Technological upgrading through the prism of shifting firm-level innovation strategies

Vitaliy Roud, HSE

NATIONAL RESEARCH UNIVERSITY

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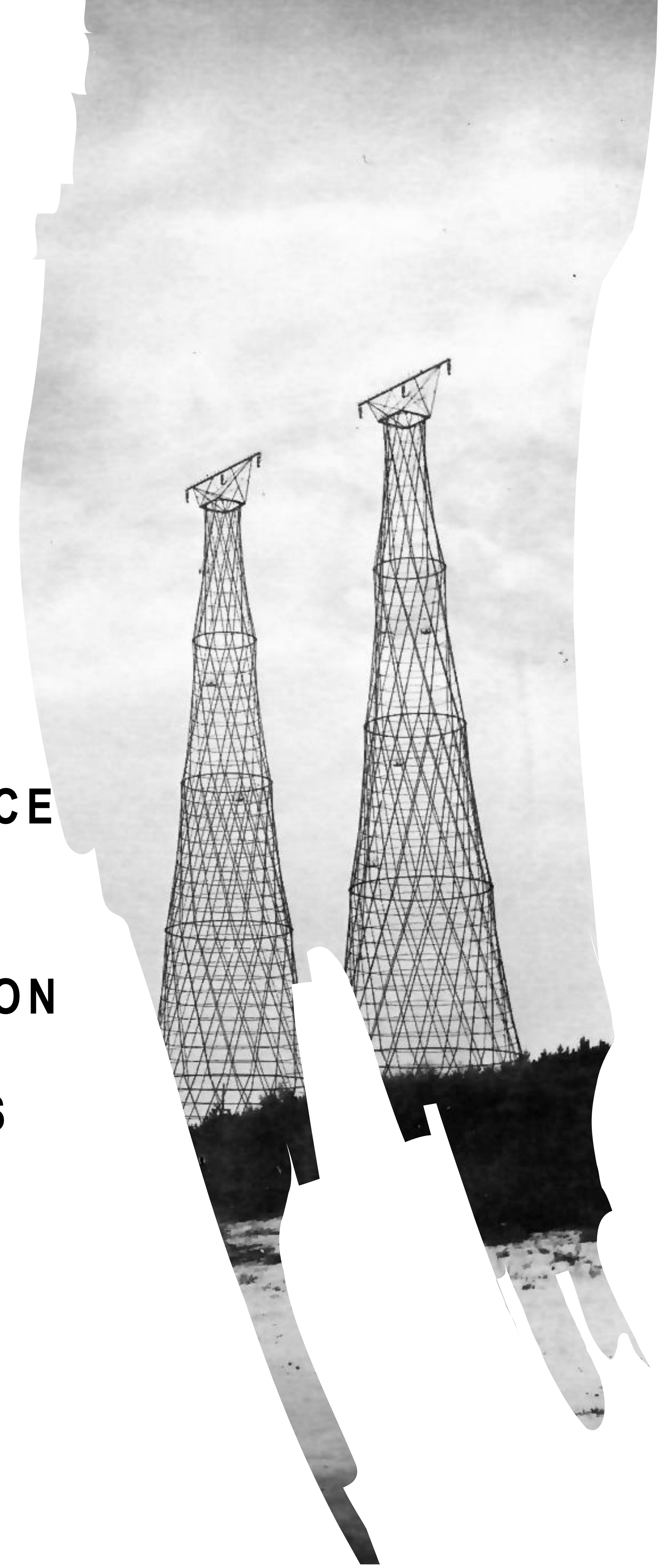
Outline

TECHNOLOGICAL UPGRADING
DISCOURSE AND DEMAND FOR NEW INDICATORS

INNOVATION SURVEYS: UNDERRATED SOURCE OF DATA FOR TU STUDIES

PROBLEM-ORIENTED FIRM-LEVEL INNOVATION TAXONOMES: A POWERFUL TOOLS FOR UNDERSTANDING HETEROGENEOUS ACTORS

THINKING ABOUT UPGRADING AS A SHIFT TOWARDS ADVANCED MODES
(AT MACRO-, SECTORAL or FIRM LEVEL): OPPORTUNITIES AND LIMITATIONS



Technological upgrading discourse

- **A definition:** Moving towards more profitable and technologically sophisticated niches via accumulation of technological capabilities (Radosevic & Yoruk, 2016)

- Often equalized to promotion within global value chains

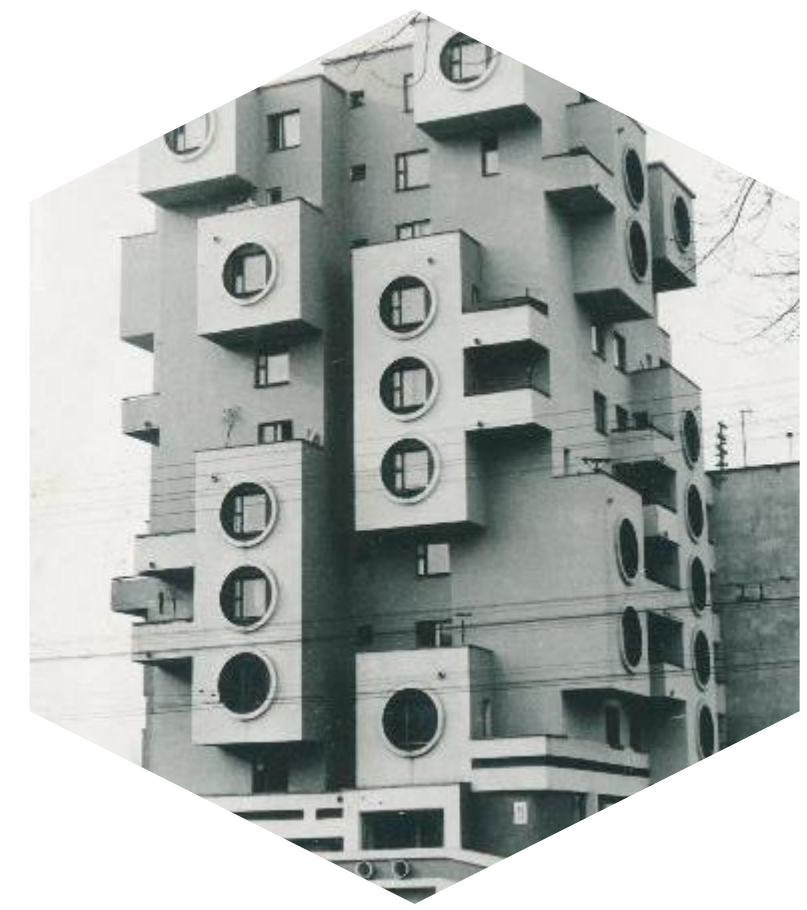
- Retrospective analysis of evolving technologies often presents a unified country-level pathway as a gradual advance of industries in a certain sequence based (Rostow, 1960, von Tunzelmann, 1995)

- This progress cannot be reduced to a single variable like intensity of R&D or productivity (Lee, 2012)

Common measures for Technological Upgrading

Dominance of macro indicators, focus on rigid classifications

(e.g. high-tech goods and services)



Refined residuals of growth: Total Factor Productivity Gaps

Econometrics models to capture total factor productivity coefficients based on long-term macro trends

Ability to produce high-tech: Input-output measures and structure of international trade

International Trade Statistics (UN) and list-based definitions of high-tech products and services

GVCs: Value-added content in final goods or exports

National statistics on country's value added structure

Structural composition: Technological complexity of economy

Indexes and models based on national statistics on GDP, imports, exports.

Recent studies: TU cases from different economic and sectoral contexts

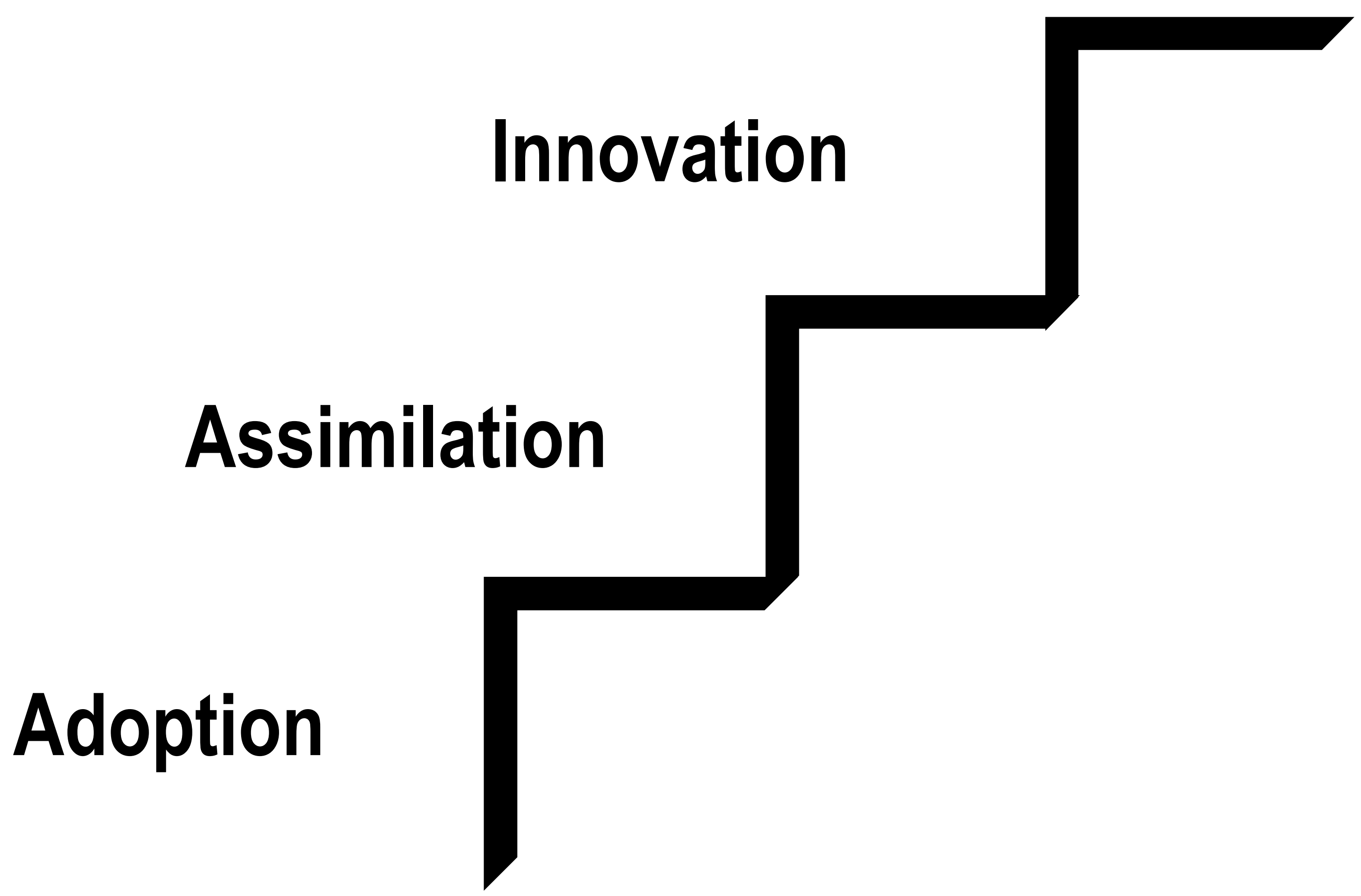
- No unified pathway. Highly diversified given economic and institutional contexts, as well as proximity to the World's technological frontier (Lee, 2013)
- Architecture of trajectories should be different for emerging and middle-income countries (Radosevic and Yoruk, 2016; Vivarelli, 2016 etc.)
- Structural change per se seems not to be associated with growth; intramural transformation within sectors is more influential (Sandven et al, 2005)
- Global knowledge is crucial, however it is not equalized with GVC upgrading. Global knowledge chains should be considered. (Yoruk, 2013)
- Convergence between the technology upgrading discourse and the 'innovation imperative' (OECD, 2015)

