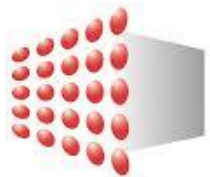


Technological development and innovation of cooling technologies



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Outline

- Motivation
- Methods and data
- Results
- Conclusion and policy implications

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Motivation

- Cooling is an important area: a rapid increase in demand & potential environmental externalities
 - Cooling units in residential sector worldwide: 3.4 billion (2016); more than 8 billion in 2050
 - Residential cooling: about 20% of total electricity use in buildings (2016); more than triple in 2050
 - Refrigerants (e.g., HFCs) for cooling: an annual growth of 10 – 15%
- Climate friendly cooling technologies
 - Support UN Sustainable Development Goals and the Paris Agreement
 - E.g., energy efficient air conditioners in ASEAN: cumulative cost saving of at least 6.6 billion USD and reduction of at least 267 MtCO₂ by 2040
- This study:
 - Develop a harmonized list to identify climate friendly cooling technologies
 - Track the technological development in key economies
 - Number of technologies and innovation portfolio
 - Driving factors of innovation

Methods and data

- Identify climate friendly cooling technologies
 - Output perspective: using patent families to measure technologies
 - Trackable records for a long period
 - Harmonized system across economies
 - Unit of research: patent family
 - A patent family may cover multiple patent applications filed in different economies
 - No double counting
 - Primary data source: PatSnap database
 - All patent authorities in the world, 1990 – 2019
 - Patent classification
 - International Patent Classification (IPC) codes established by the World Intellectual Property Organization (WIPO)
 - Cooperative Patent Classification (CPC) codes developed by the European Patent Office (EPO) and the US Patent and Trademark Office (USPTO)
 - OECD list of Patent Search Strategies for the Identification of Selected Environment-related Technologies (ENV-TECH)
 - Climate friendly cooling technologies: a subset of OECD ENV-TECH list

Methods and data

- OECD approach:
 - Search based on IPC or CPC codes
 - A patent family is considered as a climate friendly cooling technology if it contains any of the patent classification codes under research

