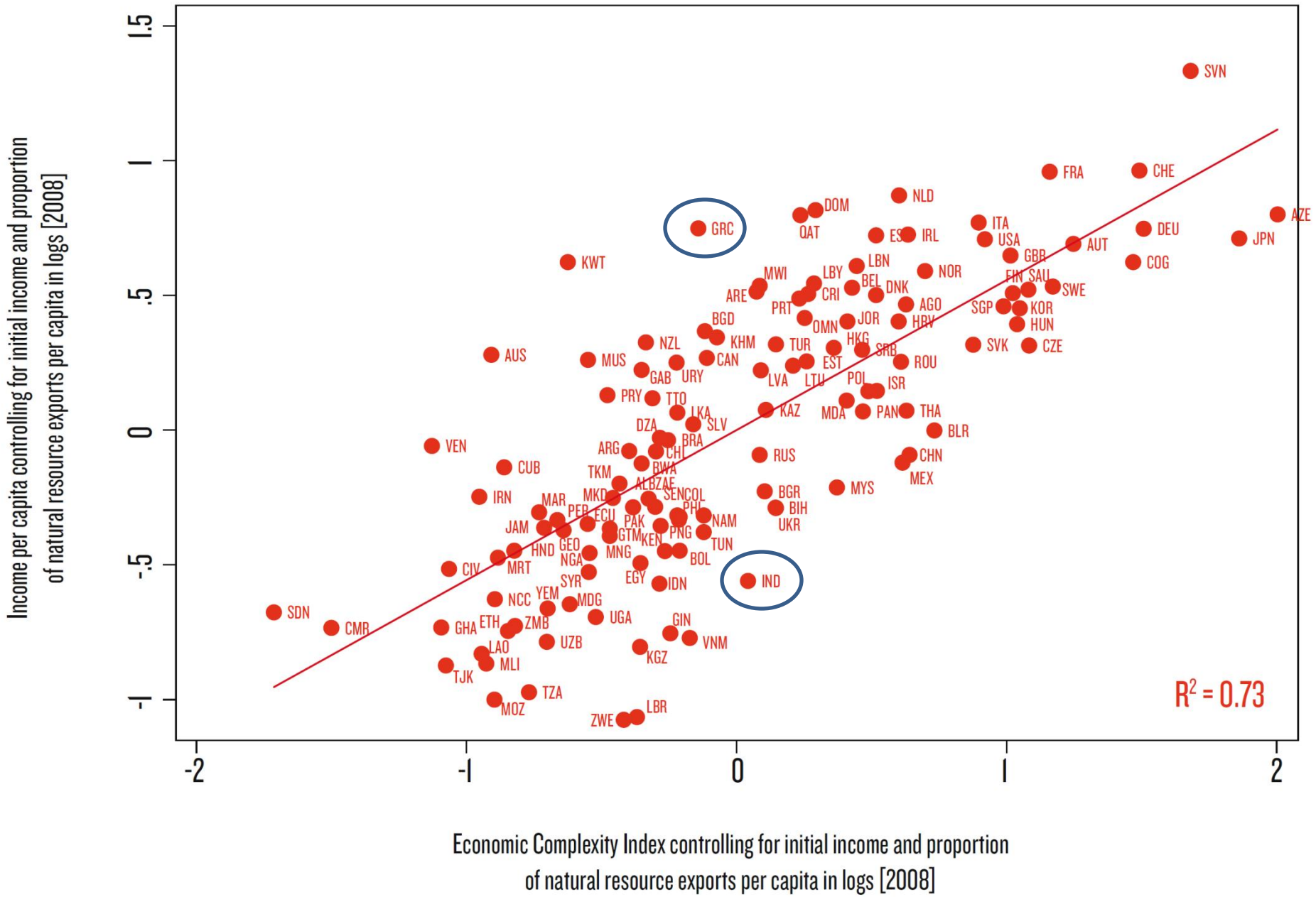
- If you average across products you get a measure of the C_{ca} matrix

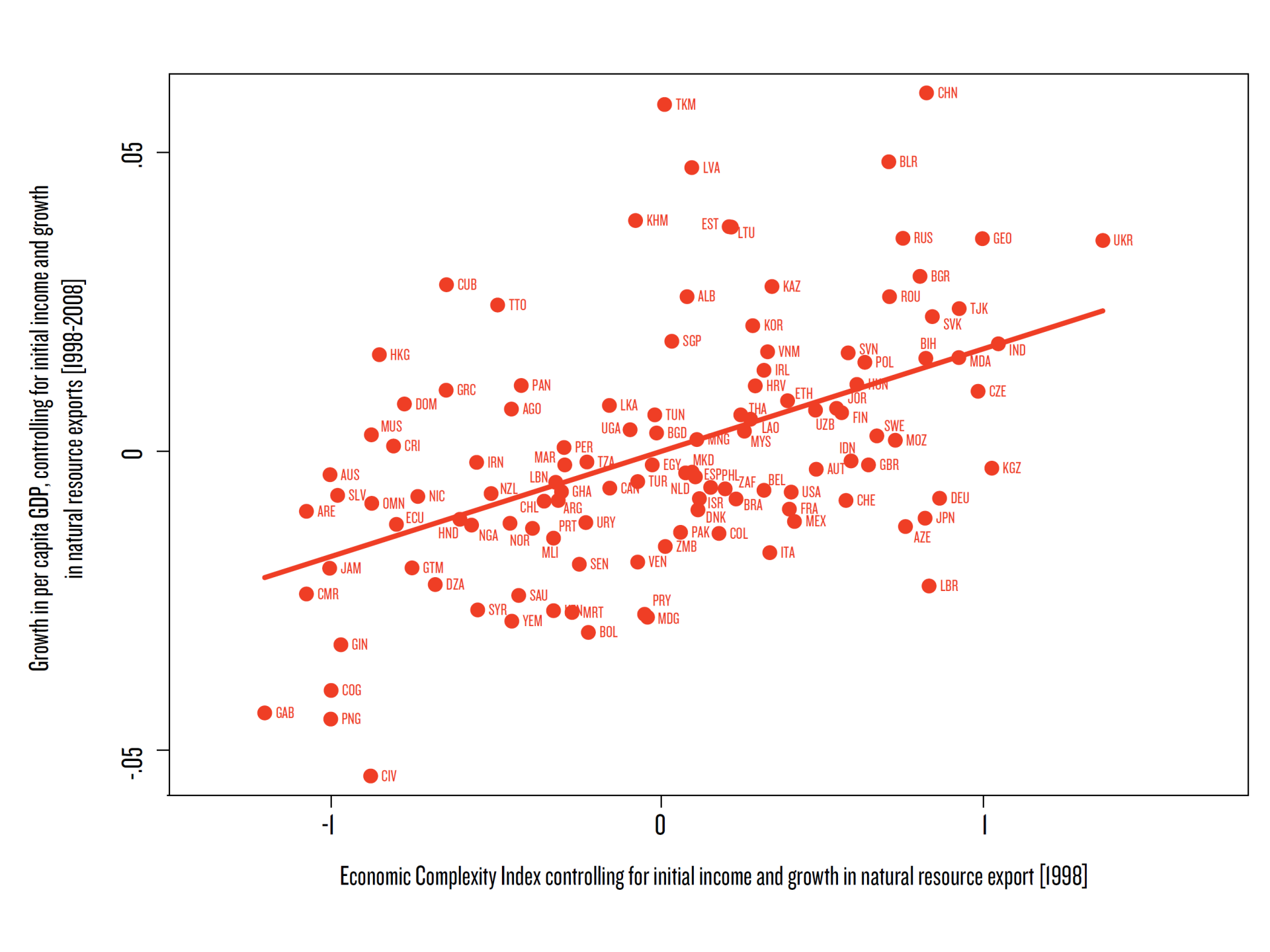
Economic Complexity Index



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
AGO
SGP
KOR
PRT
JOR
HRV
HUN
BGD
OMN
HKG
SRB
SVK
CZE
NZL
KHM
TUR
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
TKM
BWA
MEX
ALB
ZAE
SEN
COL
IRN
MKD
BGR
MYS
MAR
PER
PHL
BIH
ECU
PAK
NAM
UKR
JAM
GTM
KEN
PNG
TUN
HND
GEO
MNG
BOL
CIV
MRT
NGA
EGY
IND
SYR
IDN
SDN
NCC
YEM
MDG
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
TJK
TTO
SVK
KOR
SGP
BIH
IND
HKG
VNM
SVN
POL
MDA
IRL
HRV
HUN
CZE
GRC
PAN
ETH
JOR
DOM
AGO
LKA
THA
FIN
TUN
UZB
MUS
UGA
LAO
SWE
BGD
MNG
MYS
MOZ
CRI
PER
IDN
IRN
MAR
TZA
EGY
MKD
GBR
KGZ
AUS
LBN
ESP
PHL
ZAF
BEL
AUT
SLV
NZL
GHA
CAN
TUR
NLD
USA
DEU
NIC
CHE
OMN
CHL
ISR
BRA
FRA
ARE
ARG
DNK
JPN
ECU
URY
MEX
HND
PRT
NGA
NOR
PAK
COL
AZE
ZMB
MLI
ITA
JAM
SEN
VEN
GTM
DZA
LBR
CMR
SAU
PRY
SYR
MRT
MDG
YEM
BOL
GIN
COG
GAB
PNG
CIV

How are capabilities accumulated?