Implications:

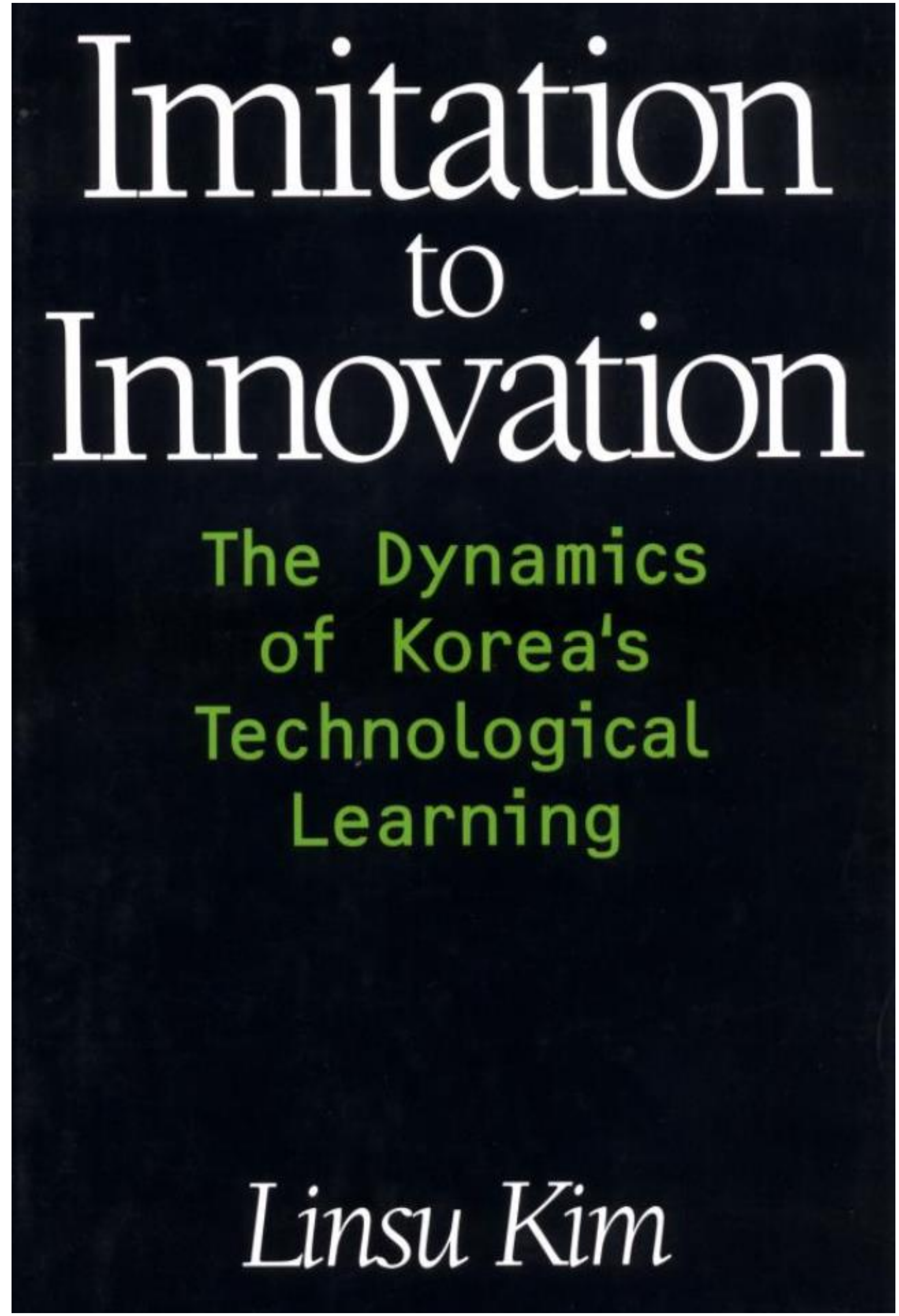
A. Capabilities to develop innovations are acknowledged to be the most landmark characteristics of the systems under consideration

B. There is a shortage of TU metrics that take into account these characteristics

Formula of TU through the development of innovation capabilities



Kim L. (1980): Stages of development of industrial technology in a less developed country: a model // Research Policy 9(3): 254-277



What can innovation measurement offer to operationalization of innovation capabilities

- Oslo Manual framework (latest: 4ed, 2018) and the Community Innovation Surveys (and harmonized excercises around the globe; 83 countries, as reported by OECD)
- Innovation: product and business process
- **Novelty of Innovation:**
  - New to a Firm or significantly improved
  - New to a Market
  - New to the World
- **Innovation activities**

Research and experimental development (R&D)
Design, engineering and other creative work
Marketing and brand equity activities
Intellectual property (IP) related activities
Employee training
Software development and database activities
Investment in tangible assets
Innovation management

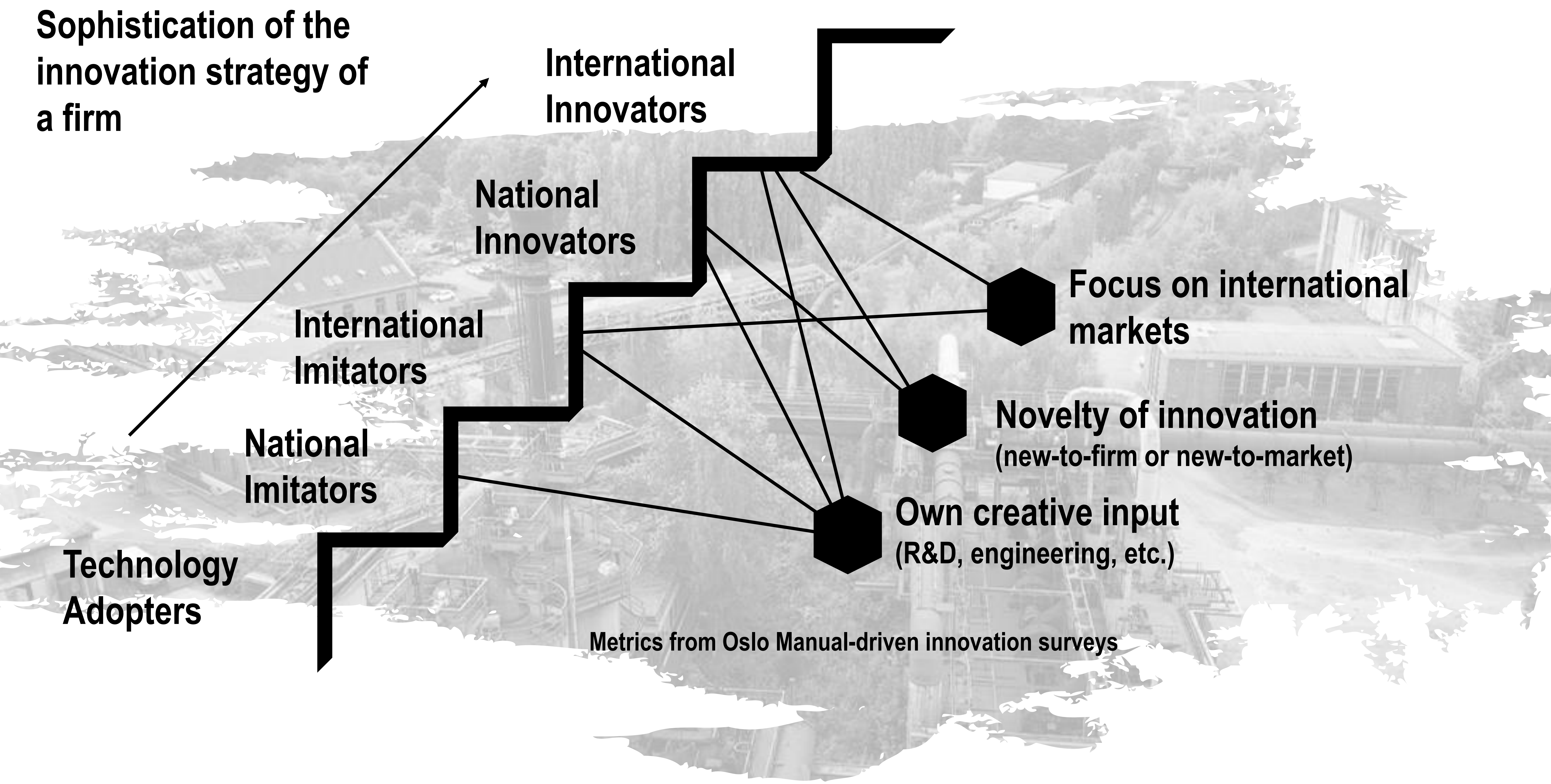
- **Effort:** created mainly by the firm, created with considerable in-house input, outsourced
- **Challenges:** Subjectivity; **Multidimensionality**

Taxonomies of innovation: facilities to balance between reasonable degree of complexity and growing sophistication of theories and empirical evidence