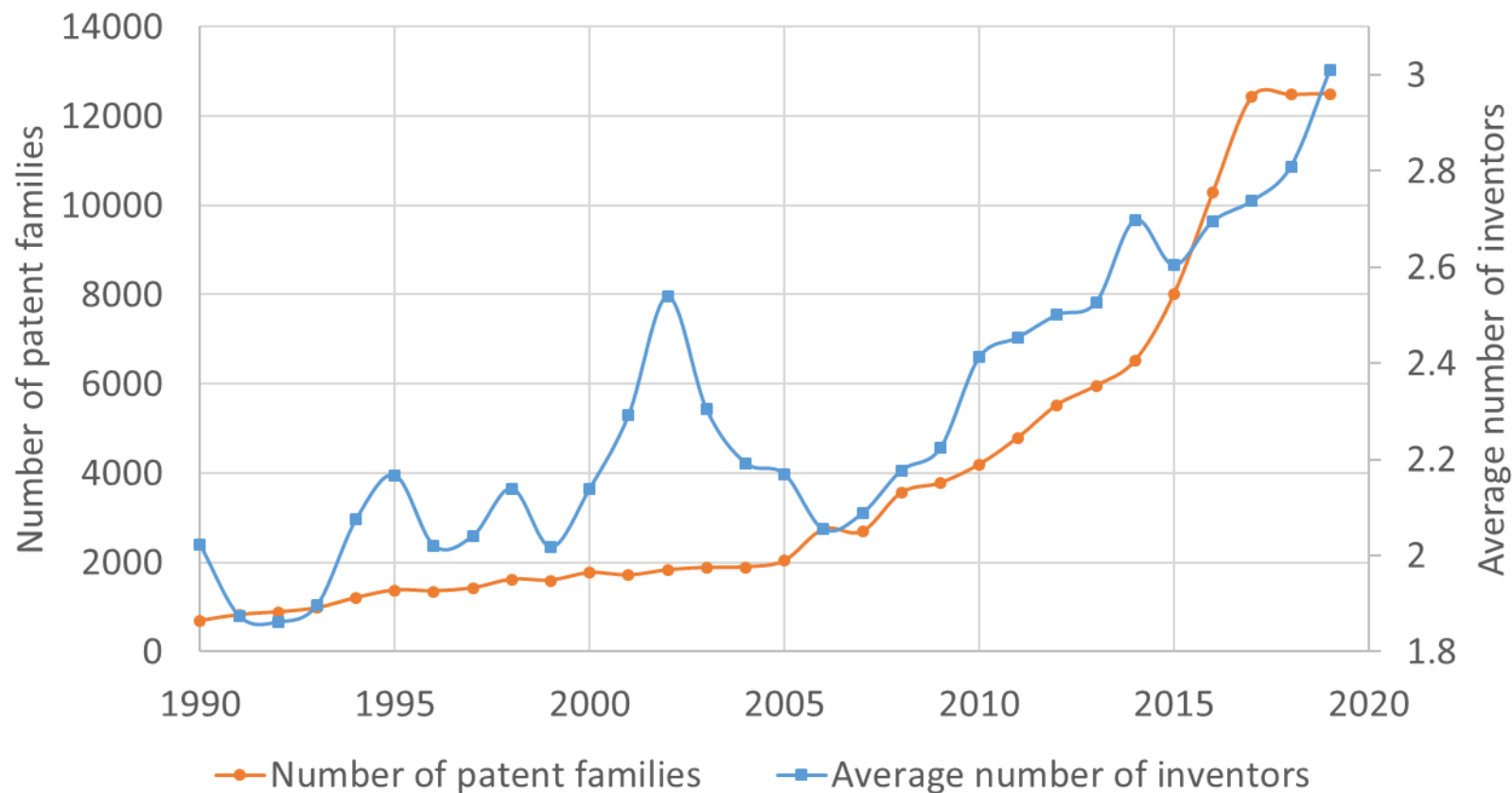
Category	Description	CPC codes
Technologies for adaption to climate change	Adapting or protecting infrastructure or their operation <ul style="list-style-type: none"> • Relating to heating, ventilation or air conditioning [HVAC] technologies • Solar heating or cooling 	Y02A 30/27; Y02A 30/272
	Adaptation technologies in agriculture, forestry, livestock or agroalimentary production <ul style="list-style-type: none"> • Greenhouse technology, e.g. cooling systems therefor 	Y02A 40/25
Climate change mitigation technologies related to buildings	Energy efficient heating, ventilation or air conditioning [HVAC]: Ultrasonic humidifiers Passive houses; Double facade technology	Y02B 30
Climate change mitigation technologies in the production or processing of goods	Technologies relating to agriculture, livestock or agroalimentary industries <ul style="list-style-type: none"> • Food storage or conservation, e.g. cooling or drying 	Y02P 60/85
	Climate change mitigation technologies for sector-wide applications	Y02P 80/10 Y02P 80/15

Methods and data

- Trends and driving factors
 - Number of patent families
 - Five key economies: PRC, Japan, Republic of Korea, USA and Germany
 - Account for about 90.4% of patent families in this field
 - Innovation portfolio
 - Relative Technological Advantage (RTA)
 - An economy's patent share in a sub-field of cooling technologies, relative to the world average
 - Larger (smaller) than 1: relative strength (weakness) in that sub-field
 - Driving factors of innovation in climate friendly cooling technologies
 - Change in number of patent families in this field is decomposed into:
 - Priority effect: share of climate friendly cooling technologies in total patents
 - Overall R&D productivity effect: number of patents per unit of R&D expenditure
 - Overall R&D intensity: share of R&D expenditure in GDP
 - Economic growth: GDP growth
 - Logarithmic Mean Divisia Index (LMDI) Decomposition