The chicken and egg problem

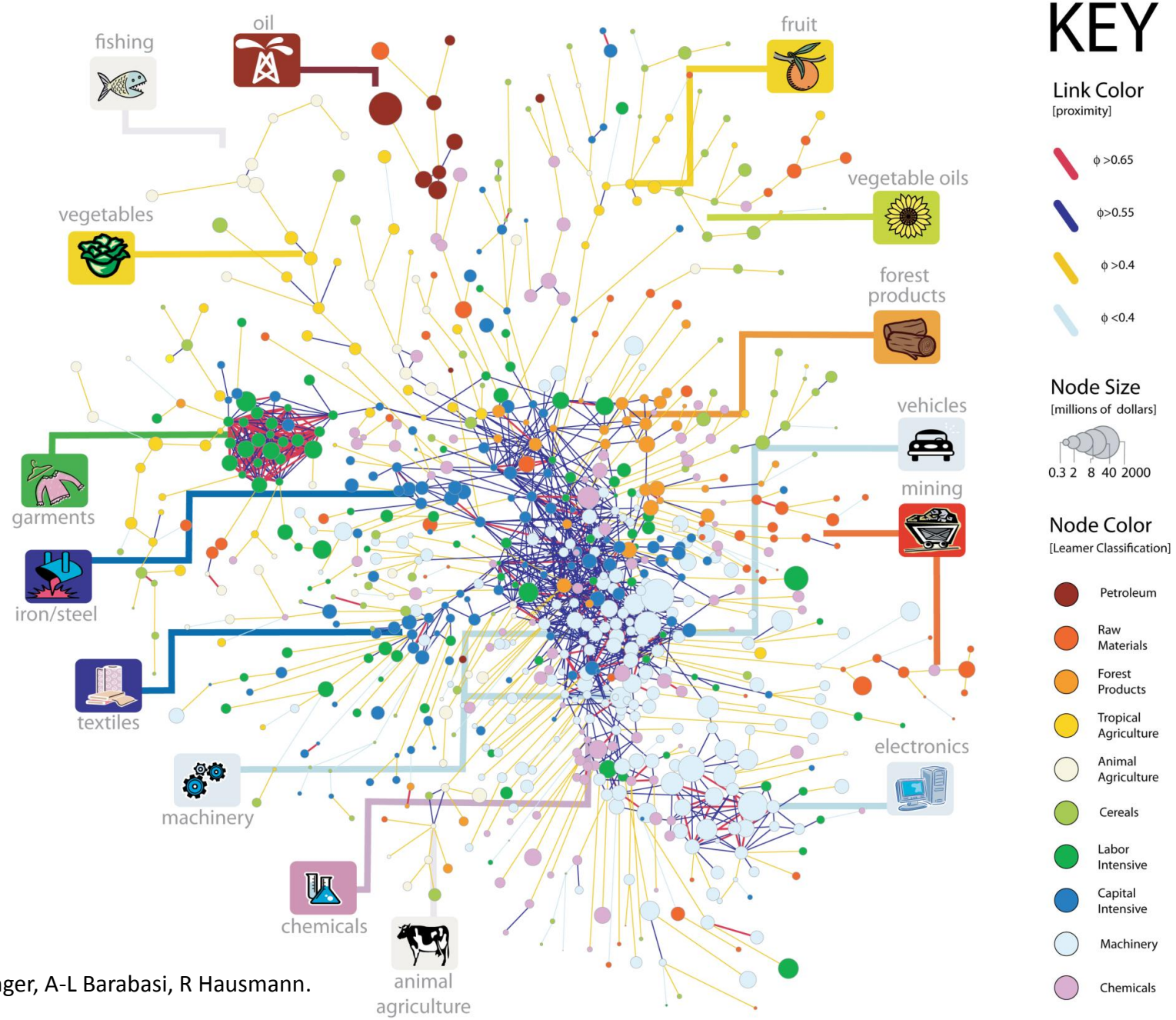
- You cannot make watches without watchmakers
- You don’t want to be watchmaker if nobody makes watches
- You cannot become a watchmaker because there are no watchmakers to learn from
- How does the world deal with this?
- By moving towards “nearby” products

What does nearby mean?

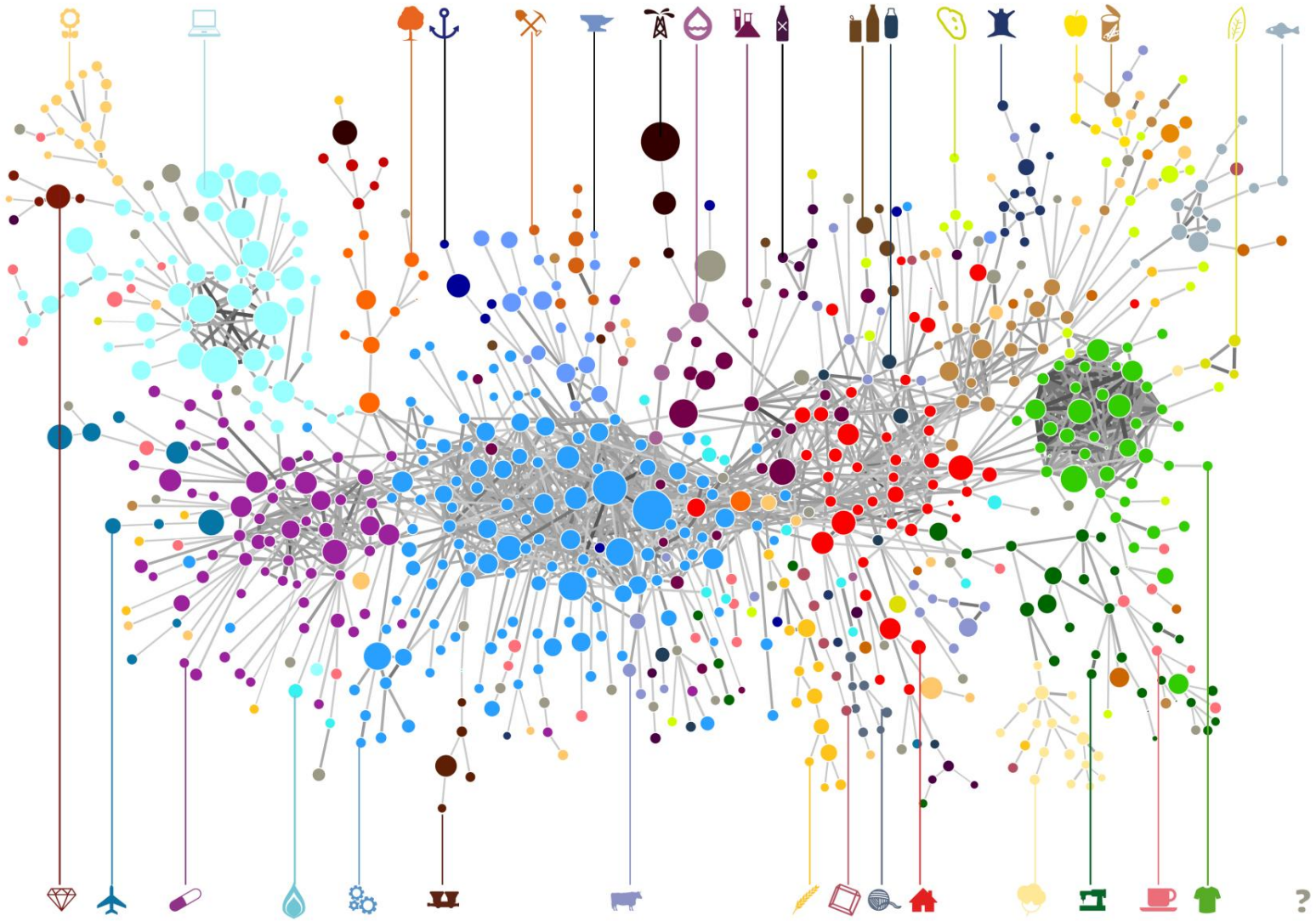
- Lets go back to the basic equation:
- $$M_{c,p} = C_{c,a} \ddot{A} P_{p,a}$$
- If you look at the probability that product are co-exported across all countries, you get a measure of how similar they are in the P_{pa} matrix