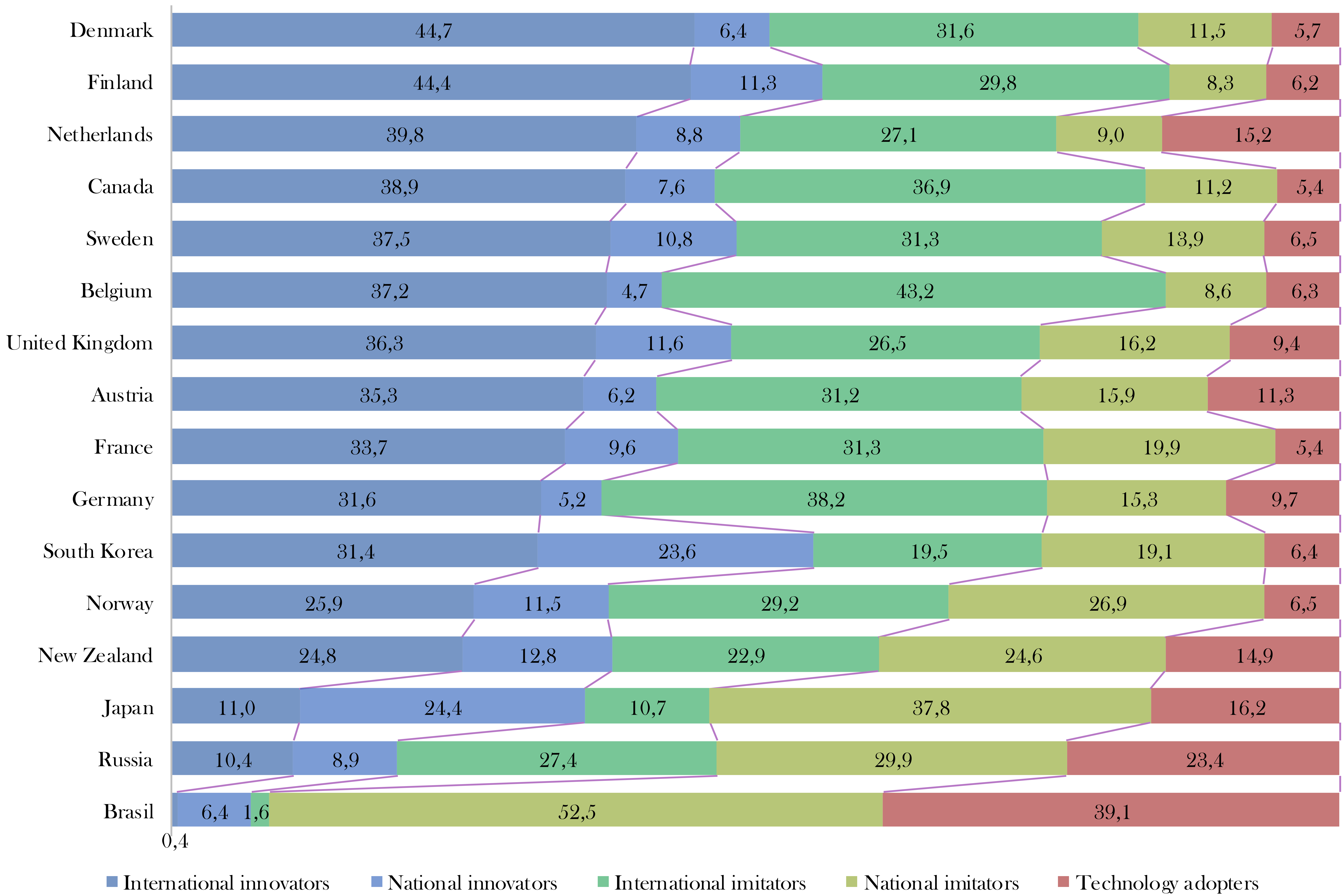
- From sectoral (Pavitt 1984, OECD 1997, Peneder 2003) to firm-level classifications (Arvanitis, Hollenstain 2001, Hollenstein 2003, Castellacci 2008, Peneder 2010, Hollenstein 2019 etc.)
- Development of methodologies: from handcraft analysis of cases towards multi-country survey data (Frenz, Lambert, 2009, 2012)
- Different principles: top-down (or 'cut-off') vs. exploratory (data-driven) clustering exercises
- Ability to identify and quantify the complex composition of heterogeneous actors within a single innovation systems at given moment.

Innovation-based indicator for TU

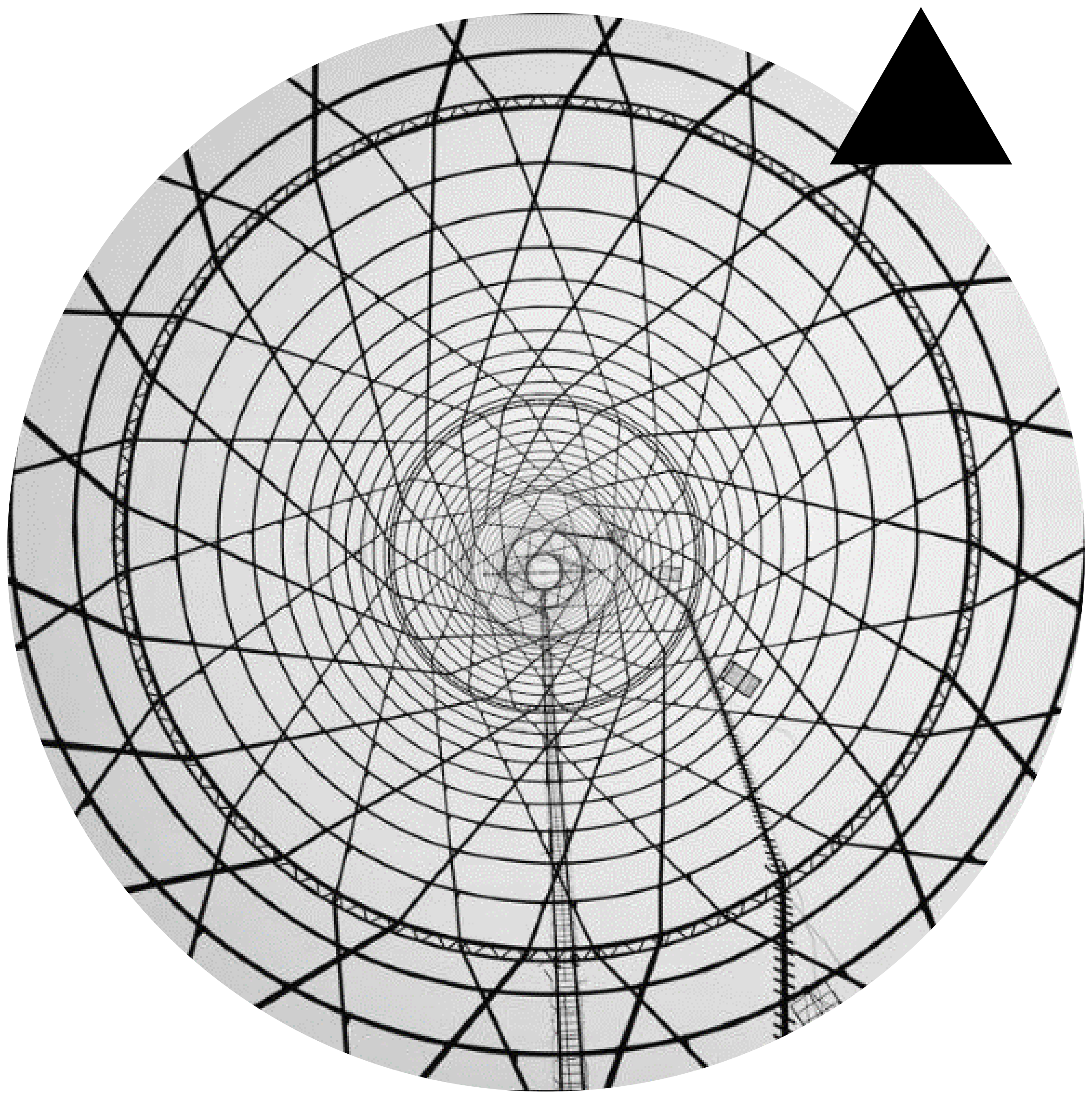
Firm-level taxonomy: Output-based innovation modes (OECD, 2009)



Innovation modes across countries



Source: OECD, 2009; Russia: author’s estimates using Russian innovation survey, 2015.



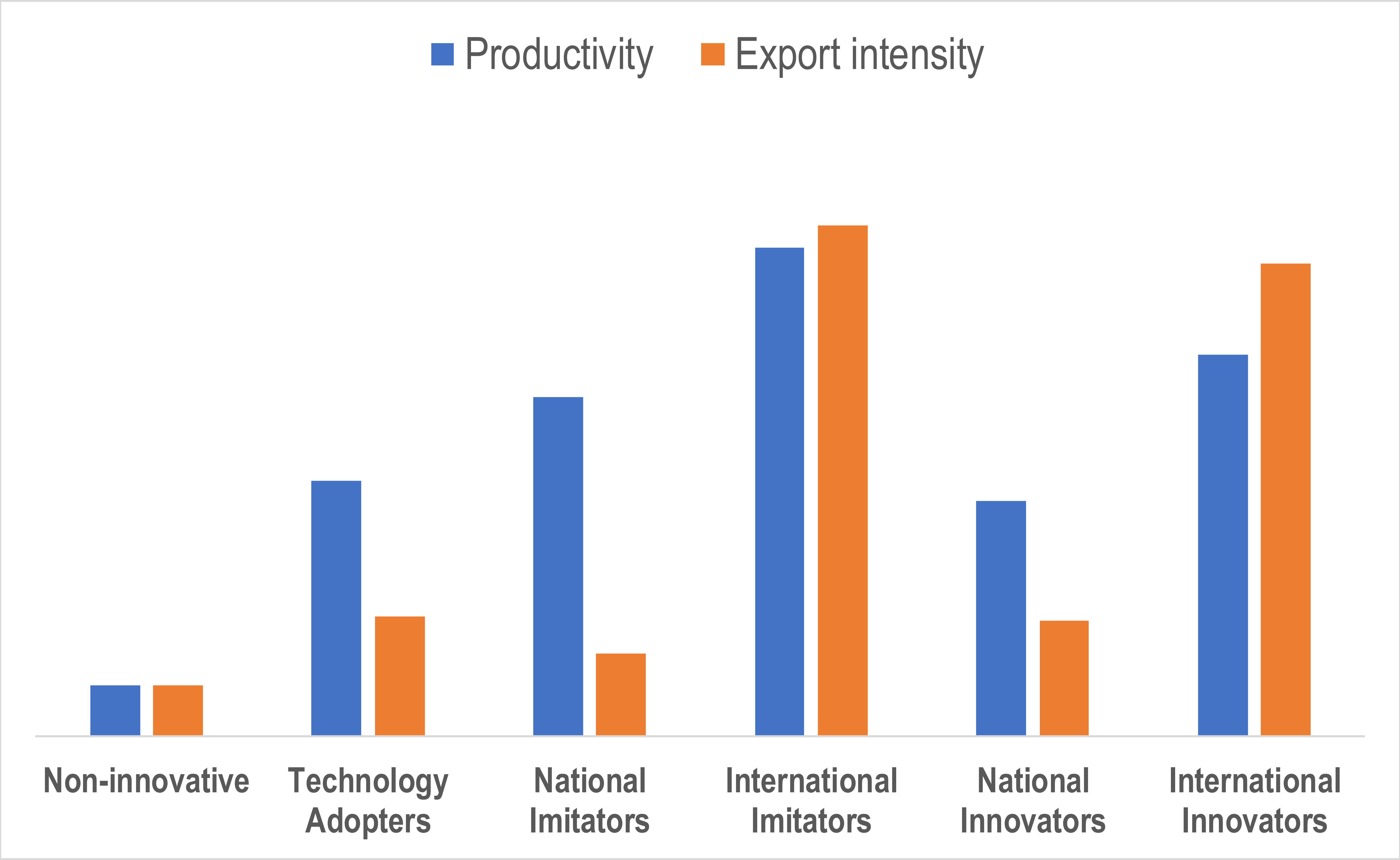
What stands behind innovation modes?

