Technology Upgrading in Emerging Economies: A New Approach to its Measurement, Results and Relationship with the Mainstream Measures

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Contributions

- The chapter applies the newly developed approach to technology upgrading to a sample of sixteen economies, the majority of which are emerging economies, in the time-span of 2002-2016.
- Results reveal **new facets of technology upgrading** processes and relative positions of countries which are not discernible through conventional mainstream approaches or composite indicators:
  - Index of technology upgrading is proxy for *long-term growth potential*, and the analysis gives us new insights into differential potentials for emerging economies.
- Furthermore, we have conducted an econometric exercise, which shows that the index of technology upgrading can significantly contribute to the explanation of changes in both total factor productivity and labour productivity.

Literature

- Syverson, 2011 (What determines productivity, JEL):
  - ***But***…Technology is too complex to be reduced to one indicator like total factor productivity (TFP) or labour productivity. Total factor productivity is about any efficiency and not necessarily about technology capability accumulation (Prescott, 1998; J. Felipe, and J.S.L. McCombie 2014).
- Global Innovation Index (https://www.globalinnovationindex.org/Home):
  - ***However***, these metrics are neither theoretically nor empirically grounded in the specific nature of technological capabilities of the emerging economies as they have to cover the entire spectrum of countries that form the global economy.
- The sole use of direct indicators like patents is of limited value for emerging economies whose technology activities are mainly taking place behind the technology frontier (Acemoglu, Aghion and Zilibotti 2006).

Literature: following Radosevic and Yoruk 2016, 2018

- We explore the dynamics and morphology of technological upgrading in sixteen economies, the majority of which are emerging economies.
- In other words we explore how *Technology Upgrading* framework stands in between aggregate theories of economic growth and micro/mezzo accounts and represents new metrics suitable for emerging economies catching up to the technology frontier.
- Technology upgrading is a multidimensional process (36 indicators overall) based on a broader understanding of innovation, which includes not only R&D, but also technology generation capabilities, production (manufacturing) capabilities (Bell and Pavitt, 1993), etc..

Motivating technology upgrading

- Need for theory and metrics of technology upgrading emphasizing challenges of MICs (Radosevic/Yoruk, 2016)

I. Technology is an important growth factor. It cannot be reduced to one variable such as R&D or TFP.

II. Current metrics are not underpinned by an understanding how technology upgrading takes place at different income levels.

III. Metrics based on growth processes in high income countries may lead to irrelevant policies in MICs (and hence policy for tackling Middle income trap).

TOWARDS THEORY OF TECHNOLOGY UPGRADING

- A key to economic growth is in improved technology capability, which cannot be reduced to a single variable (Lee, 2012) > a number of drivers.
- A multidimensional process = technology, structural change, interaction with global economy…
- Based on broader understanding of innovation, which goes well beyond R&D.
- A multi-level process = micro, mezzo and macro grounded
- At its core is structural change in various dimensions: technological, industrial, organisational.
- It is also an outcome of interaction between global forces (embodied in international trade and investment flows) and local strategies (pursued by host country firms and governments)

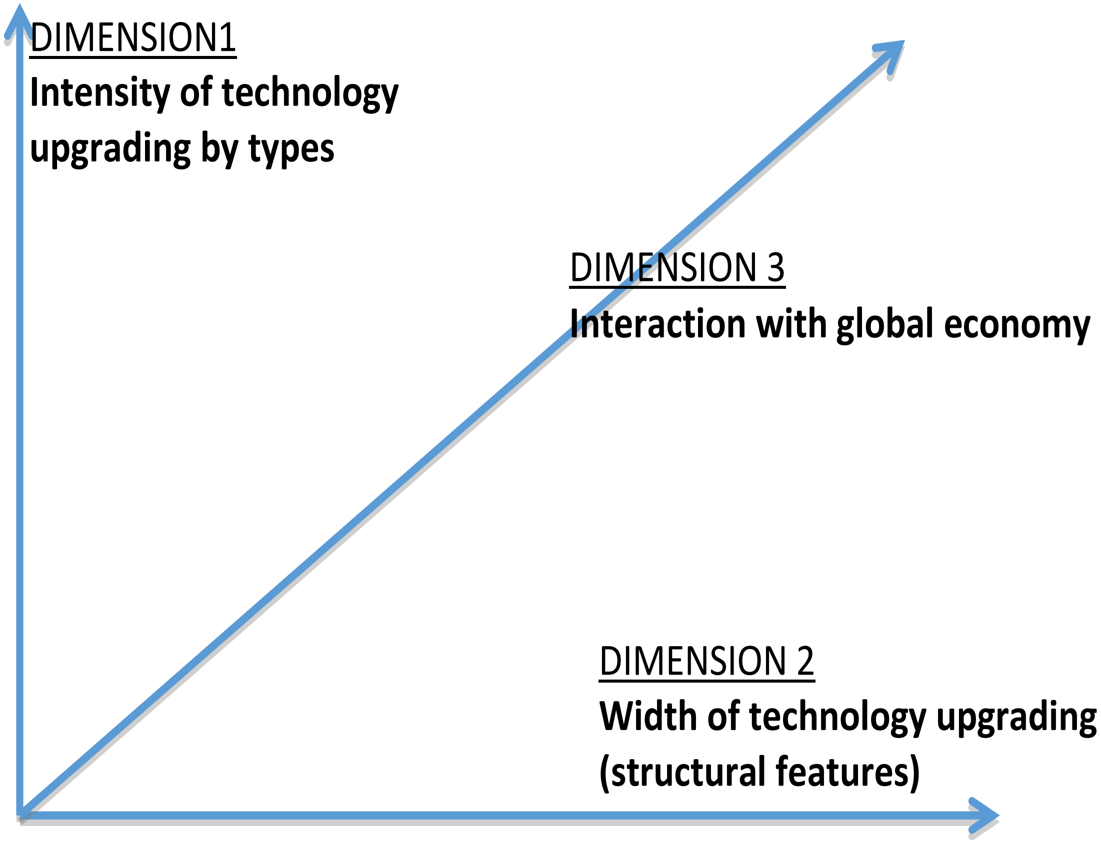
Dimensions of technology upgrading

Intensity of technology upgrading by types	• Production capability • Technology capability • R&D and knowledge intensity
Interaction with global economy	• Technology imports • Knowledge imports • Knowledge cooperation
Breadth of technology upgrading	• Infrastructure (human, physical, organizational) • Structural change • Firms' structure