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

Mapping out the Forest

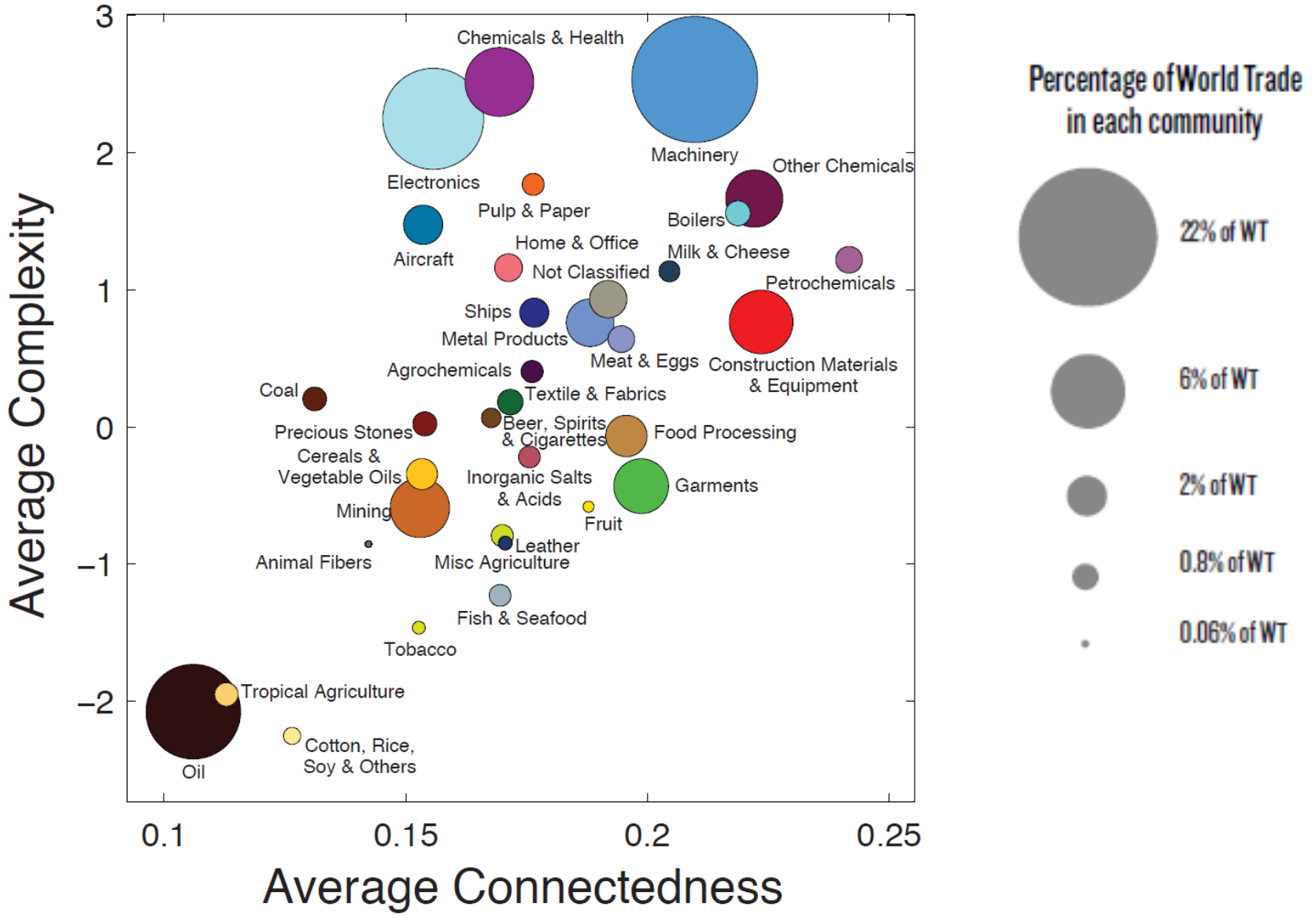


CA Hidalgo, B Klinger, A-L Barabasi, R Hausmann.
Science (2007)



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

Products differ in how many capabilities they require and in how related they are to other products



Measuring the position of a country in the product space

- A country is characterized not just by the capabilities it has
- …but by how easy it is to accumulate more capabilities
- This is affected by the proximity between the products it is able to make and other products
- We can measure this

Measuring the position in the product space

Distance between a country's capabilities and a product

$$d_{cp} = \frac{\sum_{p'}(1 - M_{cp'})\phi_{pp'}}{\sum_{p'}\phi_{pp'}}$$

Distance between a country

roducts currently not made, weighted by the complexity

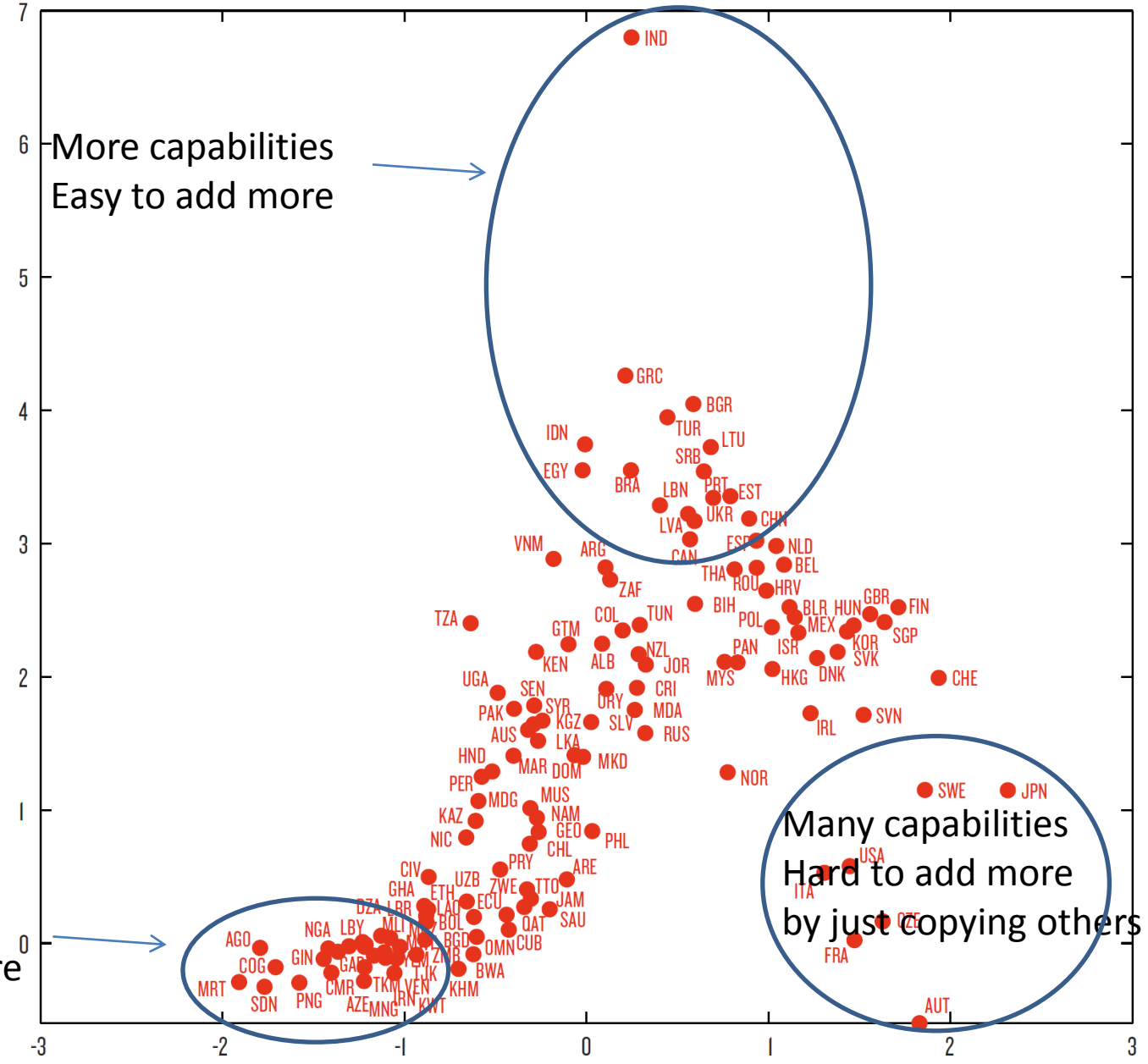
How c
you a

To the
product
you don
make

Weighted by how complex they are

$$opportunity\ value_{\ c} = \sum_{p'}(1 - d_{cp'})(1 - M_{cp'})\,PCI_{p'}$$

How close are you to other good products?