Economic performance

Efficiency of innovation

Usage of advanced technologies

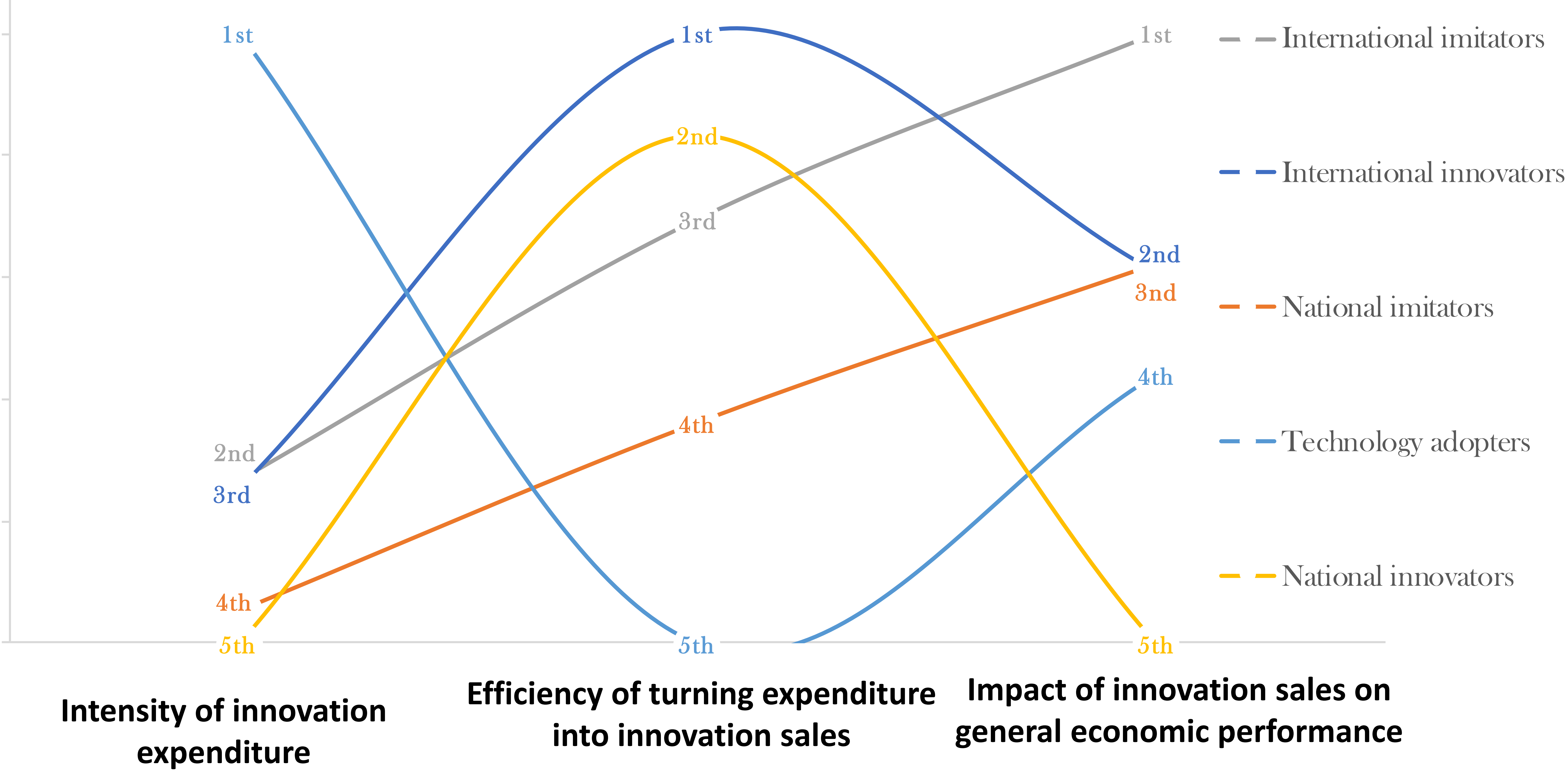
Economic performance of the innovation modes: mean productivity (per-employee total sales) and per-employee exports



*Normalized scale

Advanced modes have more efficient innovation processes, less advanced allocate more resources

EFFECT OF INNOVATION MODE ON THE INNOVATION EFFICIENCY



Roud V. Understanding the Heterogeneity of Innovation Modes // Technological Forecasting and Social Change *(2018)*

How the innovation mode relates to the actual use of advanced technologies?

Survey HSE – 2015: 1328 manufacturing enterprises

26 advanced general purpose technologies

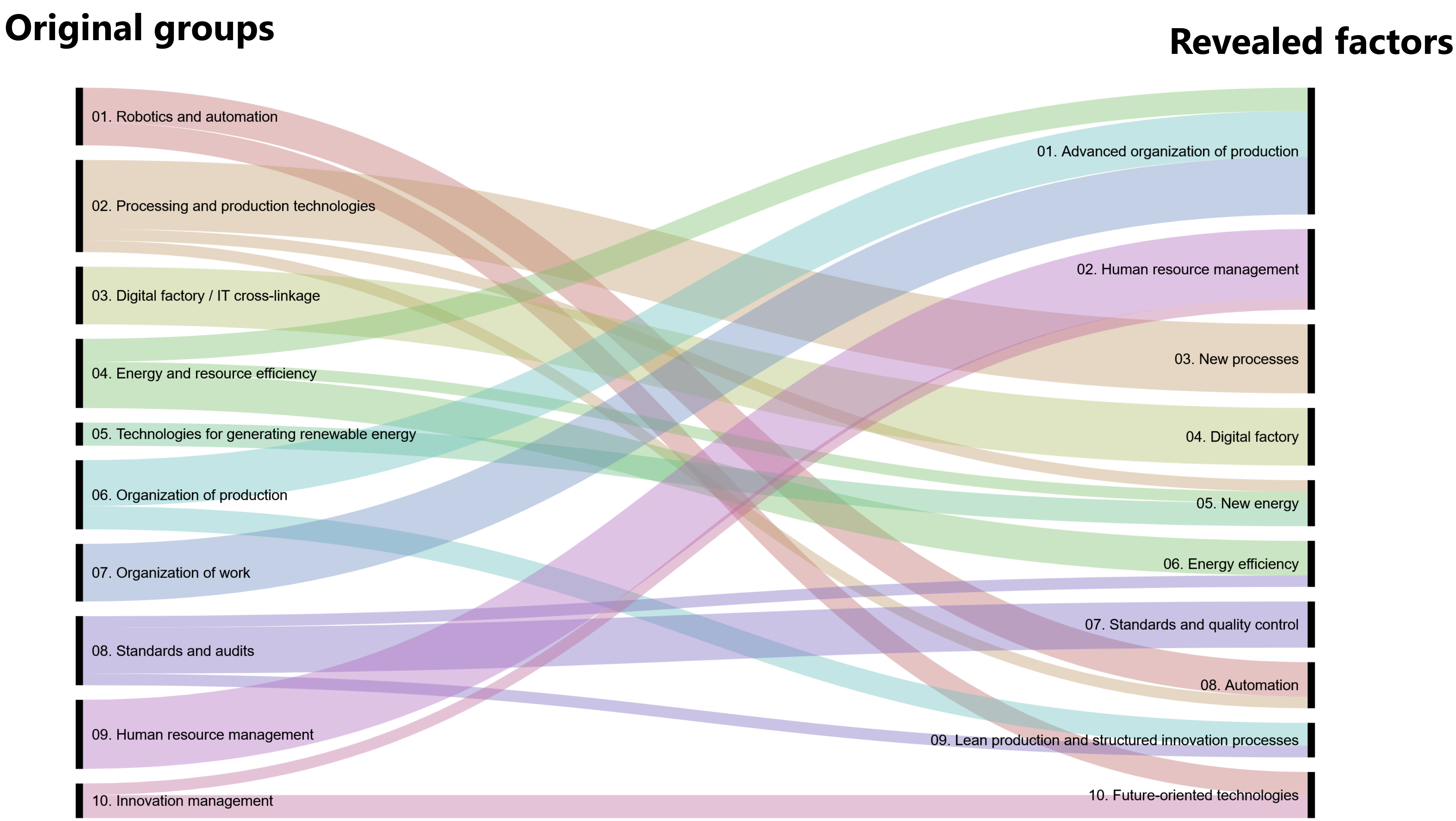
26 advanced organizational concepts

Degrees of utilization:

1 - not using; 2 - planned before 2020; 3 - early experiments; 4 - moderate; 5 - fully integrated into production