Breadth of technology upgrading: a Focus

Infrastructure: human capital and physical	• Average years of schooling • *Quality of math and science education* • *Availability of research and training services* • *Availability of S&E* • Fixed broadband Internet subscriptions • Gross fixed investments in GDP
Structural changes	• Technology diversification: changes in patenting structure (WIPO, EPO, USPTO) • *Buyer sophistication: levels and changes* • *Availability of the latest technologies: levels and changes*
Firm capabilities	• Number of firms in Forbes2000 • *Firm level technology absoprtion*

Dimensions of technology upgrading



Dimensions of technology upgrading

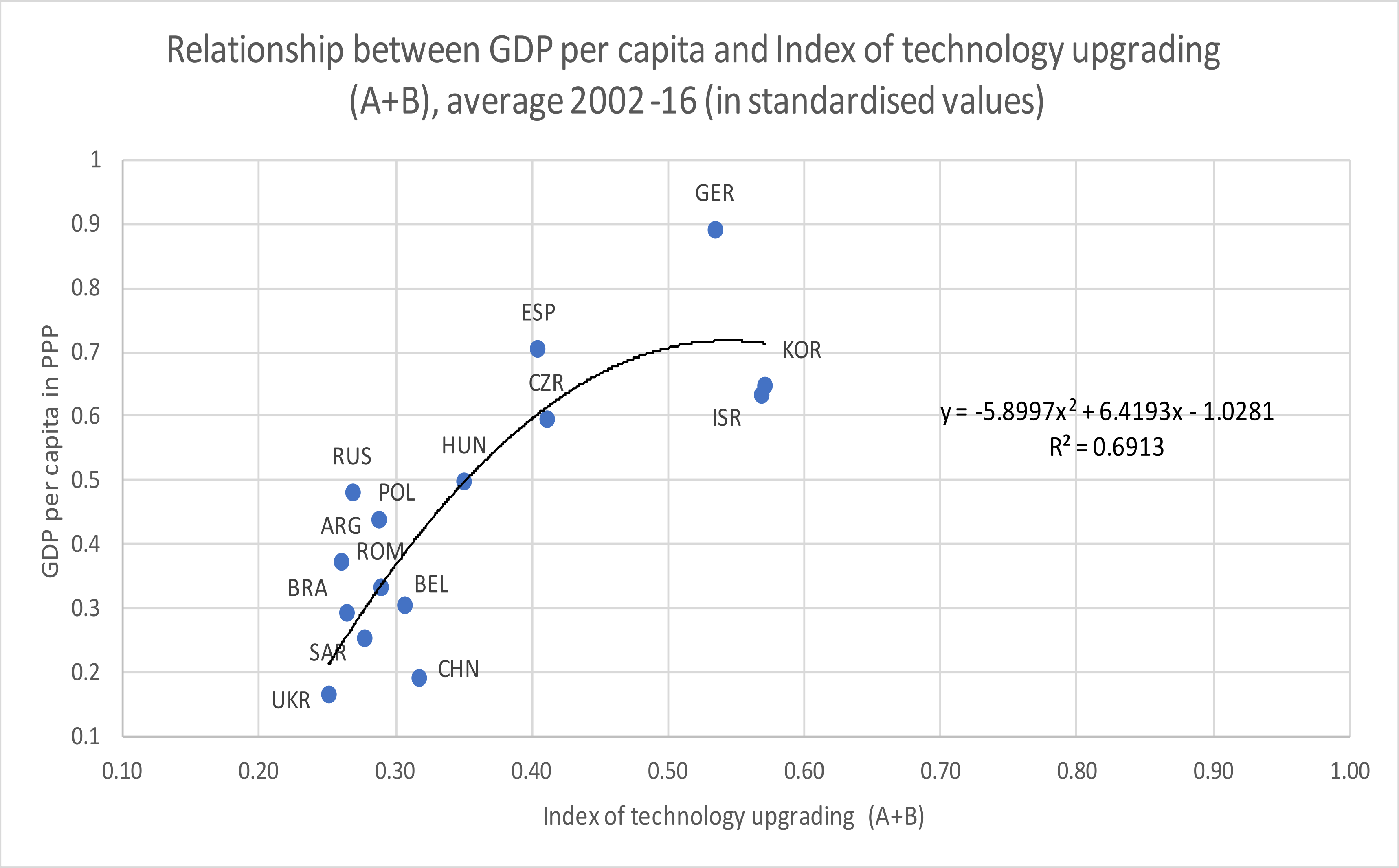
Index A: Technology Intensity (scale)
Production Capabilities
R&D Capabilities
Technology Capabilities
Index B: Structural Features (scope/breadth)
Infrastructure (IT, human, physical, organisational)
Knowledge diversification and changes of supply and demand for technology
Organisational capabilities
Index C: Interactions with the Global Economy
Technology and knowledge exchange