How many capabilities 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

Relation to standard stories

- Institutions matter
  - Because they facilitate the aggregation of capabilities through organizations and markets
- Human capital matters
  - HK is an intensive measure. PK is an extensive measure
  - Common HK may facilitate later specialization
  - And re-aggregation by making cooperation easier
- Finance matters
  - Because it may facilitate the re-aggregation of capabilities

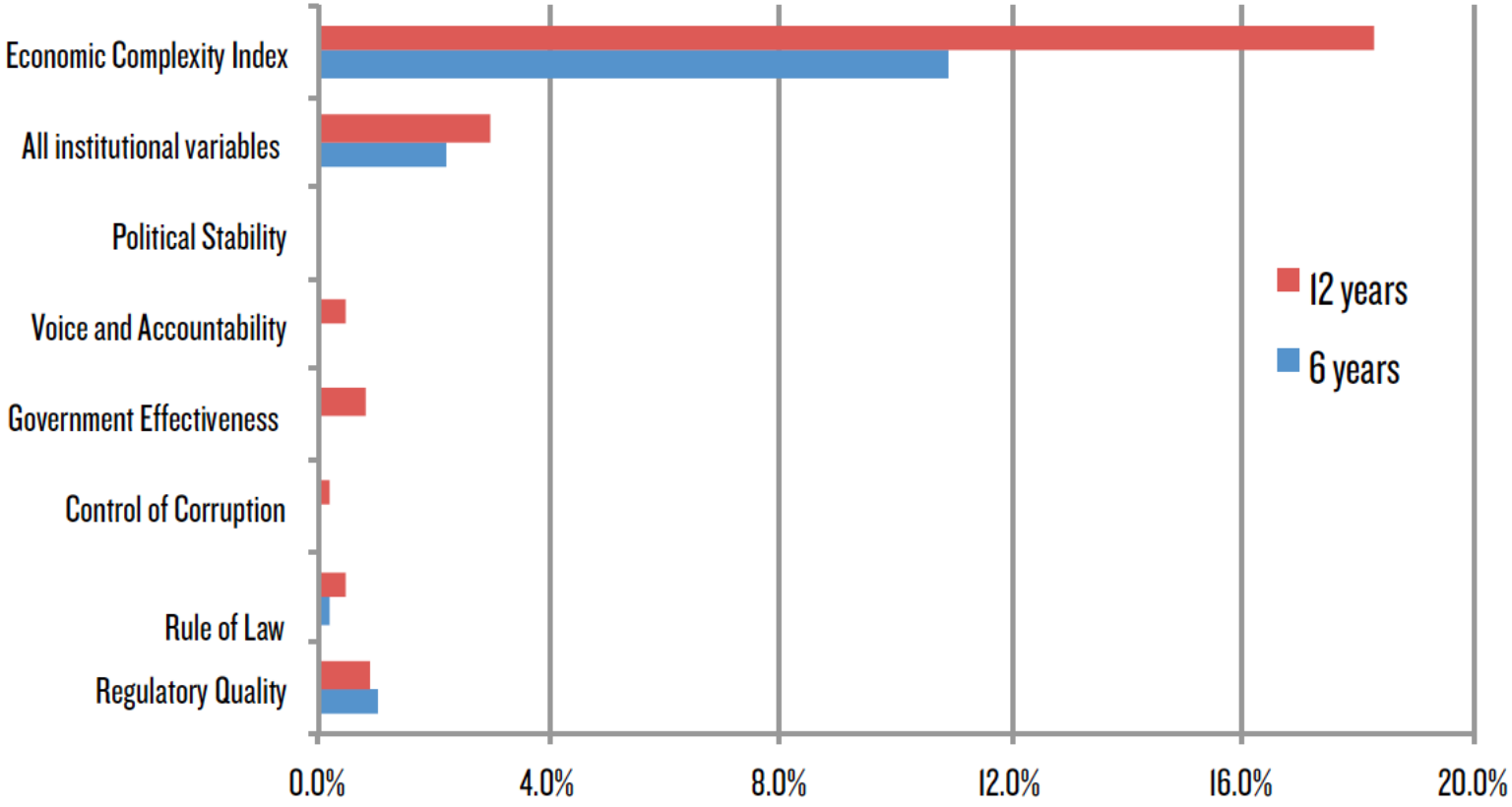
Institutions

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

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Initial GDP per capita, logs	-1.249***	-1.142***	-1.115***	-1.367***	-1.139***	-1.128***	-1.226***	-1.041***
	(0.194)	(0.268)	(0.276)	(0.194)	(0.255)	(0.273)	(0.213)	(0.300)
Increase in real NNRR exports pc	3.338***	3.301***	3.288***	3.362***	3.296***	3.262***	3.317***	3.204***
	(0.827)	(0.822)	(0.812)	(0.825)	(0.823)	(0.783)	(0.826)	(0.769)
Initial Economic Complexity Index	1.459***	1.500***	1.506***	1.377***	1.502***	1.446***	1.471***	1.425***
	(0.274)	(0.285)	(0.283)	(0.297)	(0.285)	(0.273)	(0.287)	(0.312)
Initial Opportunity value Index	0.483**	0.467**	0.484**	0.509***	0.482**	0.502***	0.486**	0.561***
	(0.186)	(0.190)	(0.188)	(0.183)	(0.188)	(0.185)	(0.187)	(0.199)
Initial Control of Corruption		-0.213						0.209
		(0.316)						(0.875)
Initial Government Effectiveness			-0.290					-0.381
			(0.369)					(0.775)
Initial Political Stability				0.372				0.845**
				(0.252)				(0.403)
Initial Rule of Law					-0.237			-0.795
					(0.341)			(0.841)
Initial Regulatory Quality						-0.251		-0.091
						(0.433)		(0.608)
Initial Voice and Accountability							-0.066	0.024
							(0.343)	(0.435)
Constant	12.514***	11.697***	11.508***	13.454***	11.667***	11.620***	12.342***	11.033***
	(1.563)	(2.109)	(2.147)	(1.564)	(2.002)	(2.093)	(1.675)	(2.308)
Observations	119	119	119	119	119	119	119	119
R-squared	0.461	0.463	0.464	0.468	0.463	0.464	0.461	0.485
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

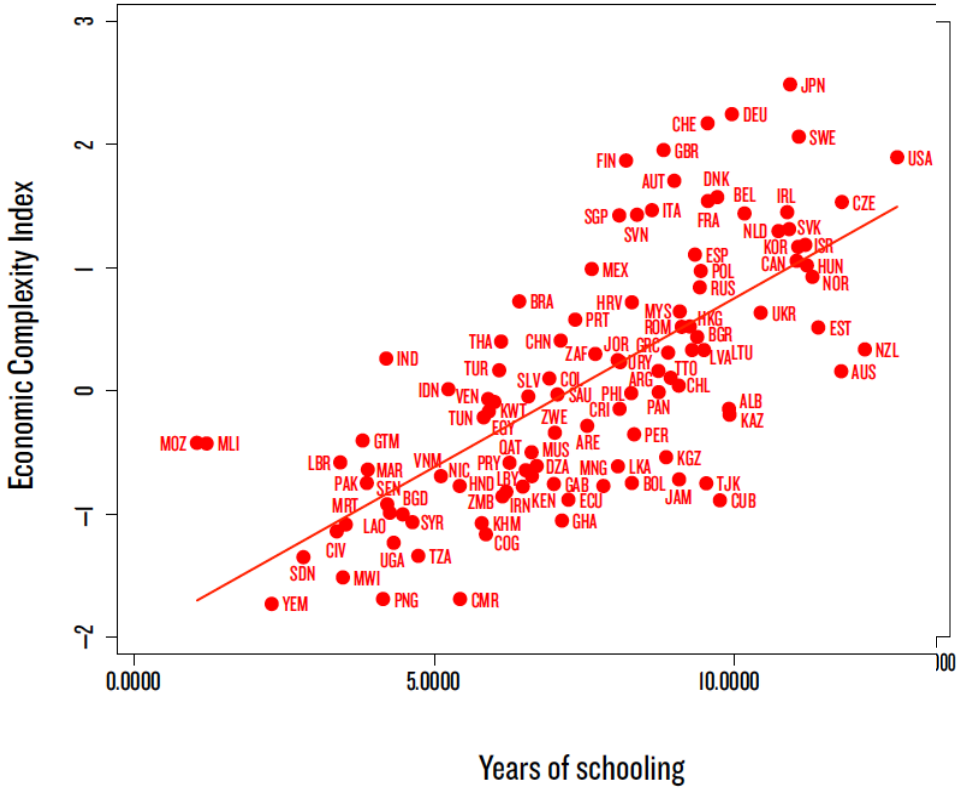
Who can account for growth? Complexity vs. Governance