1. Robotics and automation	Industrial robots/handling systems in manufacturing and assembly
	Automated Warehouse Management Systems for on-site logistics and order picking
	Technologies for safe human-machine cooperation (e.g. cooperative robots, “fenceless” stations, etc.)
	Intuitive, multi-modal programming methods (e.g. voice input, identification of gestures, demonstrated trajectories)
	The drones (unmanned aerial vehicles), for example - in logistics, monitoring of areas, aerial photography.
2. Processing and production technologies	Using a laser as a tool (e.g., cutting, welding, forming (shaping), structuring)
	Processing techniques for alloy construction materials (aluminium, magnesium, titanium alloys, etc.)
	Processing techniques for composite materials (e.g. carbon fibre, fibreglass)
	Manufacturing technologies for micromechanical components (micromachining, lithography, microinjection)
	Prototyping / manufacturing using additive technologies (such as three-dimensional printing process, laser sintering powders, stereolithography)
	Nanotechnological production processes (e.g. surface processing)
	Biotechnology (use of biological structures in production)
	Technology of complex processing of raw materials, catalysts and technical polymers
3. Digital factory / IT cross-linkage	Digital exchange of operation scheduling with suppliers/customers (supply chain management systems)
	Virtual reality and/or simulation in production reconfiguration (e.g. production flows, single process steps)
	Virtual reality and/or simulation in product design/ development (e.g. digital prototyping)
	Product Lifecycle Management
	IT systems for storage and management of ideas (idea management systems)
4. Energy and resource efficiency	Dry processing/minimum lubrication
	Control system for shut down of machines in off-peak periods
	Recuperation of kinetic and process energy (waste heat recovery)
	Combined cold, heat and power (Bi-/Trigeneration) for own use or resale
	Own generation of heat and / or electricity, allowing to completely abandon the centralized network services
	Technology of reduce heat losses in buildings
5. Technologies for generating renewable energy	Technologies for power generation via solar or wind energy, hydropower, biomass or geothermal energy
	Technologies for heat generation via solar energy, biomass or geothermal energy
6. Organization of production	Methods of Value Stream Mapping/Design
	Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors)
	Production controlling by pull principles (e.g. Internal zero-buffer principle, KANBAN)
	Methods for optimizing of change-over time (e.g. SMED)
	Methods of Total Productive Maintenance (Preventive Maintenance, maintenance by workmen, maintenance plans, etc.)
	Methods of Total Quality Management (Zero Defects Concepts, EFQM, etc.)
7. Organization of work	Method of 5S (“work place appearance and cleanliness”)
	Standardized and detailed work instruction (“standard work“)
	Integration of tasks (planning, operating or controlling functions with the machine operator)
	Methods for continuous improvement process (CIP, KAIZEN, quality circle, etc.)
	Team work in manufacturing and assembly
8. Standards and audits	Visual Management (Display board in production for work processes and work status)
	ISO 9000 et seq. certification (quality management audit)
	Six Sigma
	ISO 14031 certification (environmental audit)
	ISO 50001:2013 certification (energy audit)
	Methods of investment evaluation, taking into account the entire life cycle costs (e.g. Total Cost of Ownership)
9. Human resource management	Formalized sessions for idea generation among employees
	Instruments to maintain more experienced employees or their knowledge in the factory (e.g. training programs, incentive systems, or similar)
	Working time specifically dedicated for creativity and innovation (incl. e.g. changes in production processes)
	Talent development program (e.g. promotion of young talents for senior posts, special training programs, etc.)
	Employee training for skills related to creativity and innovation (e.g. problem solving, idea generation or brainstorming techniques)
	Involvement of experts from research organizations and higher education institutions to participate in the performance of research and innovation projects
10. Innovation management	Analysis of global technological trajectories, identification of future trends with Foresight (including Delphi surveys, scenario analysis)
	Formal methods of product development (structured quality functions, etc.)
	Working with the "early users" - consumers who tend to use new technologies

Constructing the technology sophistication space: factor analysis



10 factors explain 89% of variance

Advanced innovation modes are the most active users of technology

Factor	Innovation mode: International innovators	National innovators	International imitators	National imitators	Technology adoption	Non-innovative
1. Advanced organization of production	0.579	0.471	0.805	0.250	0.353	-0.091
2. Human resource management	0.703	0.313	0.221	0.235	0.251	-0.059
3. New processes	0.653	0.364	0.265	0.036	-0.022	-0.032
4. Digital factory	0.787	0.298	0.102	0.264	0.235	-0.065
5. New energy	-0.095	0.116	-0.053	0.121	0.133	-0.008
6. Energy efficiency	0.136	0.138	0.436	0.026	0.064	-0.032
7. Standards and quality control	0.897	0.345	0.674	0.227	0.842	-0.087
8. Automation	0.265	0.324	0.166	0.158	0.872	-0.044
9. Lean production and structured innovation processes	0.574	0.184	0.387	0.219	-0.192	-0.053
10. Future-oriented technologies	0.087	-0.143	-0.329	0.140	-0.505	-0.007

(average normalized factor score; higher value = higher degree of tech usage)

International innovators

Best at advanced organization of production, advanced HRM, utilize new production processes and are more 'digital'.

Standartization and quality control, lean production.

However: less concerned about energy efficiency; don't exploit future-oriented technologies

International imitators

Most extensive users of advanced organizational methods; focus on standards, energy efficiency and lean production

Technology adopters

Leaders in standardization and quality control, automation. Don't care about future-oriented technologies and structured innovation processes

Non-innovative

Absolute followers in terms of technology and organizational methods

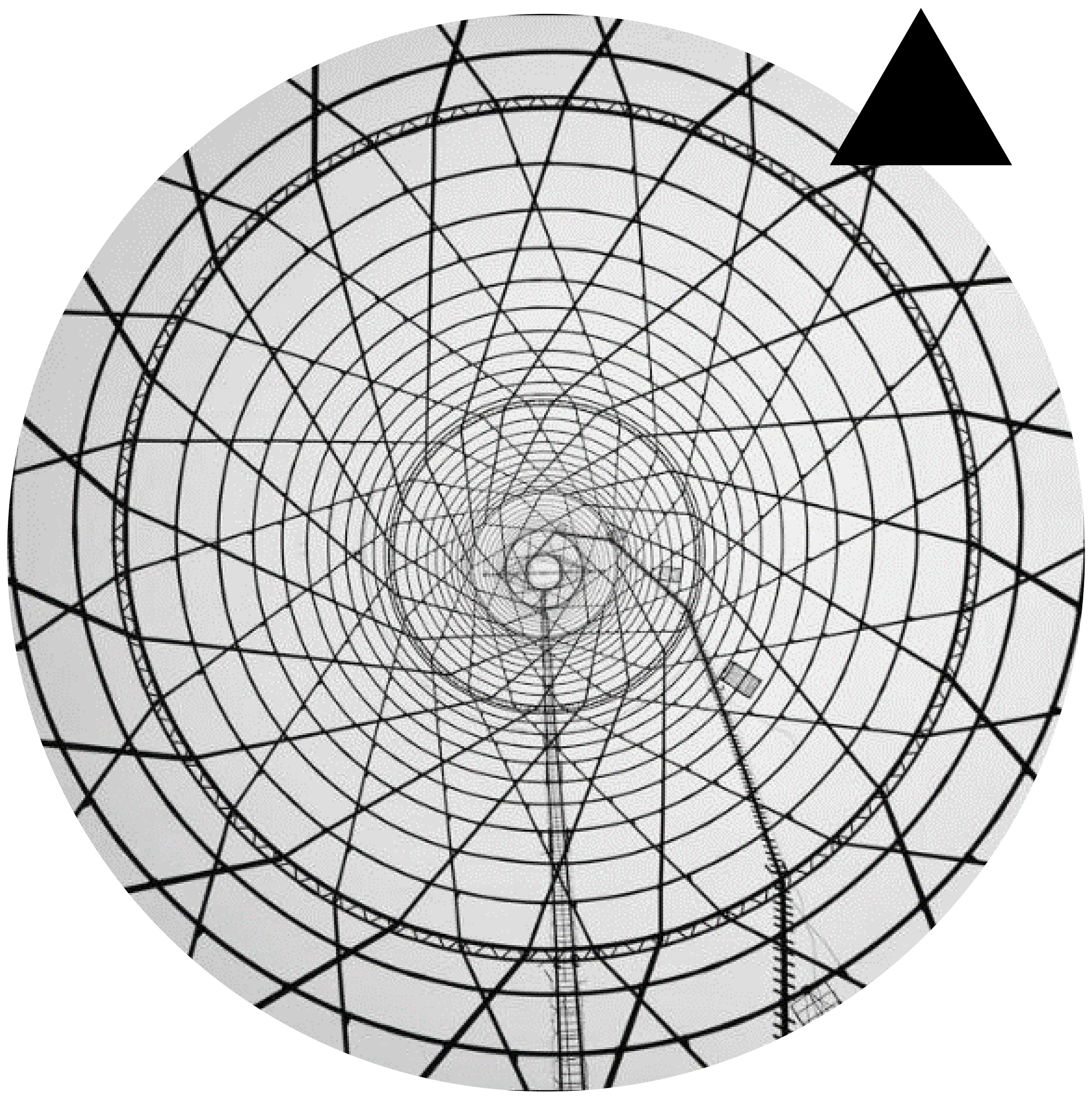
National innovators

Pattern somewhat similar to international innovators but more modest in magnitude. More attention to new energy sources, less structured innovation processes

National imitators

Modest focus on efficient organization, digitalization, standardization; no usage of new processes

***significance controlled by Turkey post-hoc test**



How can we facilitate the upgrading?

By creating environment favorable for the sophisticated innovation strategies

Do we understand the needs of heterogeneous innovation modes?

Heterogeneous perception of institutional environment, demand for policy measures

INTERNATIONAL INNOVATORS (9.7% of innovation-active industrial enterprises)

BARRIERS: Difficulties with attracting additional finance, inefficiency of import-export regulation

MEASURES: Reduction of administrative barriers, innovation-oriented state purchases

NATIONAL INNOVATORS (8.9%)

BARRIERS: Obsolete technical regulation and standards

MEASURES: Grants and subsidies

INTERNATIONAL IMITATORS (26.8%)

BARRIERS: Inefficiency of state support, lack of qualified personnel

MEASURES: Tax incentives, accelerated depreciation for innovation spending

NATIONAL IMITATORS (34%)

BARRIERS: Shortage of qualified personnel, lack of information about prospective markets, underdeveloped innovation infrastructure

MEASURES: Grants and subsidies

TECHNOLOGY ADOPTERS (20.5%)