Sample

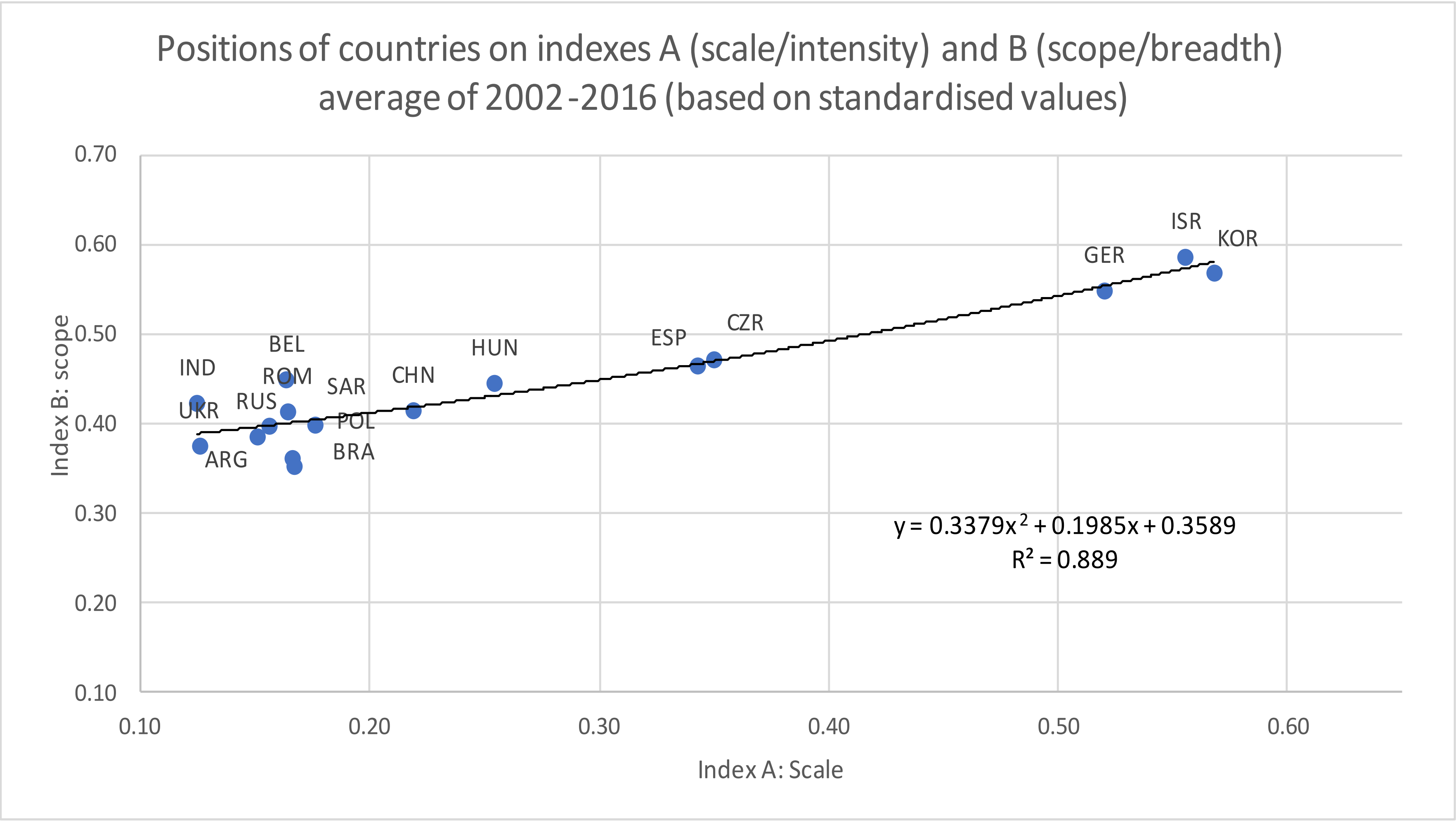
We aim to explore the diversity of technology upgrading paths rather than generate the representative sample of broadly defined middle-income economies. For that purpose, we have selected the following groups of countries:

1. China, India, and South Africa due to their global importance
2. Central and East European economies (Poland, Czech Republic, Hungary, Romania, Russia, Ukraine, and Belarus). – as two different models of growth – foreign led vs. domestic led modernisation.
3. Comparisons of Eastern Europe with Latin America - two resource-based economies (Brazil, Argentina)
4. South Korea as a paragon of catching up, i.e. model case for the emerging economies. Israel – a contemporary model of high tech upgrading, although its productivity levels show that high tech does not automatically lead to high productivity in the overall economy. Germany is taken as a developed country and is a relevant reference for CEE but also for China. Spain, EU South economy is an example of a successful 'intermediate economy' (Molero, 1995) caught in the middle-income trap in between technology and cost drivers of growth.