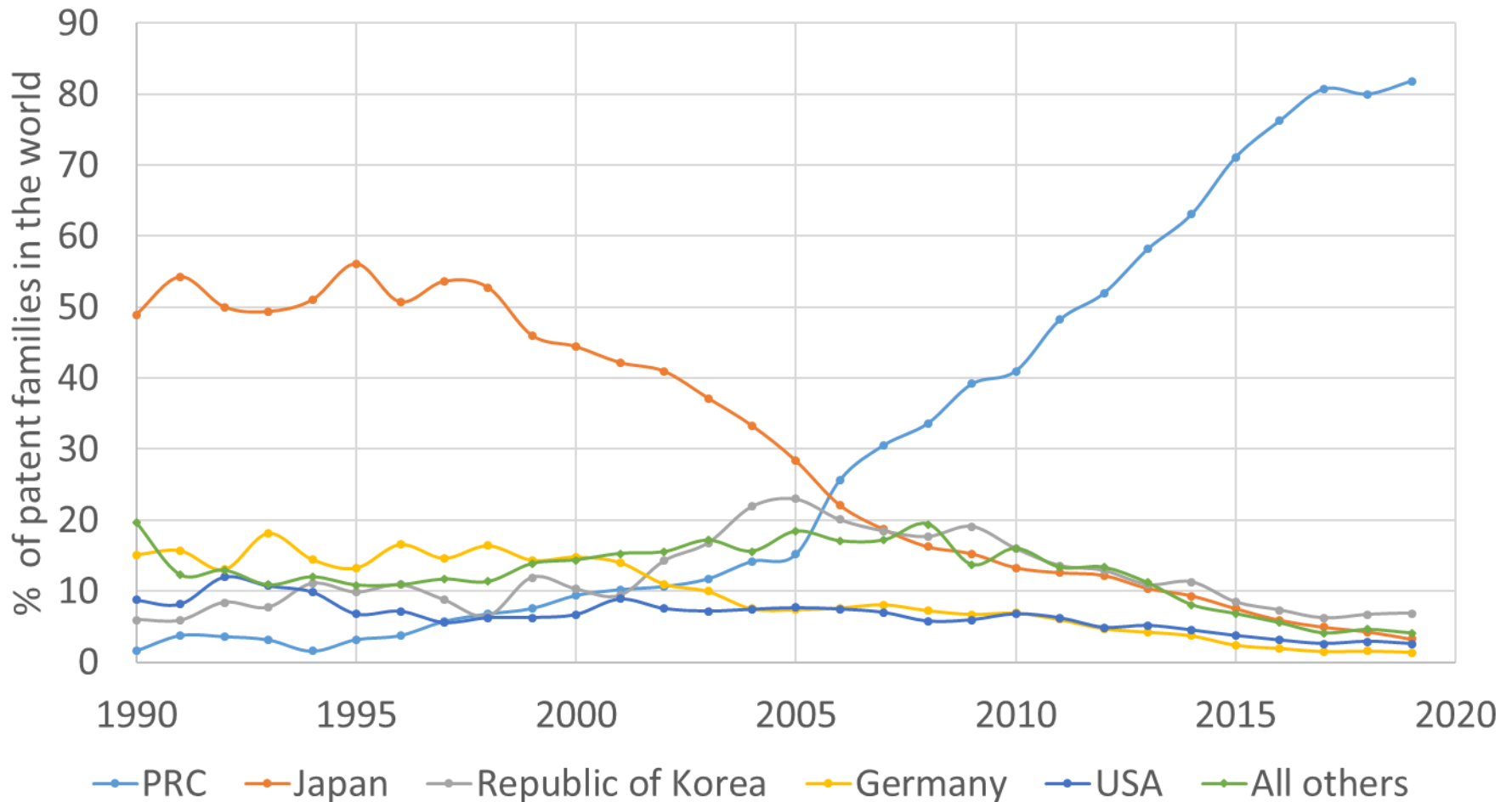
Results

- Over 1990 – 2019: 118396 patent families from 54 economies
 - Growing innovation in this field
 - Innovation is moving to larger research teams



Results

- Rising innovation from PRC since 2005
 - The 11th Five-Year Plan: setting targets for renewables and energy conservation