BARRIERS: Factors that limit networking

MEASURES: Support from the development institutions

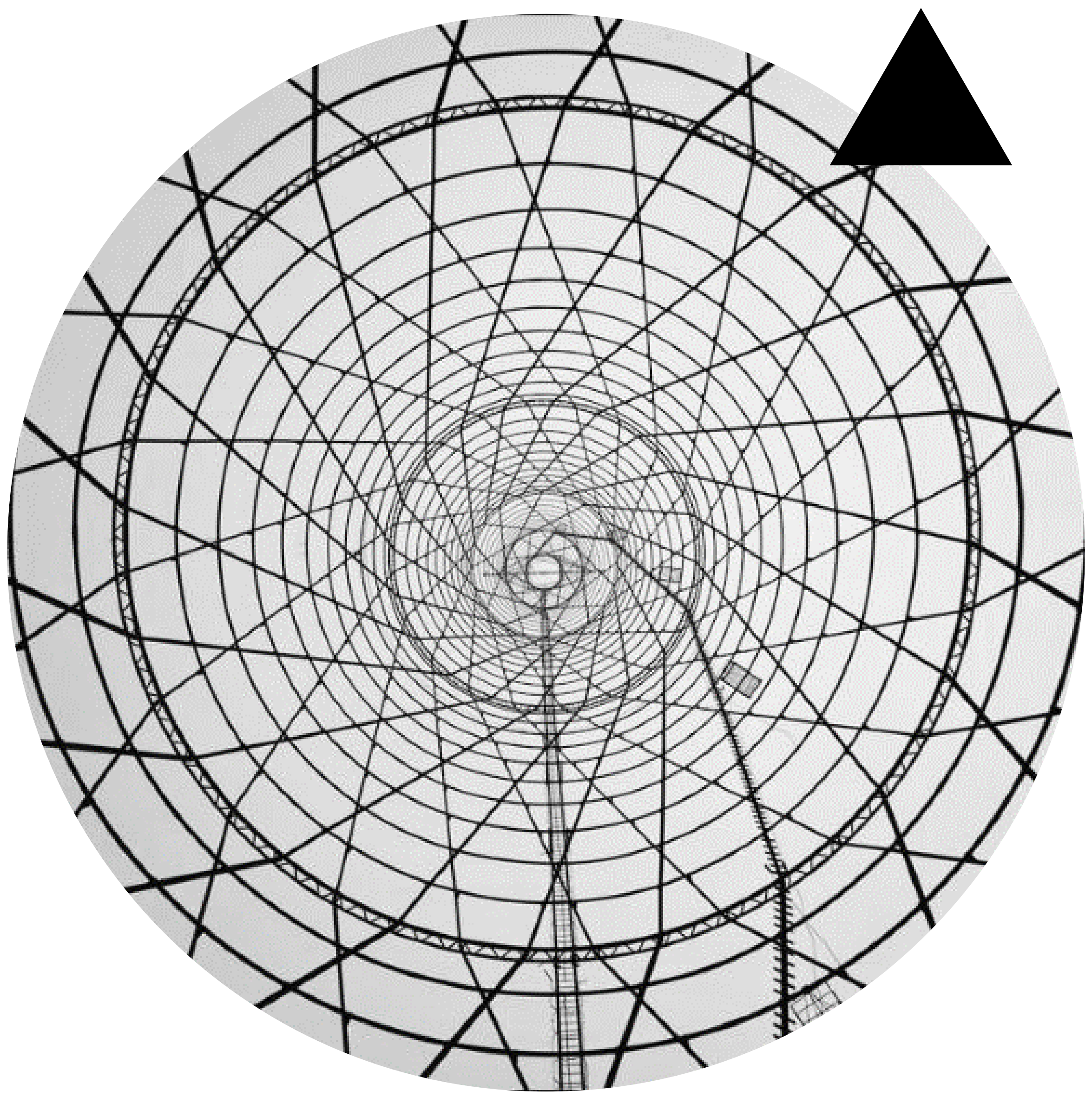
NON-INNOVATIVE (90% of all industrial enterprises)

BARRIERS: Poor innovation culture; Low demand on innovation

MEASURES: Acquisition of rights for budget-sponsored R&D results

To facilitate upscaling of best practices we need to understand the ‘efficient minority’ – a challenge for consensus-type policymaking

Roud V. Understanding the Heterogeneity of innovation Modes // Technological Forecasting and Social Change *(forthcoming)*



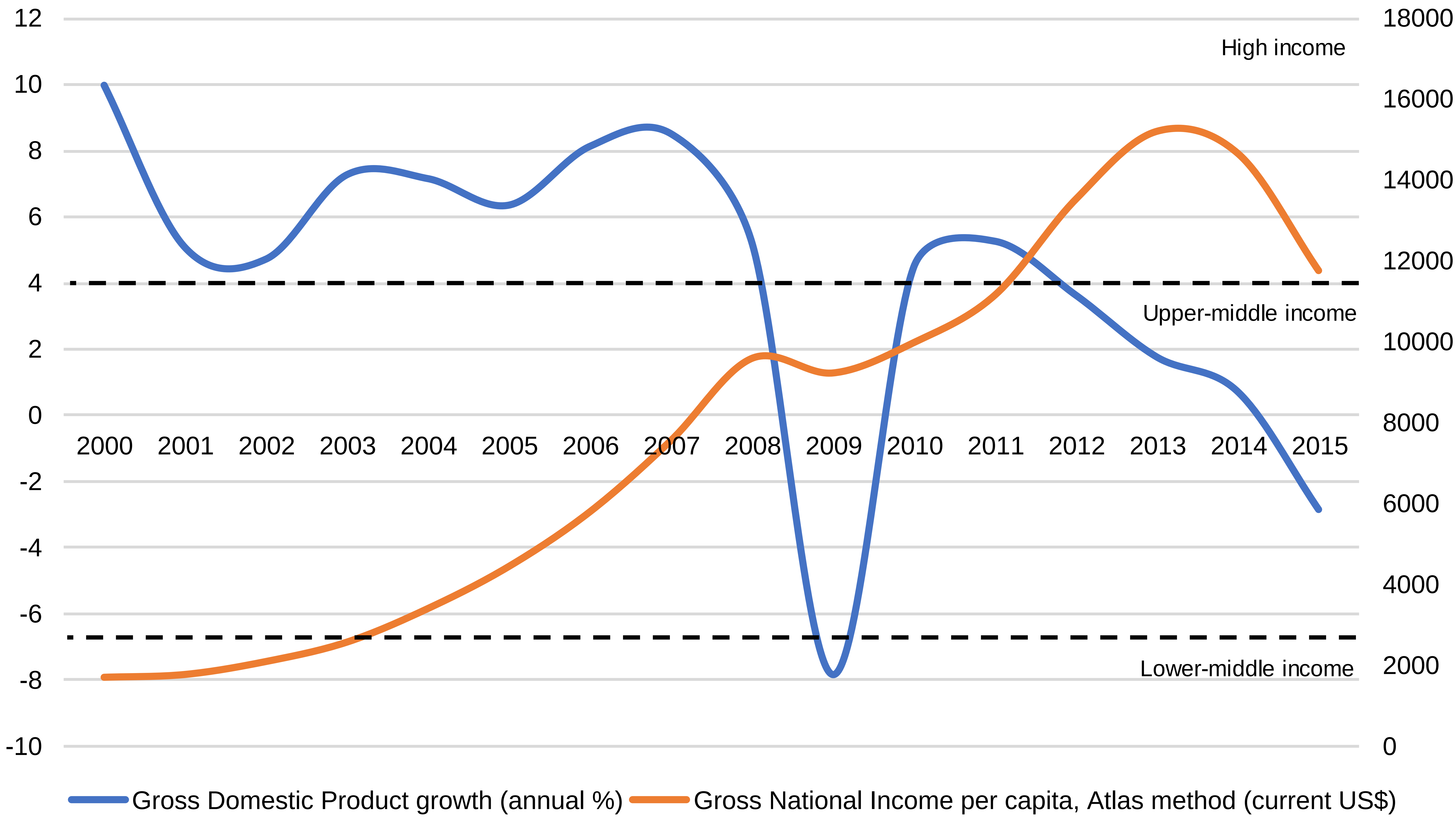
Towards understanding the dynamics of upgrading

Path dependence and institutional lock-in

Firm-level persistence of innovation

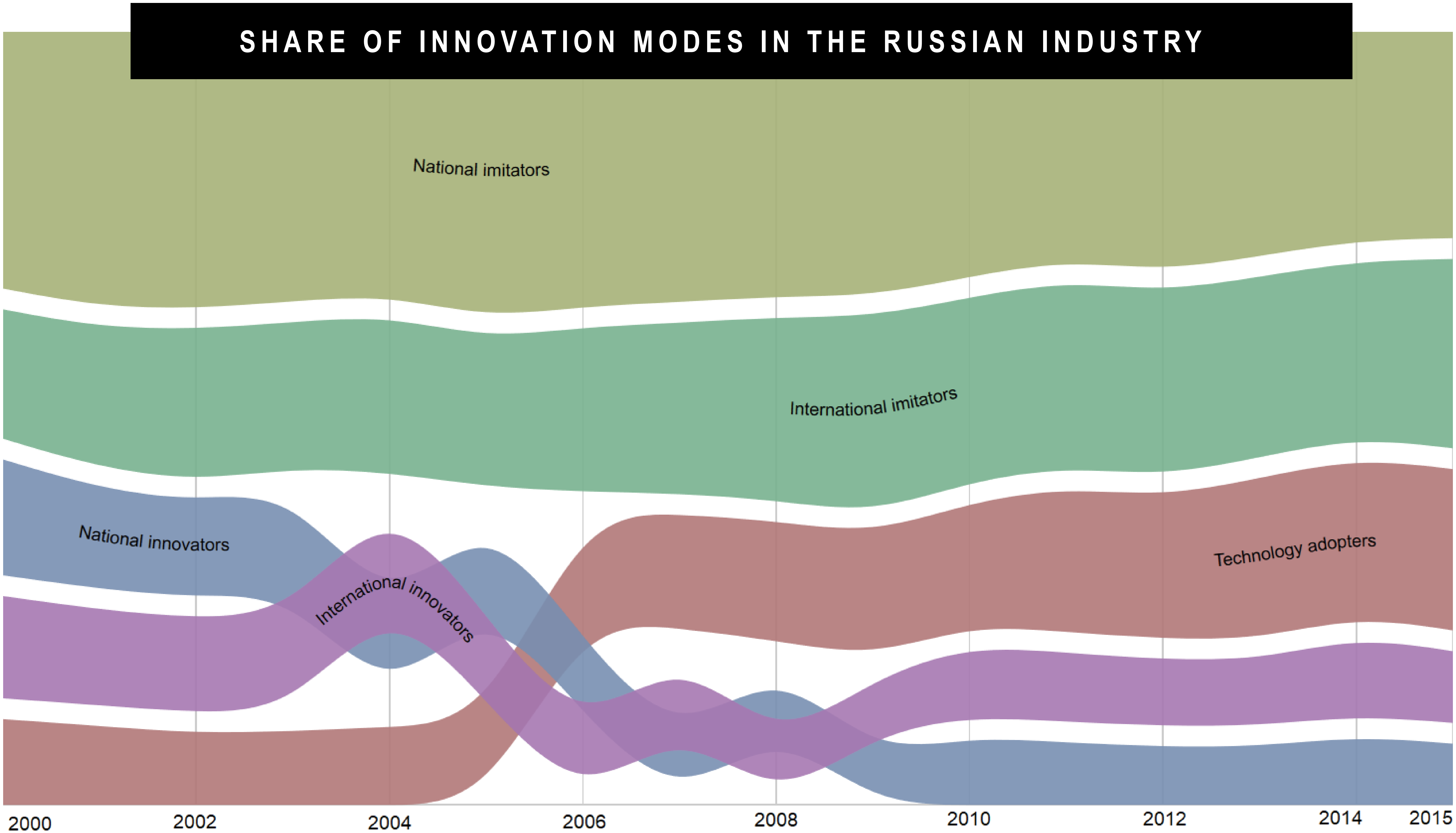
Sectoral regimes of innovation: technological patterns, competitive environment, etc.