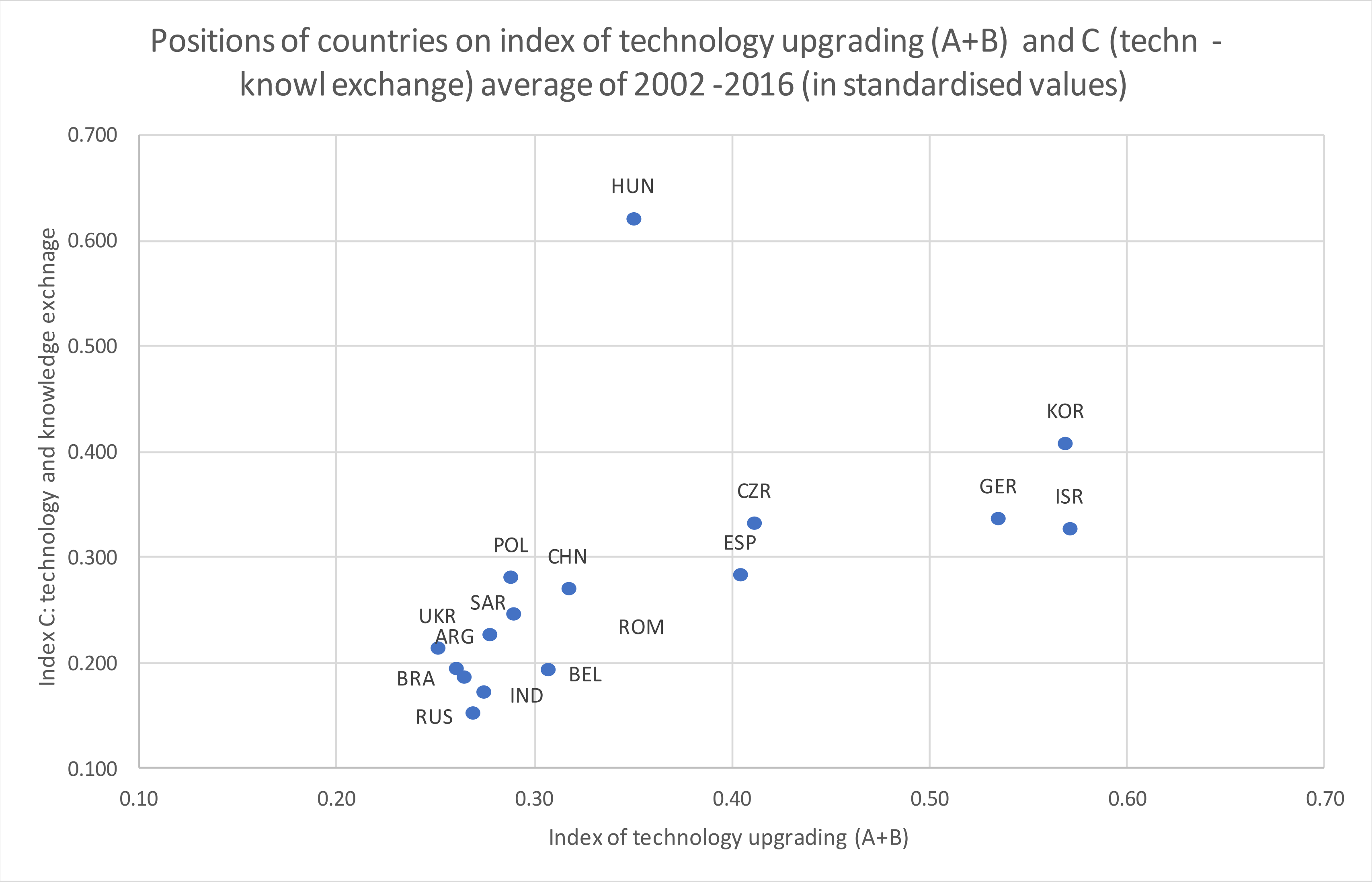
Technology Upgrade and GDP per capita



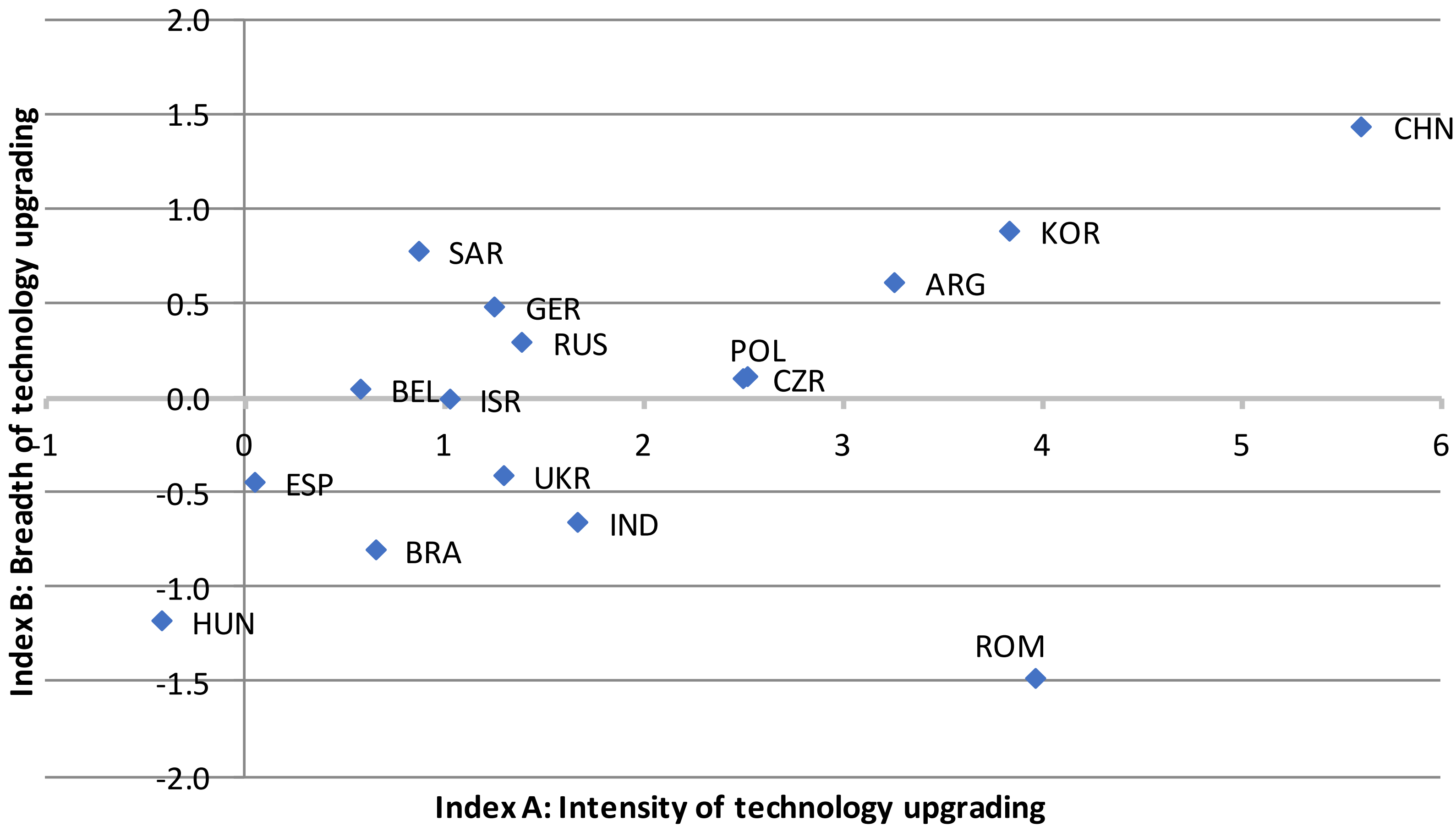
Technology Upgrade decomposed



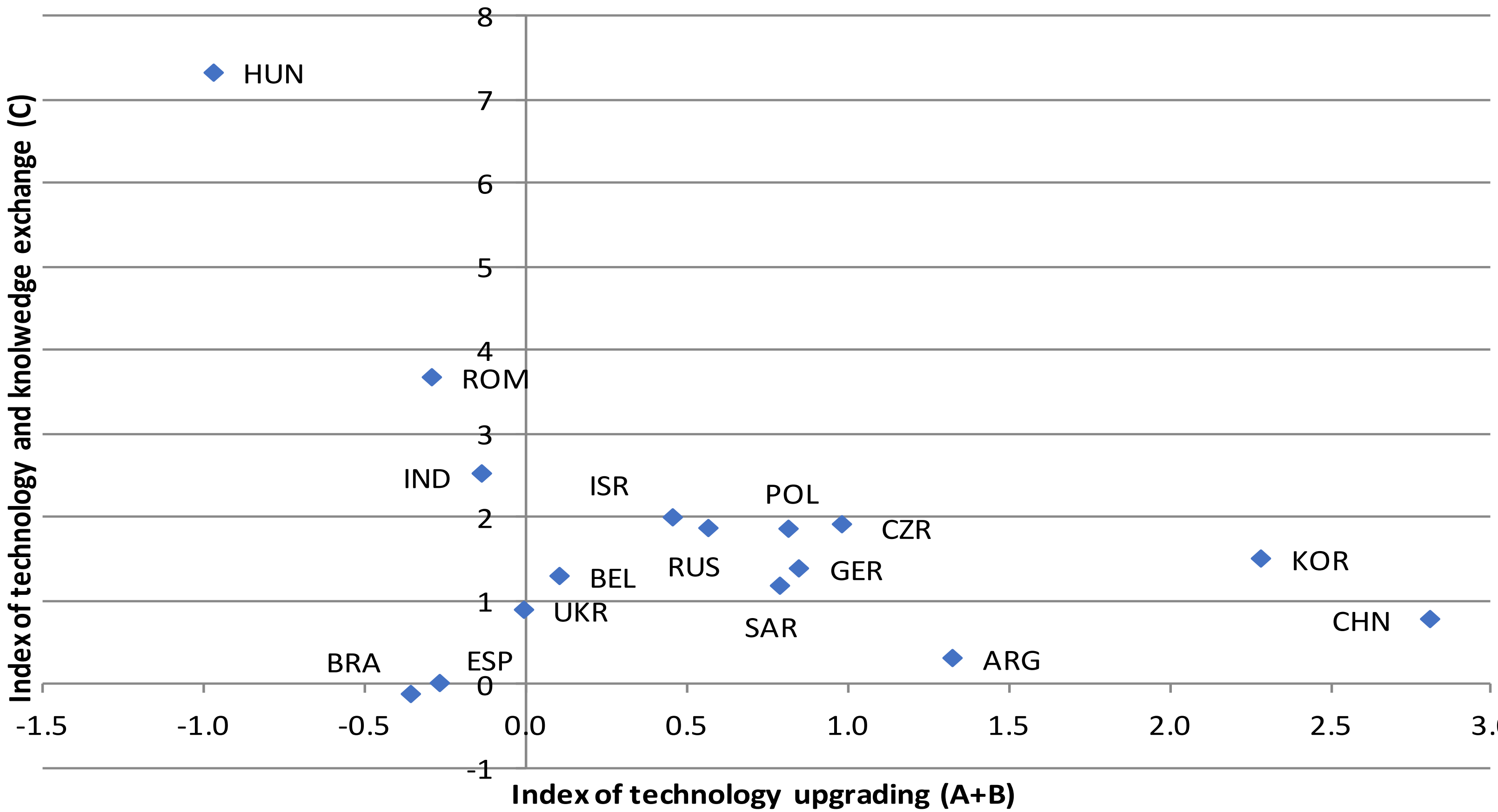