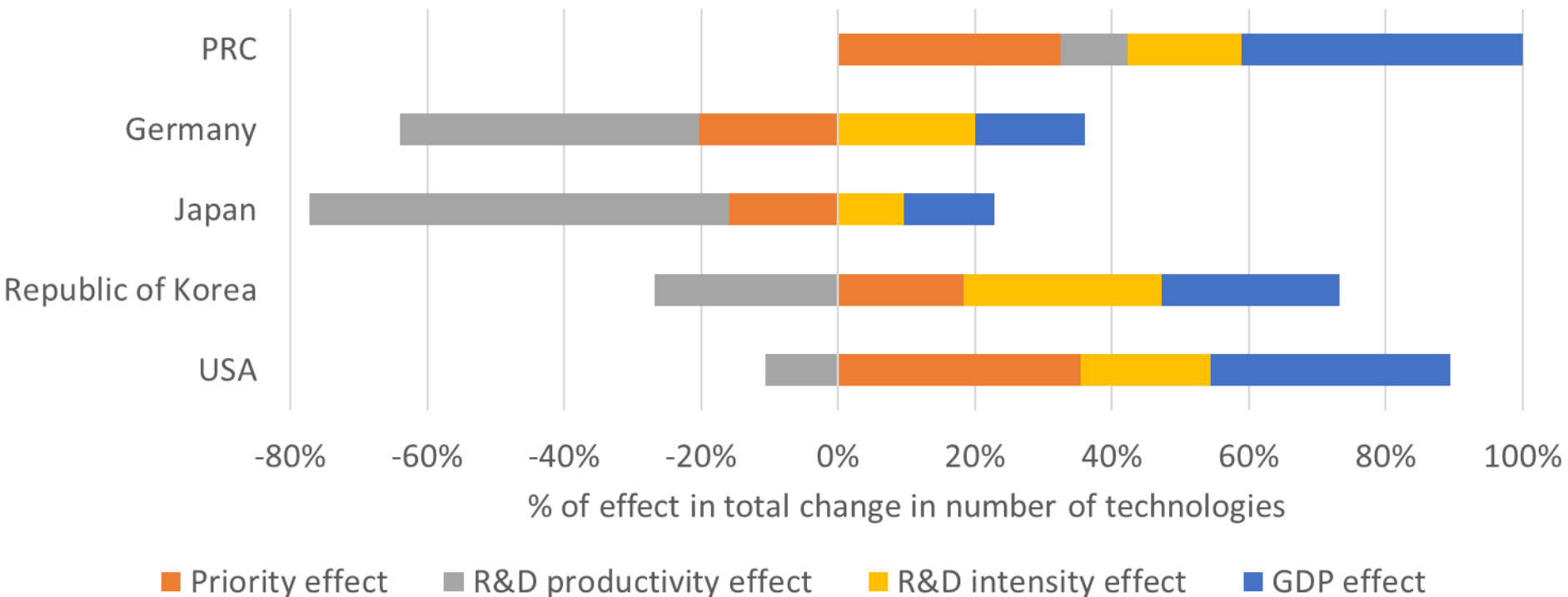
Results

- Innovation portfolios
 - Red color: Relative Technological Advantage (RTA) > 1
 - Blue color: Relative Technological Advantage (RTA) < 1
 - Different innovation portfolios across economies
 - Specialization VS diversification

Innovation field	World	Share (%)	RTA				
			CHN	KOR	JPN	DEU	USA
Adaption related to infrastructure	7130	6.02	0.77	2.24	0.72	1.00	0.96
Adaption related to production of goods	42110	35.57	1.19	0.78	1.23	0.19	0.28
Mitigation related to buildings	52394.50	44.25	0.84	1.02	0.98	1.84	1.53
Mitigation related to production of goods	4452.33	3.76	1.26	0.46	0.68	0.17	0.31
Mitigation related to sector-wide production	12309.17	10.40	1.05	1.18	0.57	0.50	1.48
Total	118396	100.00					

Results

- Driving factors of climate friendly cooling technologies over 1990 – 2019
 - Key negative factor: declining R&D productivity
 - Key driving factors:
 - Economic growth: PRC and Japan
 - R&D investment: Germany and Republic of Korea
 - Priority effect: USA



Conclusion and policy implications

- Growing innovation in climate friendly cooling technologies
 - Transition in innovation hub in this field
- Heterogeneity in innovation portfolios and driving factors of innovation across key economies
 - National needs
 - Technological capabilities and competencies
 - International collaboration
 - Identify and match core competencies
 - Exchange and application of knowledge
- Patents as a useful tool supporting evidence-based policymaking
 - Measurability and traceability
 - Application of patent search strategies for environmental technologies
 - Linkages between climate policy, public finance policy, and science and technology policy

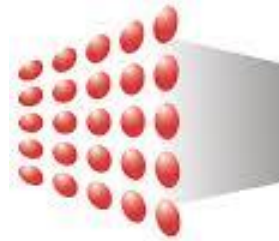
Thank you!

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