An explanation for Russia’s macro trends: high levels of GNI per capita but the growth model is not sustainable?

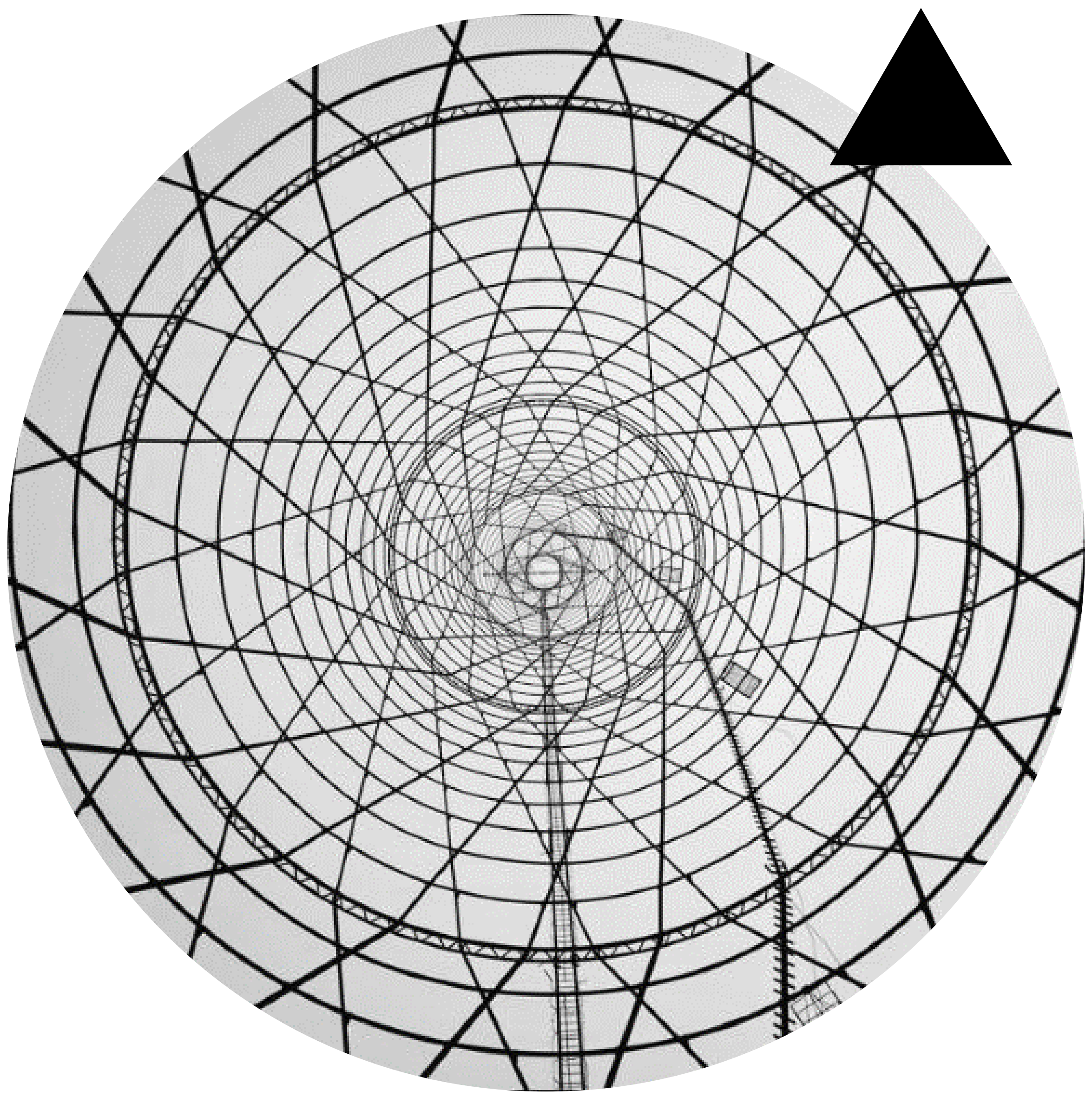


(dominant share of crude oil and gas in exports, stagnation of industry structure)

Meso-level trends based on micro-level estimates: ability to capture bounded change (or lock-in, as here)



Gokhberg L., Roud V. Structural changes in the national innovation system: longitudinal study of innovation modes in the Russian industry // Economic Change and Restructuring. 2016. Vol. 49. No. 2. P. 269-288.



Better targets for structural policies – identify the country's innovation capabilities at the sectoral level: the industry regime based on the propensity of firms towards specific innovation modes

Constructing industry-level trajectories: econometrics helps to refine the industrial organization issues

DATA

361000 firm-level observations from Russian innovation survey:
2000-2015, NACE rev 1.1 C, D, E (Mining, Manufacturing, Utilities)

ECONOMETRICS

Multinomial choice regression – probabilities of innovation modes per sector at given time period,
controls: size and ownership structure

FOR AN INDUSTRY IN GIVEN TIME PERIOD: FIRM'S PROPENSITIES TOWARDS MODES (88 industry-period estimates)

Mode	Marginal effect on probability of mode	S.E.
Non-innovation	0.0180**	(0.00886)
Technology adoption	0.00902***	(0.00284)
National imitators	0.00971*	(0.00544)
International Imitators	-0.0149***	(0.00448)
National innovators	-0.00526	(0.00401)
International Innovators	-0.00861***	(0.00313)

Example: Food&Beverages, 2012-2015

CLUSTERING OF INDUSTRIES BASED ON THE PROPENSITIES TO MODES

	5 Types of industries identified:				
Dimension: propensity to mode	Low innovation	Technology adoption	Local imitation	International imitation	Broader innovation
Non-innovative	0.0585	0.0104	0.0117	0.0048	-0.0821
Technology adoption	0.0008	0.0175	0.0056	0.0036	0.0116
National imitation	-0.0208	-0.006	0.0057	-0.0022	0.0224
International imitation	-0.0124	-0.0036	-0.0119	0.0034	0.0191
National innovation	-0.0134	-0.0113	-0.002	-0.0075	0.0078
International innovation	-0.0083	-0.0056	-0.0064	0.0009	0.0155
	Average propensity to a mode within the clusters (cluster profile)				

5 industry regimes:

- **Low innovation** (maximum propensity to non-innovative firm-level mode, negative propensity to all innovation-related strategies)
- **Technology adoption** (maximum propensity to technology adoption)
- **Local imitation** (higher probability of technology adoption and national imitation)
- **International imitation** (propensity to international imitation and technology adoption)
- **Broader innovation** (propensity to innovation-driven strategies)

Dynamics over 16 years

Industry regime	2000-2003	2004-2007	2008-2011	2012-2015
Low innovation	7	4	5	2
Technology adoption	1	4	5	10
Localization	2	2	1	1
Internationalization	6	8	6	4
Broader innovation	6	4	5	5

10 – Mining;

17,18,19 – Textiles, clothes, leather

21 – Paper

26 – Plastics

31 – Electrical machinery

34 – Automobiles;

36 – Manufacturing n.e.c.;

40 – Utilities

UPGRADED: 8 industries

20 – Wood

24.4 – Pharmaceuticals

27 – Basic metals

28 – Non-metallic mineral products

29 – Machinery and equipment n.e.c.