Technology Upgrade and Knowledge exchange

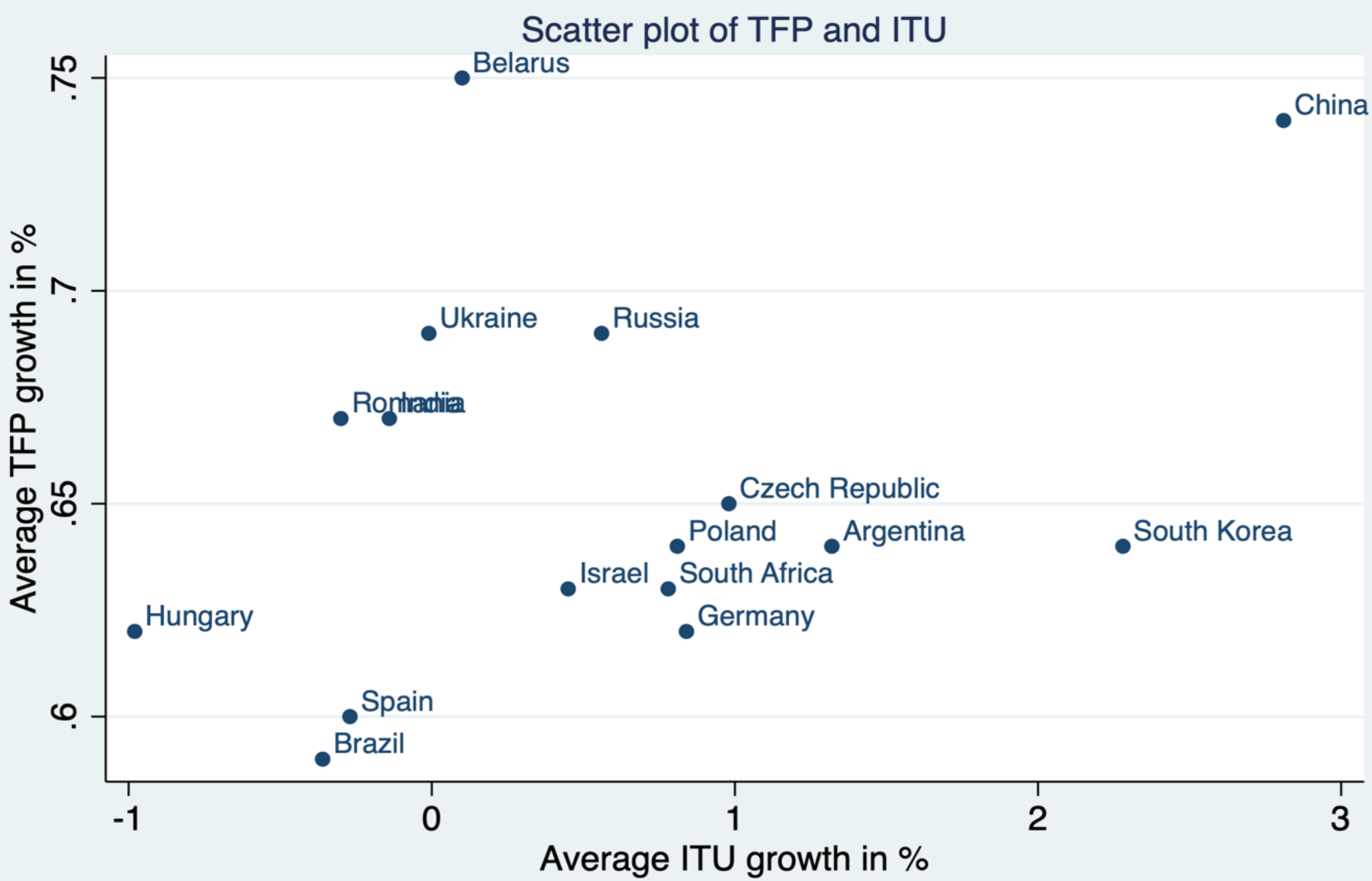


Relationship between average rates of growth of intensity (A) and breadth (B) of technology upgrading, 2002 -2016