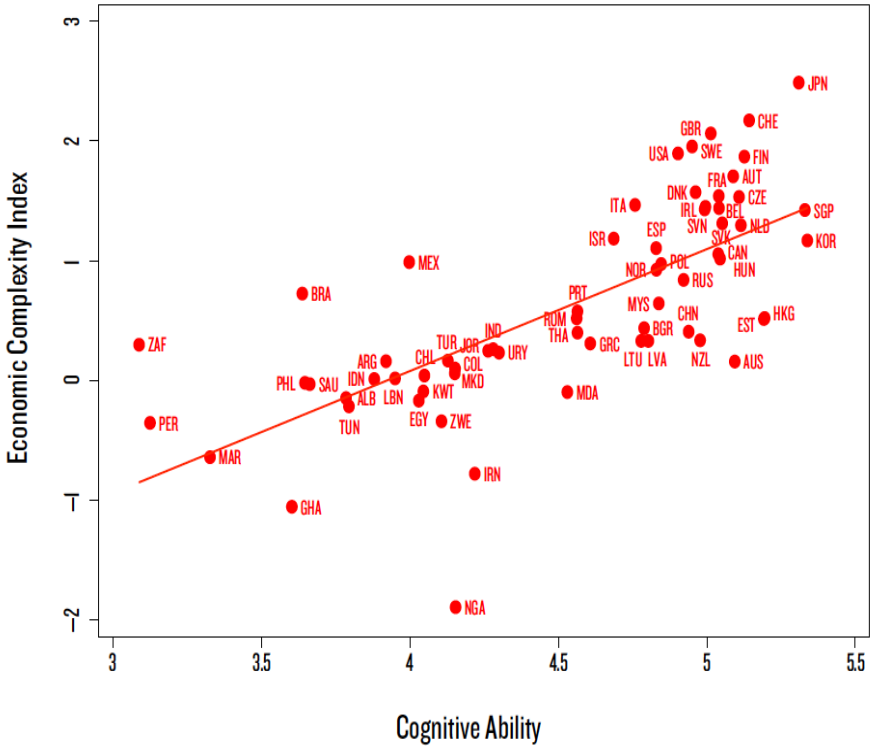


Human capital vs productive capabilities

- Human capital is measured at the level of individuals
  - Years of schooling
  - Controlling for PISA results
- Standard measures of HK look at how much of the *same* curriculum or of the *same* skills do people hold
- HK characterizes a society by the *average* of HK held by individuals
- Our measures are about the diversity of the capabilities countries have
- Intensity vs. spectrum of light

Complexity vs. schooling





Education

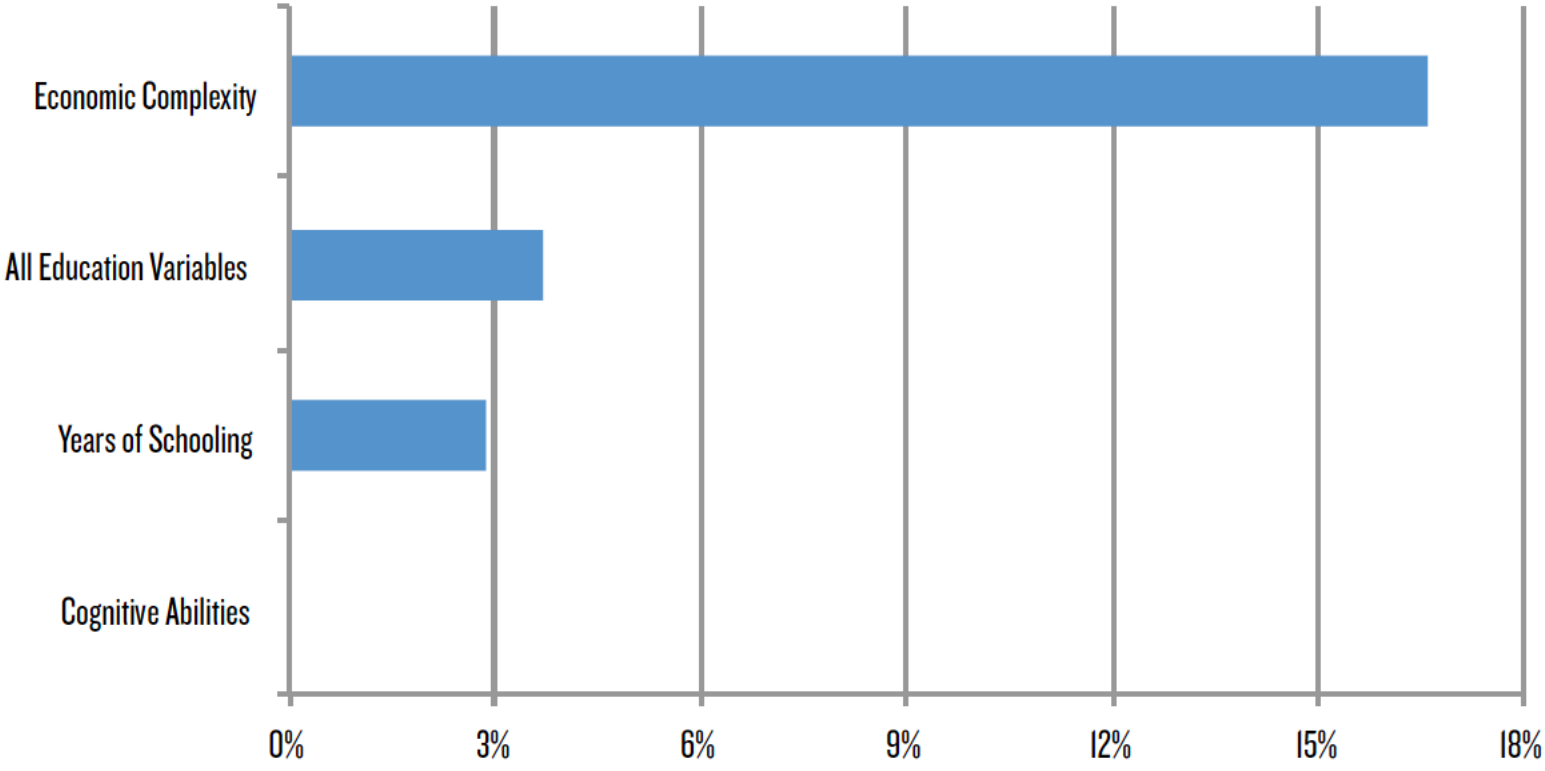
Dependent variable: 10 year real GDP growth per capita (%)

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)
Initial percentage of Secondary Complete			0.045***		0.027
			(0.015)		(0.021)
Initial percentage of Tertiary Complete				0.009	-0.069*
				(0.029)	(0.038)
Constant	6.996***	8.383***	8.452***	8.376***	8.136***
	(1.187)	(1.235)	(1.175)	(1.207)	(1.184)
Observations	261	261	261	261	261
R-squared	0.386	0.406	0.407	0.386	0.417
Year FE	Yes	Yes	Yes	Yes	Yes

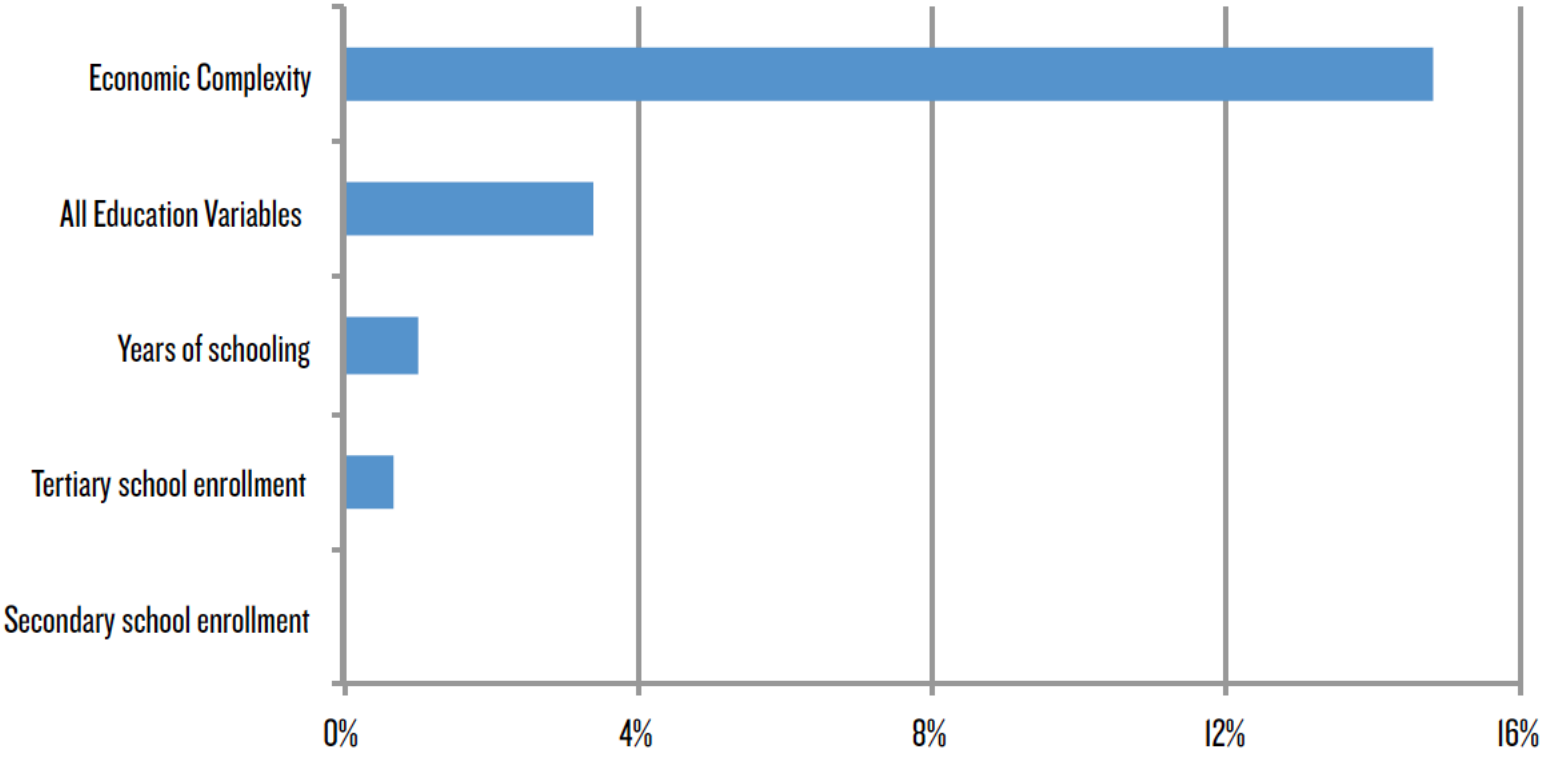
Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Who can account for income?