32, 30 – Radio, TV and computers

33 – Precision instruments

35.3 – Aircraft and spacecraft

MANTAINED POSITIONS: 8

15 – Food & Beverages

22 – Publishing and printing

23 – Coke, refined petroleum and nuclear fuel

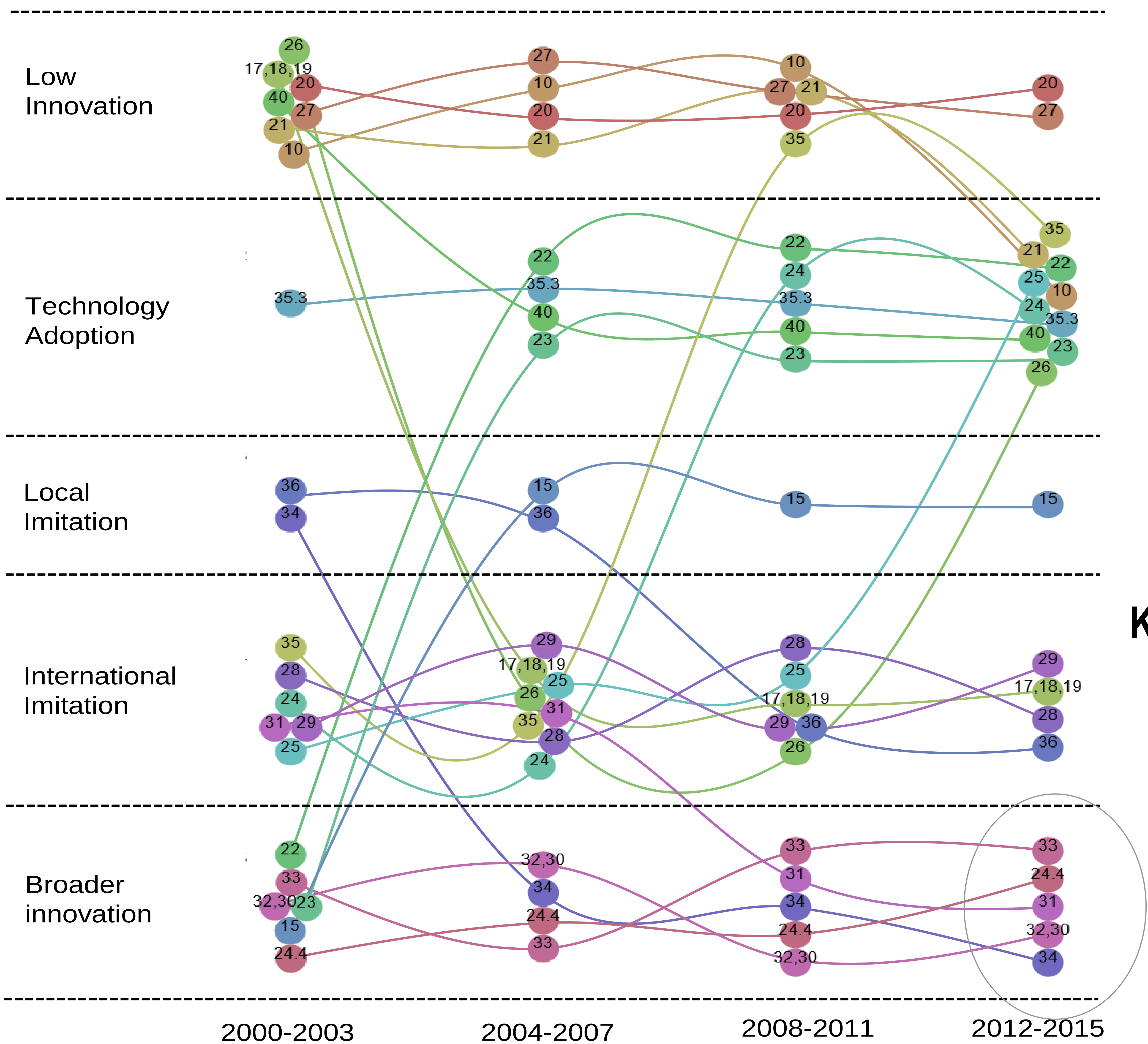
24 – Chemicals

25 – Rubber

35 – Other transport

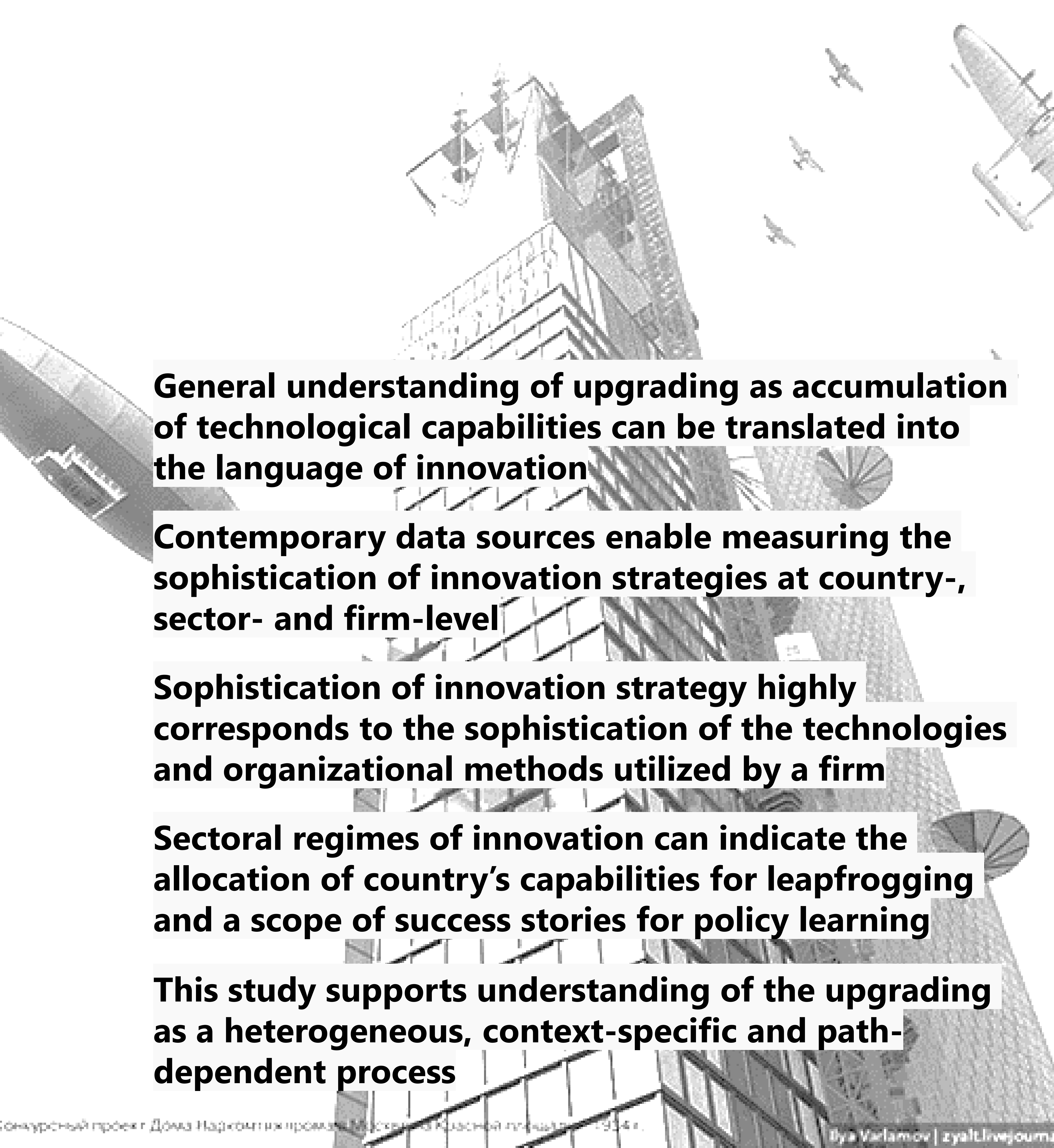
DOWNGRADED: 6

Tracing industry regimes based on changing propensities to modes



Key to understanding the heterogeneity of framework conditions: some sectors succeed where other fail

TRAJECTORIES OF SECTORAL UPGRADING (OR DOWNGRADING)



General understanding of upgrading as accumulation of technological capabilities can be translated into the language of innovation

Contemporary data sources enable measuring the sophistication of innovation strategies at country-, sector- and firm-level

Sophistication of innovation strategy highly corresponds to the sophistication of the technologies and organizational methods utilized by a firm

Sectoral regimes of innovation can indicate the allocation of country's capabilities for leapfrogging and a scope of success stories for policy learning

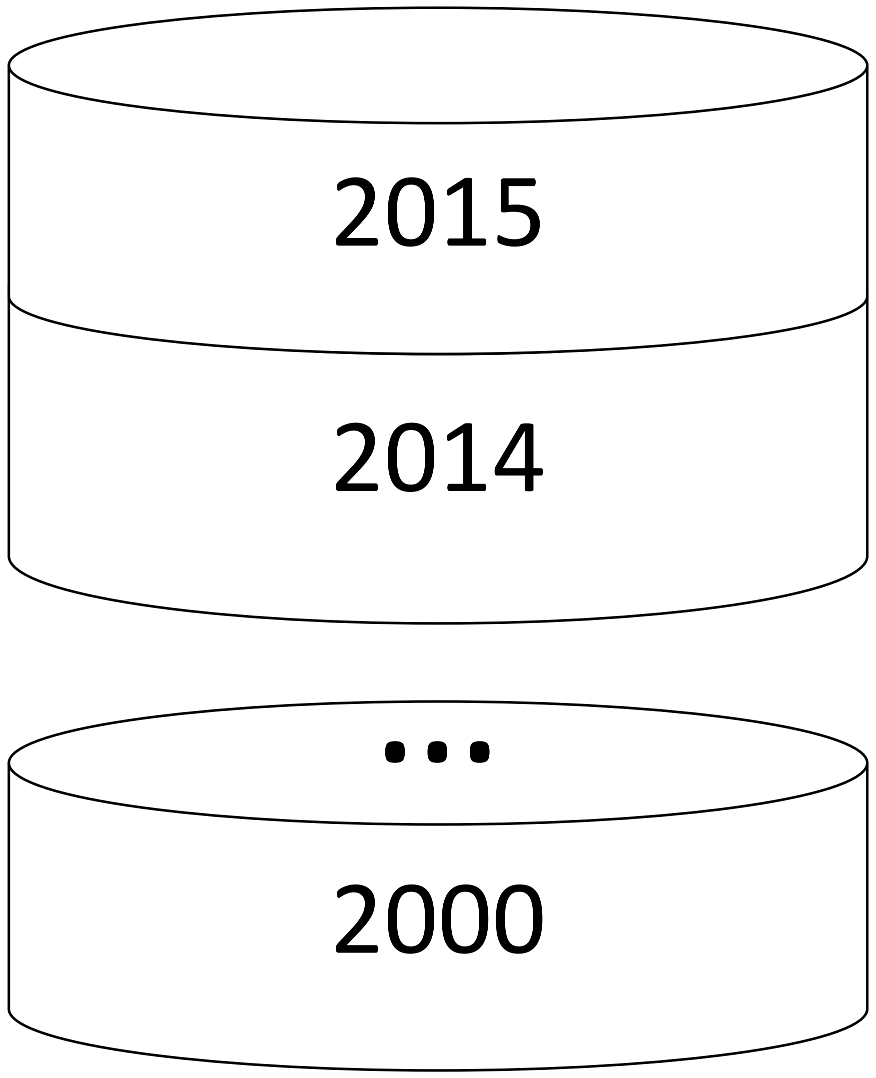
This study supports understanding of the upgrading as a heterogeneous, context-specific and path-dependent process

HIGHLIGTS

Proposed indicators may be applied in a broad range of countries that have the practice of Oslo Manual-driven innovation surveys

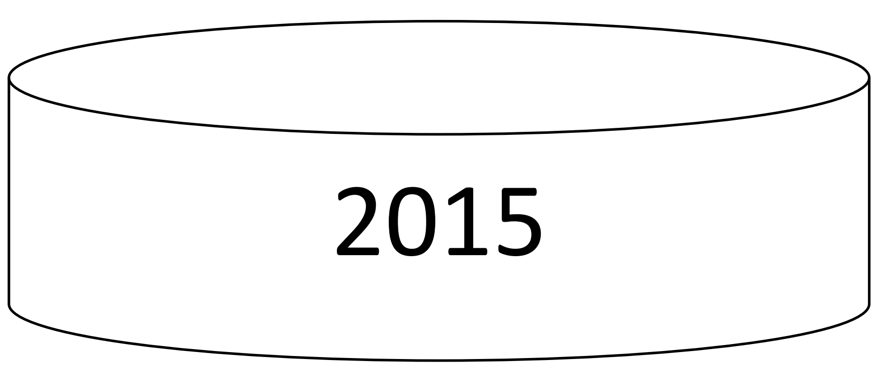
Limitations: exclusively empirical and data-hungry excercise

Database 1: Russian National Innovation Survey



- **Oslo Manual-compliant**, annual mandatory statistical survey executed by Rosstat (national statistical office).
- Firm-level data: pooled cross-sections **2000-2015**.
- NACE C, D, E: **361 000** observations total (~22 500 annually)
- Anonymized data provided by HSE ISSEK

Database 2: Survey of innovation behavior of enterprises



- **1325** manufacturing enterprises in 2015
- Structured interviews with top-managers
- **Oslo Manual-compliant indicators** of innovation
- **Extended set of questions** on innovation strategy, attitudes towards public support mechanics
- Funded by HSE ISSEK

A source of evidence to complement other metrics and methods of analysis

Images: Shysev Museum of Architecture; Duisburg Nord Landscape Park; Wikimedia; Ilya Varlamov

vroud@hse.ru

Thank you