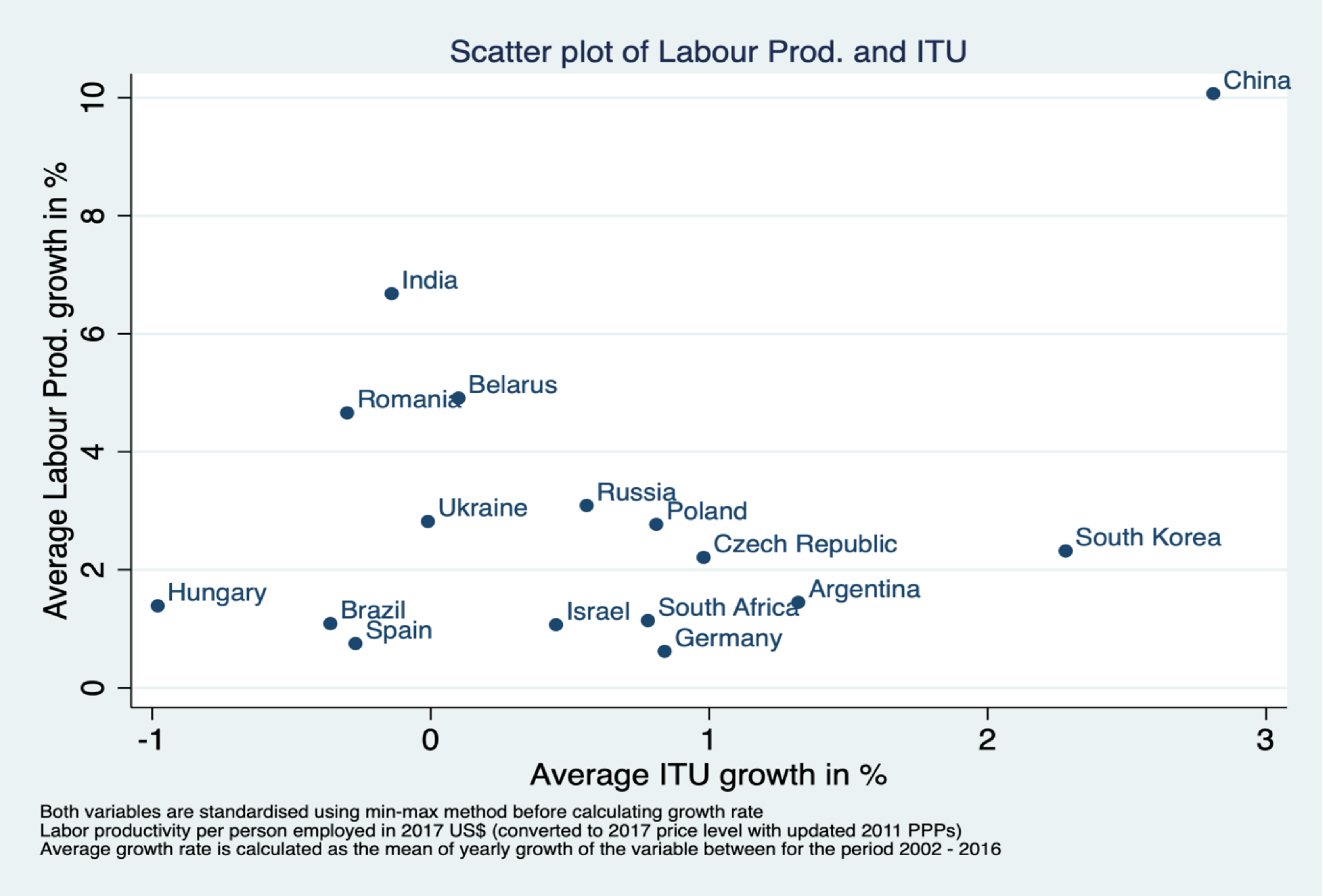


Relationship between average rates of growth of index of technology upgrading (A+B) and index of technology and knowledge exchange (C), 2002-2016