Who can account for growth?



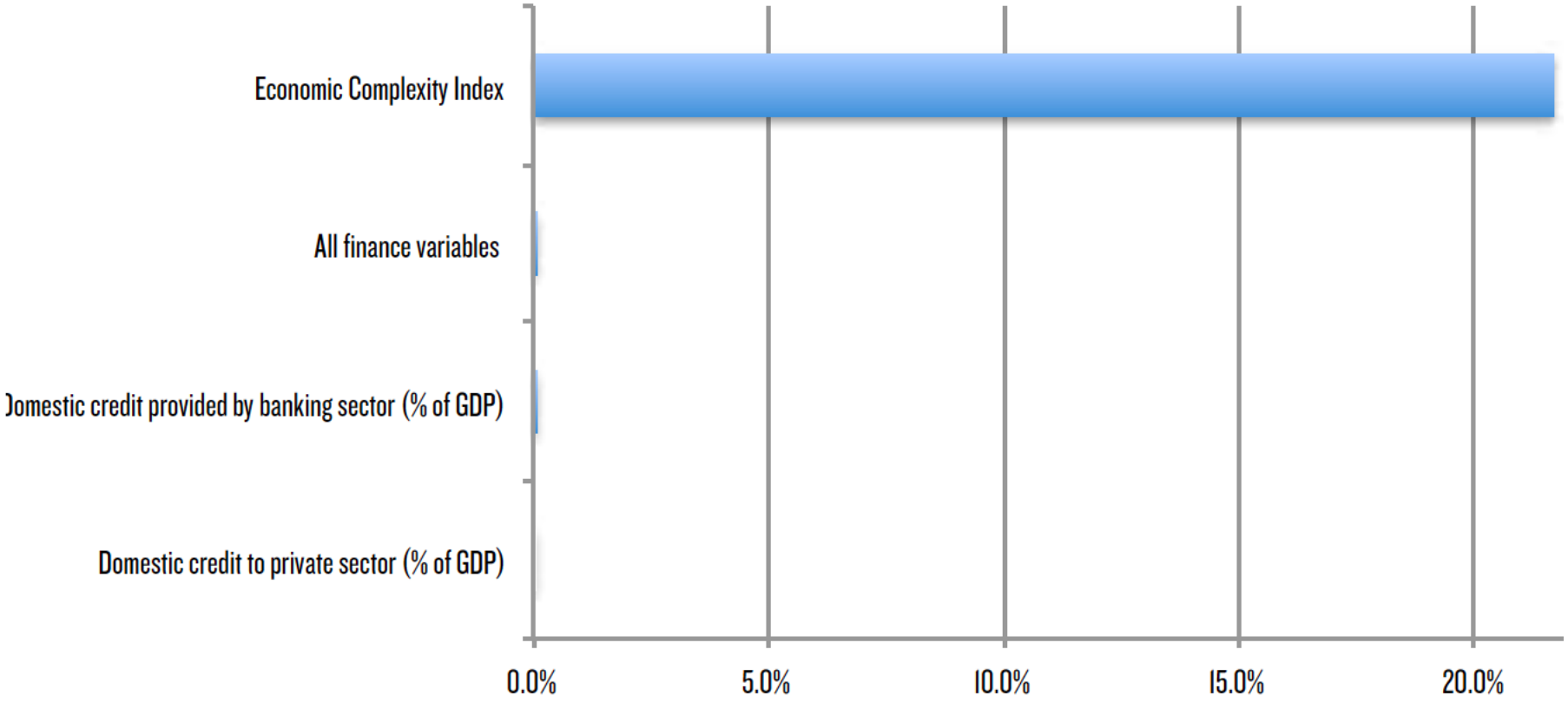
Finance

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

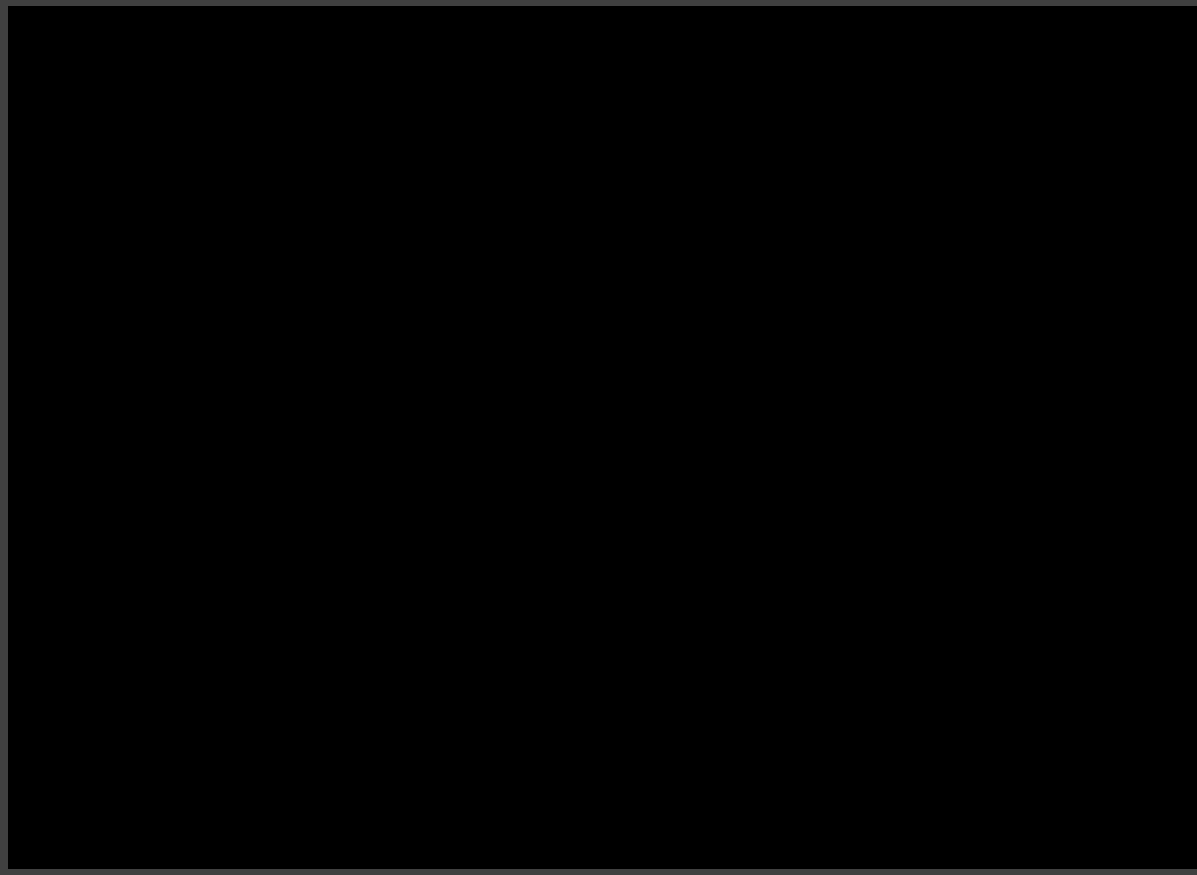
VARIABLES	(1)	(2)	(3)	(4)
Initial GDP per capita, logs	-0.756***	-0.712***	-0.720***	-0.781***
	(0.151)	(0.159)	(0.178)	(0.178)
Increase in real NNRR exports pc	3.927***	3.757***	3.889***	3.728***
	(1.008)	(0.966)	(1.007)	(0.948)
Initial Economic Complexity Index	0.939***	1.091***	0.985***	1.079***
	(0.213)	(0.243)	(0.227)	(0.240)
Initial Opportunity value Index	0.859***	0.831***	0.855***	0.821***
	(0.218)	(0.229)	(0.228)	(0.212)
Initial Domestic credit provided by banking sector (% of GDP)		-0.007**		-0.013**
		(0.003)		(0.005)
Initial Domestic credit to private sector (% of GDP)			-0.003	0.010
			(0.005)	(0.008)
Constant	6.040***	6.058***	5.900***	6.485***
	(1.162)	(1.177)	(1.272)	(1.288)
Observations	273	273	273	273
R-squared	0.474	0.482	0.475	0.485
Year FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