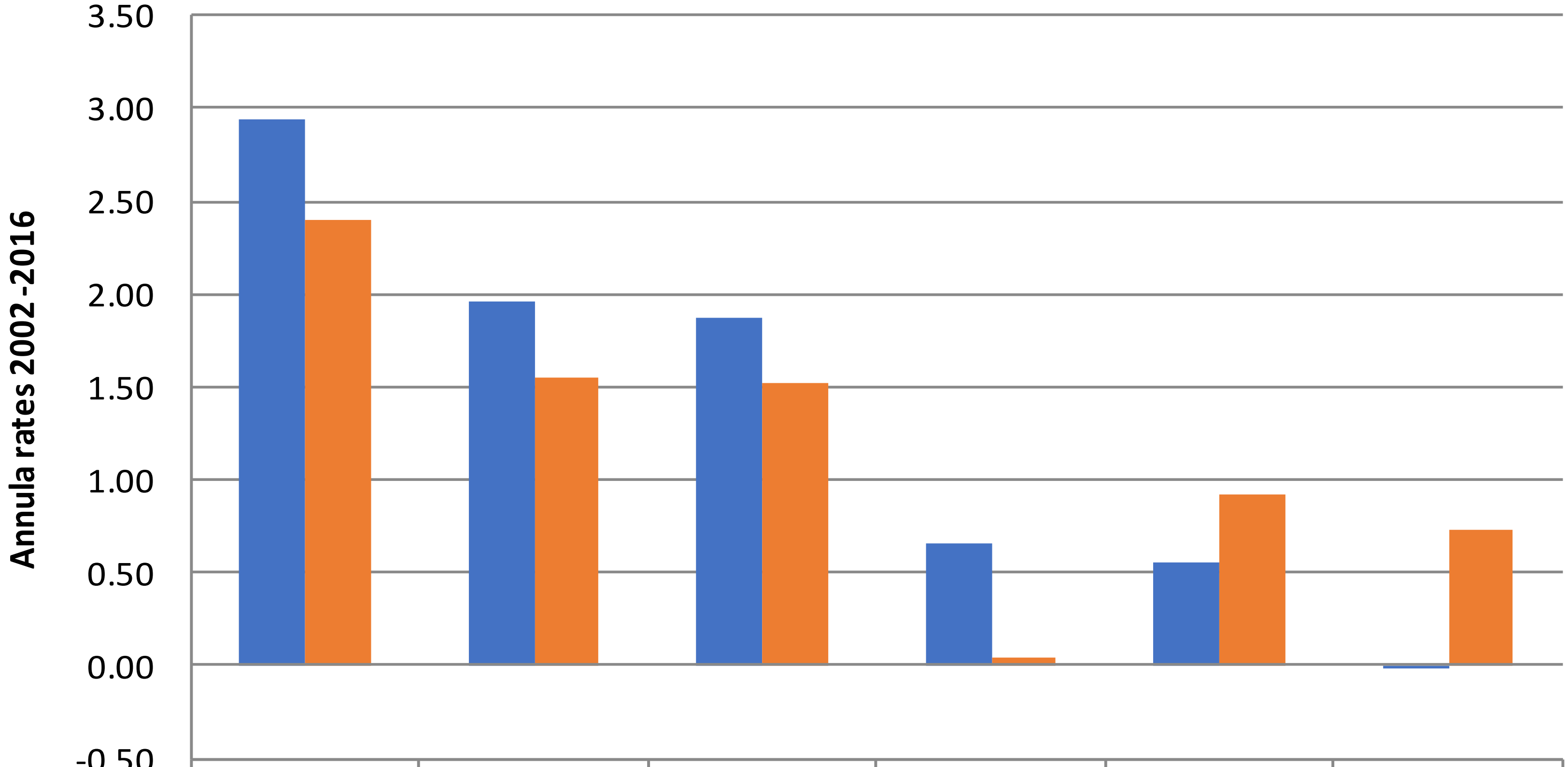




Both variables are standardised using min-max method before calculating growth rate
TFP is calculated as the residual of GDP growth minus the input contributions
Average growth rate is calculated as the mean of yearly growth of the variable between for the period 2002 - 2016


Scatter plot of Labour Prod. and ITU
Average Labour Prod. growth in %
0
2
4
6
8
10
-1
0
1
2
3
Average ITU growth in %
China
India
Belarus
Romania
Russia
Ukraine
Poland
Czech Republic
South Korea
Hungary
Argentina
Brazil
Israel
South Africa
Spain
Germany
Both variables are standardised using min-max method before calculating growth rate
Labor productivity per person employed in 2017 US$ (converted to 2017 price level with updated 2011 PPPs)
Average growth rate is calculated as the mean of yearly growth of the variable between for the period 2002 - 2016

Average annual changes in 2002-2016 period



	Lab Prod Growth in %	Growth of index C	Growth of index A	TFP Growth in %	Growth of ITU	Growth of index B
average	2.94	1.96	1.87	0.65	0.55	-0.01
StDev	2.40	1.55	1.52	0.04	0.93	0.73

A decomposition of the Cobb-Douglas: TFP and Labour Productivity

- $VA = AK^{\alpha}L^{1-\alpha}$
- We consider the ***A*** component, commonly referred to as "Total Factor Productivity", as being a function of three components of technology upgrading. These are Index A (intensity or scale), Index B (scope or breadth) and Index C (Knowledge and technology interaction with the global Economy or "Technology Exchange" for short). So we can write:
- $A = f(I_a, I_b, I_c)$
- $VA = \bar{A}\, I_a^{\alpha}\, I_b^{\beta}\, I_c^{\gamma}\, K^{\delta}\, L^{(1-\alpha-\beta-\gamma-\delta)}$
- We then log-linearize the equation and re-arrange:
- $logVA = log\bar{A} + \alpha log(I_a) + \beta log(I_b) + \gamma log(I_c) + \delta log(K) + (1-\alpha-\beta-\gamma-\delta)log(L)$
- $logVA - \delta log(K) - (1-\alpha-\beta-\gamma-\delta)log(L) = log\bar{A} + \alpha log(I_a) + \beta log(I_b) + \gamma log(I_c)$
- $logA = logTFP = logVA - \delta log(K) - (1-\alpha-\beta-\gamma-\delta)log(L)$
- estimable equation directly:
- $logTFP = log\bar{A} + \alpha log(I_a) + \beta log(I_b) + \gamma log(I_c) + \epsilon$
- Taking deltas and including fully-fledged country and time fixed effects in order to take into account unobserved heterogeneity and common macro-shocks, we then estimate the following equation with a clustered standard error at the level of the country:
- $\Delta logTFP_{it} = \widehat{\alpha}\Delta log(I_a)_{it} + \widehat{\beta}\Delta log(I_b)_{it} + \widehat{\gamma}\Delta log(I_c)_{it} + D_i + D_t + \Delta\epsilon$

- $VA = AK^{\alpha}L^{1-\alpha}$
- $\frac{VA}{L} = \frac{AK^{\alpha}L^{1-\alpha}}{L} = \frac{AK^{\alpha}}{L^{\alpha}} = A\left(\frac{K}{L}\right)^{\alpha}$
- We can write the labour productivity as a function of A and Capital-Labour ratio
- $Labour_{Productivity} = A(Capital\_Labour\_Ratio)^{\alpha}$
- $log\left(\frac{VA}{L}\right) = logA + \alpha log\left(\frac{K}{L}\right)$
- When A is a function of I_A I_B I_C, we can re-write:
- $log\left(\frac{VA}{L}\right) = log(I_A I_B I_C) + \alpha log\left(\frac{K}{L}\right) = logI_A + logI_B + logI_C + \alpha log\left(\frac{K}{L}\right)$
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- $\Delta log\left(\frac{VA}{L}\right)_{it} = \Delta logI_{A_{it}} + \Delta logI_{B_{it}} + \Delta logI_{C_{it}} + \alpha\Delta log\left(\frac{K}{L}\right)_{it} + D_i + D_t + \Delta\epsilon_{it}$

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- When A is a function of I_A I_B I_C, we can re-write:
- $log\left(\frac{VA}{L}\right) = log(I_A I_B I_C) + \alpha log\left(\frac{K}{L}\right) \quad = logI_A + logI_B + logI_C + \alpha log\left(\frac{K}{L}\right)$
- Taking deltas and including fully-fledged country and time fixed effects in order to account for unobserved heterogeneity and common macro-shocks, we then estimate the following equation with clustered standard errors at the level of the country:
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Total Factor Productivity and Labour Productivity

Dependent Growth TFP	Index A	Index B	Index C	Full Model
Growth TU Intensity	4.205*			3.089
	(2.315)			(2.626)
Growth TU Scope		5.174*		4.13
		(2.792)		(3.169)
Growth Tech Exchange			-0.703	0.329
			(1.169)	(1.389)
Year Dummies	Y***	Y***	Y***	Y***
Constant	2.895***	3.169***	2.917***	3.102***
	(0.642)	(0.752)	(0.654)	(0.752)
Observations	224	224	224	224
Number of id	16	16	16	16
Adjusted R-squared	0.386	0.388	0.374	0.388

Dependent Variable Growth Labour Productivity	Index A	Index B	Index C	Horse Race
Growth TU Intensity	3.155			1.062
	(2.726)			(2.975)
Growth TU Scope		7.984**		7.565**
		(3.209)		(3.176)
Growth Tech Exchange			-1.722	-0.168
			(1.54)	(1.757)
Year Dummies	Y***	Y***	Y***	Y***
Constant	4.208***	4.616***	4.233***	4.592***
	(0.63)	(0.754)	(0.634)	(0.758)
Observations	224	224	224	224
Number of id	16	16	16	16
Adjusted R-squared	0.368	0.392	0.363	0.386

A focus on TFP

	Index 1	Index 2	Index 3	I1 I2 I3	Index 4	Index 5	Index 6	I4 I5 I6	I1 to I6
Growth of Prod. Cap.	2.610**			2.458**					2.566**
	(1.096)			(1.097)					(1.007)
Growth of Tech. Cap.		1.03		0.576					0.703
		(1.076)		(1.139)					(1.348)
Growth of R&D			2.619	2.121					3.042
			(3.479)	(3.397)					(3.506)
Growth of Infrastructure					2.42			2.278	-1.876
					(3.255)			(3.437)	(3.865)
Growth of Str. Change						1.952		2.006	2.009
						(1.374)		(1.354)	(1.251)
Growth of Firm-Cap.							0.647	0.458	0.535
							(0.885)	(0.993)	(1.226)
Year Dummies	Y***	Y***	Y***	Y***	Y***	Y***	Y***	Y***	Y***
Constant	2.975***	2.800***	2.886***	2.888***	2.955***	3.039***	2.943***	3.104***	2.990***
	(0.687)	(0.624)	(0.641)	(0.636)	(0.675)	(0.698)	(0.652)	(0.739)	(0.702)
Observations	224	224	224	224	224	224	224	224	224
Number of id	16	16	16	16	16	16	16	16	16
Adjusted R-squared	0.396	0.377	0.377	0.393	0.376	0.383	0.375	0.381	0.395

Regressions Results

- The **Index of Technology Upgrading** ITU (A+B) explains *both* the growth of TFP and growth Labour Productivity.
- The **index of technology and knowledge exchange** (Index C) is *never* a critical explanatory element of the growth of neither TFP nor the growth of Labour Productivity. As argued earlier, Index C measures the scale and intensity of knowledge and technology exchange but not the absorption of imported knowledge and technology. For example, if imported knowledge is not absorbed or is not complemented by its technology efforts, there will be no improvements in the overall efficiency of the economy.
- The patterns of the TFP / Labour Productivity growth – Technology upgrading nexus are indeed different as far as the subcomponents are concerned:
  - TFP growth is mainly explained by index A (scale/intensity/depth) of technology upgrading and in particular by production capability (Index 1). Intuitively this seems plausible as production capability refers to capabilities to work efficiently on a given technology through improved non-physical and non-technological investments like better management practices, quality improvements and better organisation.
  - Labour Productivity appears to be driven by Index B (breadth/scope) of technology upgrading. In particular, broadly defined structural change (index 5) and firm organisational capabilities (index 6) play a key role in explaining improved productivity. This would suggest that the labour productivity is driven by diversification to more productive technology intensive activities, improved demand for and supply of technology as well as by internationalisation of domestic firms and by the growth of their organisational capabilities.

Conclusions I

- Index of technology upgrading and its two components (scale and scope) correlate well with the income levels of economies but not with an index of technology exchange.
- Countries have followed their own paths of technology upgrading on different sub-components of technology upgrading.
- Korea and China are the only economies which have improved on all three sub-components of the breadth of technology upgrading while Brazil is the only economy that has fallen behind on all three sub-components.
- In between two extreme (Korea and Brazil) we find a variety of country specific patters of technology upgrading.

Conclusions II

- Our econometric exercise demonstrates that
  - the index of Technology Upgrading can significantly contribute to the explanation of changes in both TFP and LP.
  - Index of technology exchange (C) is a component if TU but does not form the index as it operates as moderating variable ->substitute or complement of TU
  - Index C does not have explanatory power, which suggests that openness towards technology exchange by itself will not contribute to increased TFP and labour productivity unless complemented by own technology accumulation activities.

Policy implications

- First, need to go beyond R&D driven growth and broaden the scope of innovation policy to include production (manufacturing) capabilities into policy thinking and framework.
- Second, technology upgrading is inextricably linked to structural transformation by broadening its scope (breadth).
  - Coordination failures in this area are far more pervasive and coordination successes more difficult to achieve than in the case of investments in R&D, production and technology generation capabilities

Policy implications 2

- Third, only technology exchange is not enough for technology upgrading unless complemented with technology capability building.
- Technology upgrading requires coordination across many institutional and policy spaces, and in the context of the global value chain globalisation seems quite challenging to achieve.
- ***Fourth, coordination among the three components of technology upgrading is essential.*** This requires systemic policies which cut across conventional policy areas.
- Limitations. First, the choice of indicators that form the background of analysis is never a satisfactory activity. Second, our analysis would also benefit from longer time series as well as from a larger sample of countries.

THANK YOU