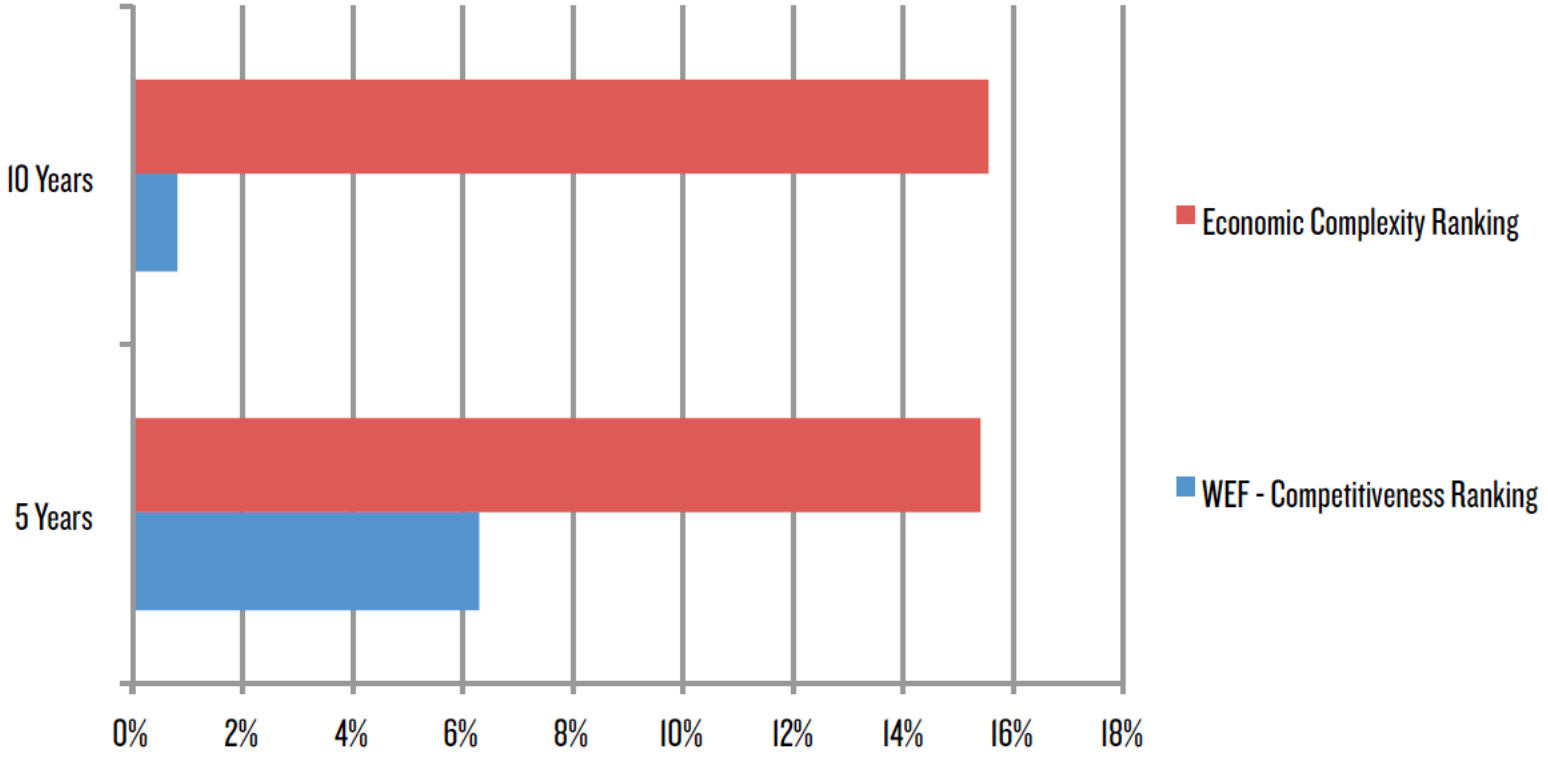
Who can account for growth? Complexity vs. Financial Depth



Competitiveness as the secret of growth

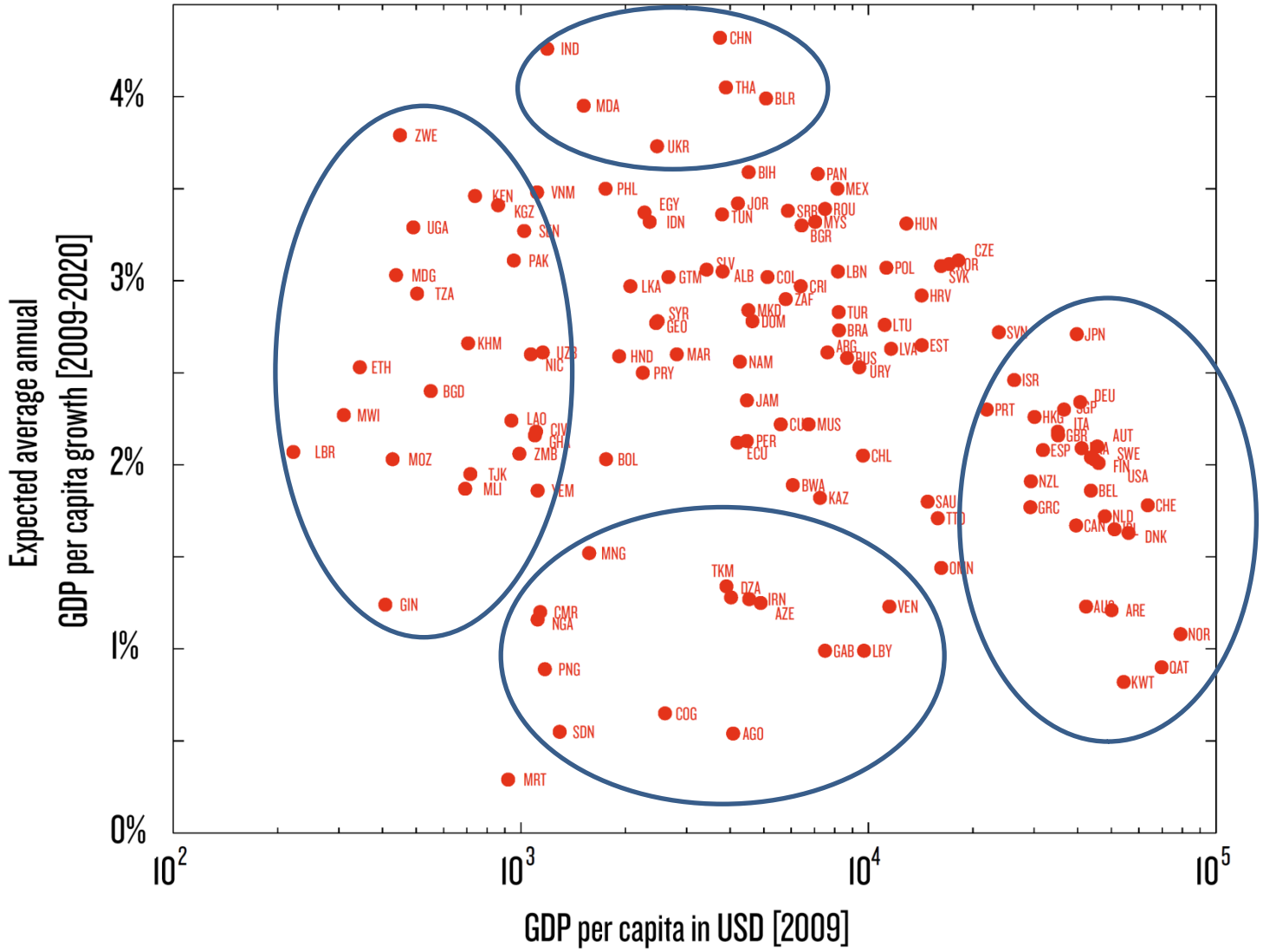


Who can account for growth? Complexity vs WEF-Competitiveness

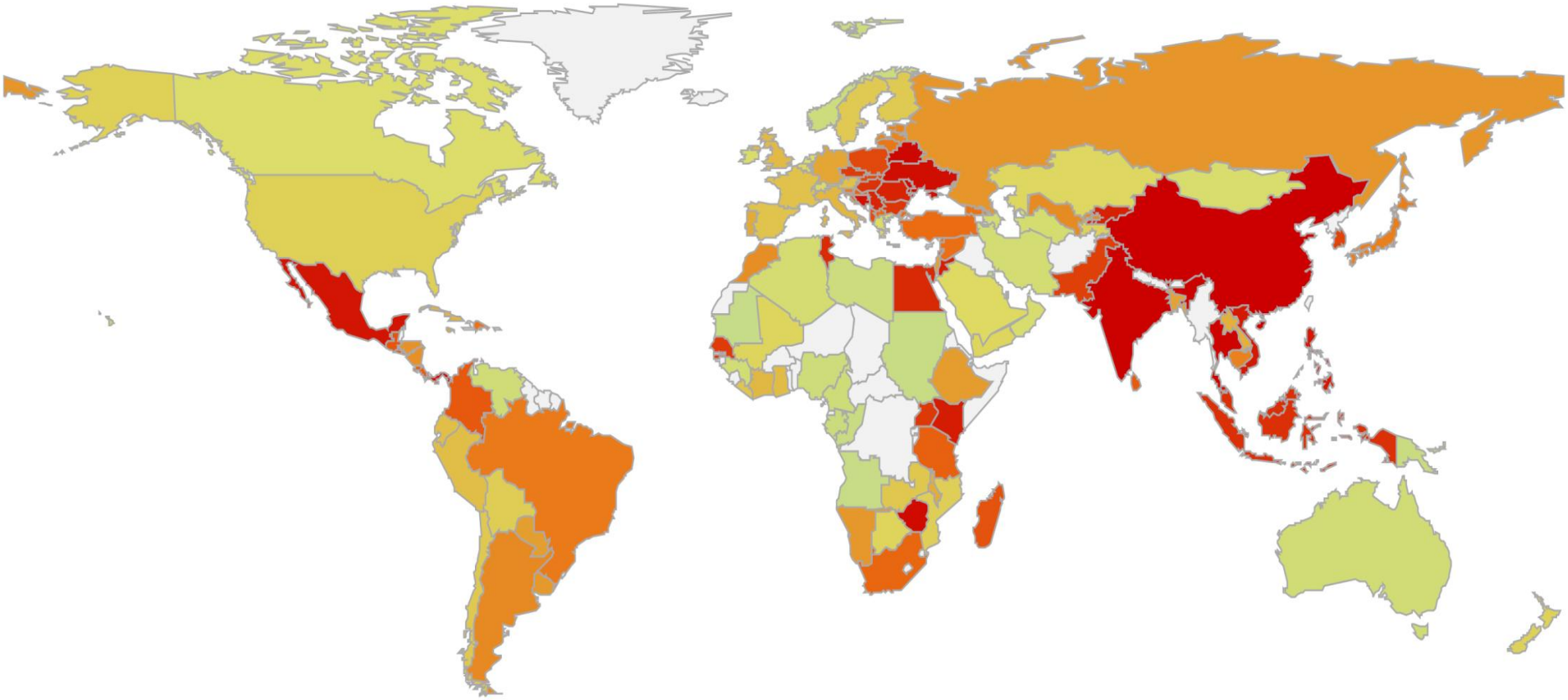


Projections to 2020

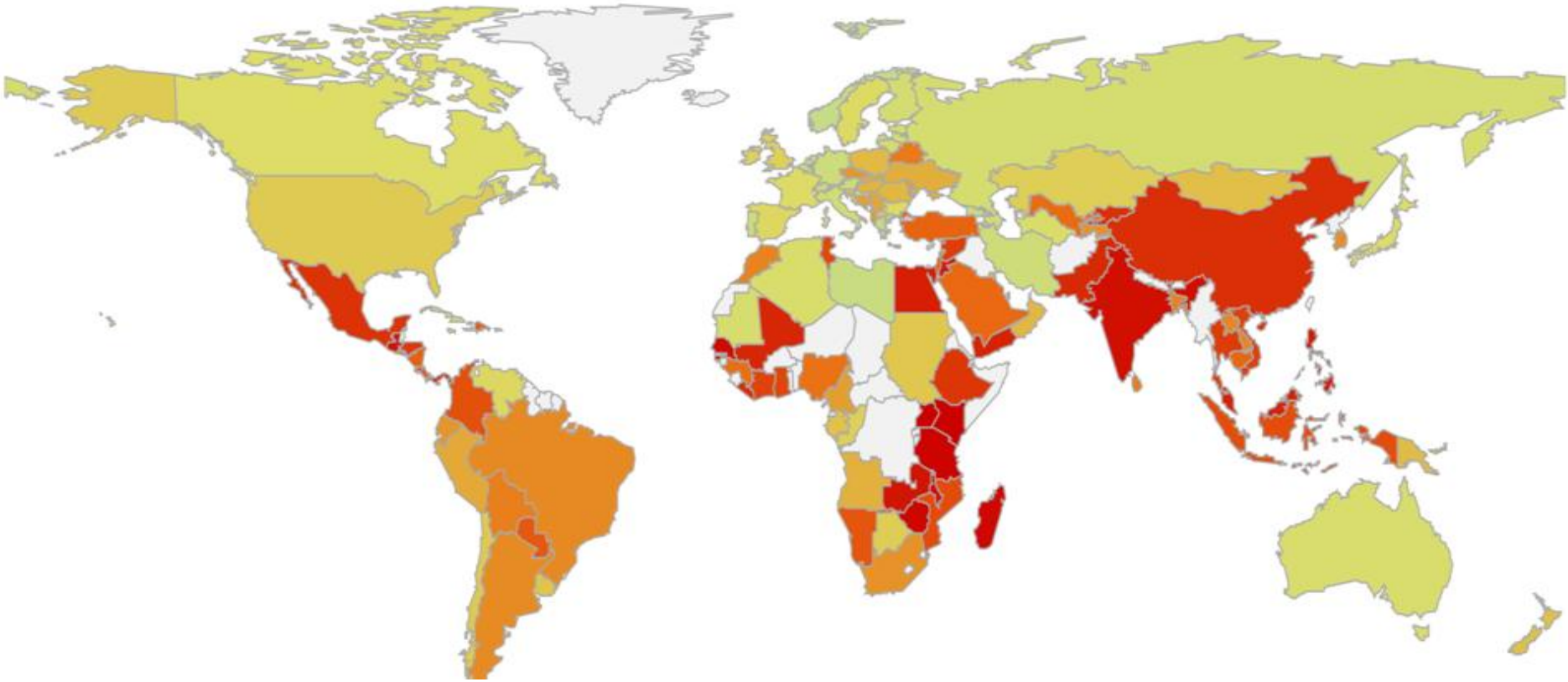
Who will grow? Who will catch up?



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



Who will grow faster?
Total GDP growth to 2020



Why does Nigeria export mainly oil?

Not because it has a lot of it

Country	**Non-hydrocarbon**	**Hydrocarbon**
	Goods exports per capita, USD	
Nigeria	15	433
	Ratio to Nigeria's exports	
Mexico	138.8	0.7
Iran	12.1	1.9
Algeria	3.6	3.3
Venezuela	11.7	4.0
Angola	2.6	5.4
Saudi Arabia	80.1	14.6
Libya	22.6	15.6
Norway	653.0	33.1

Other countries that have more oil have even more non-oil

Country	**Non-hydrocarbon**	**Hydrocarbon**
	Goods exports per capita, USD	
Nigeria	15	433
	Ratio to Nigeria's exports	
Mexico	138.8	0.7
Iran	12.1	1.9
Algeria	3.6	3.3
Venezuela	11.7	4.0
Angola	2.6	5.4
Saudi Arabia	80.1	14.6
Libya	22.6	15.6
Norway	653.0	33.1

Why is Chile so specialized in copper?Exports per capita

	Chile	New Zealand	Australia	Canada	Norway
Mineral Exports	1.0	0.0	1.7	1.5	11.1
Primary exports	1.0	1.6	2.0	2.1	8.6

Why is Chile so specialized in copper?Exports per capita

	Chile	New Zealand	Australia	Canada	Norway
Mineral Exports	1.0	0.0	1.7	1.5	11.1
Primary exports	1.0	1.6	2.0	2.1	8.6
Other goods exports	1.0	3.0	3.3	10.4	11.9
Service exports	1.0	6.6	6.7	6.6	19.9
GDP pc at PPP	1.0	2.0	2.6	2.7	4.2

A set of propositions for discussion

- Low income countries are undiversified
- …because they have few productive capabilities
- …and so they make few simple, low productivity products
- Diversification of capabilities and of industries is made difficult by coordination failures that are particularly severe in low income countries, given the dearth of existing capabilities that can be combined with new ones
- These coordination failures have first order costs and require a policy response
- So diversification is not just a correlate of growth
- More on the policy implications later…