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Institute for European Analysis and Policy

Jean Monnet Centre of Excellence on EU Inclusive Open Strategic Autonomy

Critical Raw Materials and MNE Strategies under Paradigm Shift

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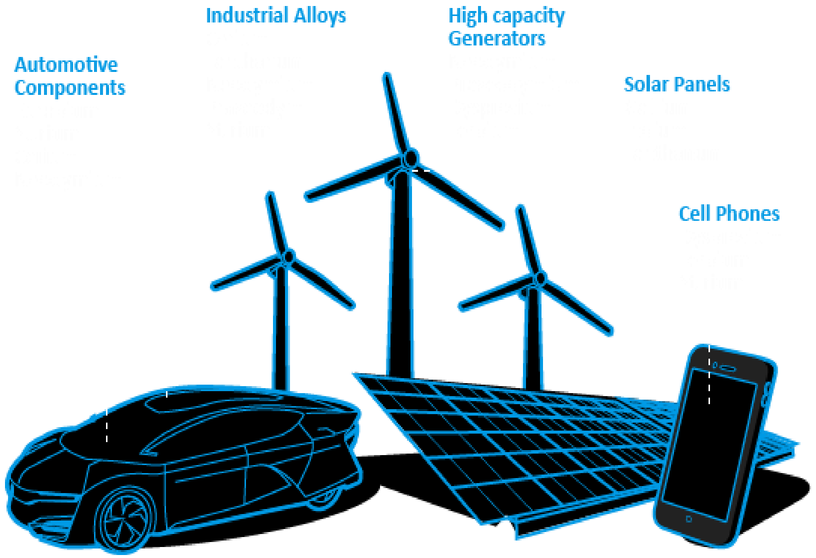
This presentation

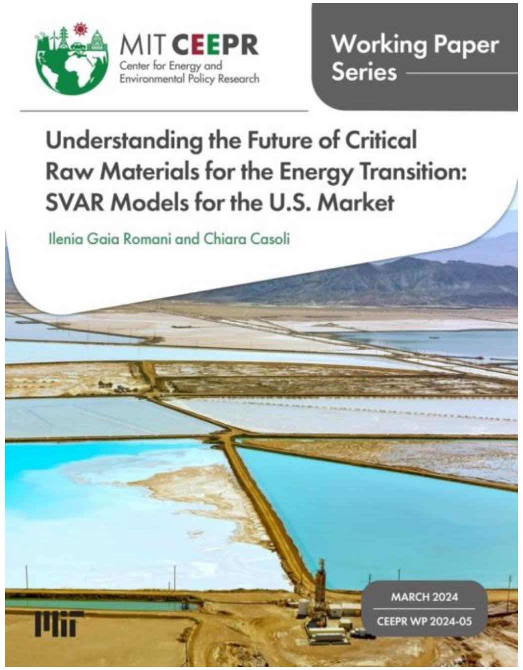
- Short background on Critical Raw Materials (CRMs) and their relevance
- Theoretical framework(s): *material-based technological paradigm* and Multinational Enterprises (MNE) technological accumulation
- Preliminary evidence on the relevance of CRMs in shaping MNE technological and internationalisation strategies
- Ongoing research

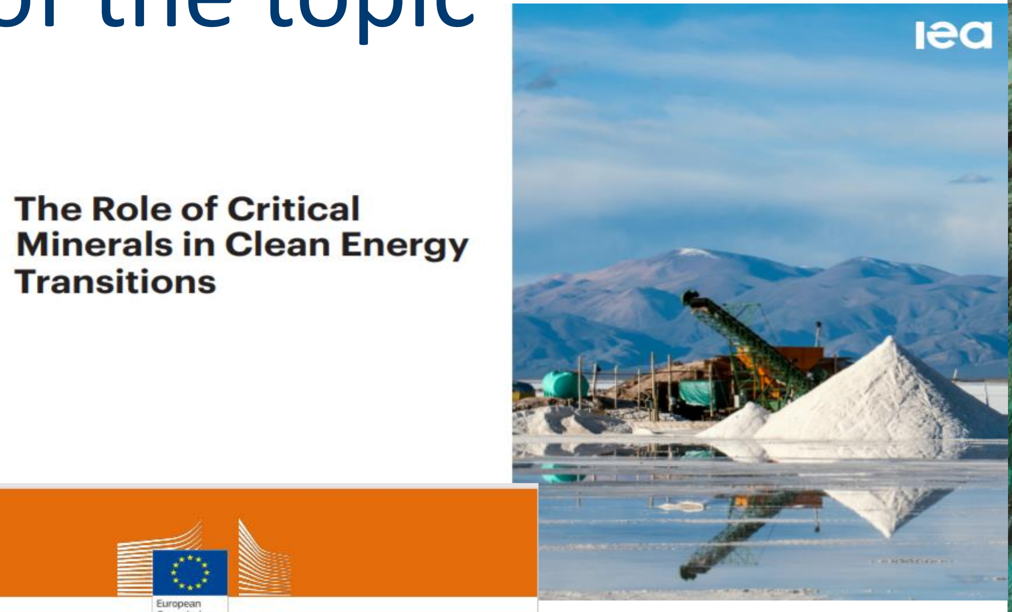
Short background on CRMs

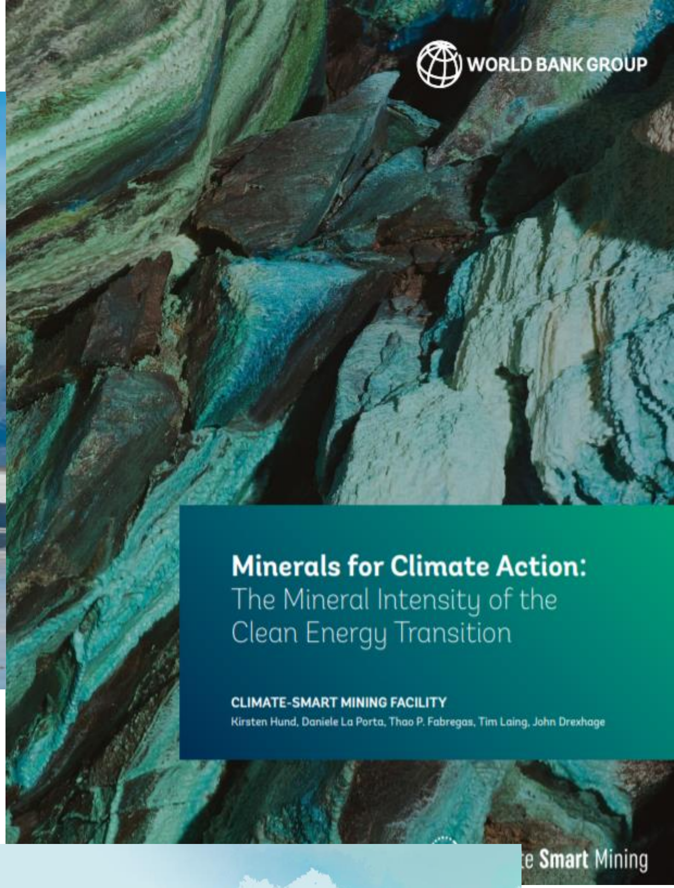
- CRMs are the «vitamins» or «spices» of industry – only used in small quantities, but providing essential chemical, mechanical and electrical properties
- Shift of global energy industry towards zero-carbon and digitalisation result in increasing demand for CRMs
- High and growing supply chain risks
- Previous work:
  - Diemer, A., Iammarino, S., Perkins, R., & Gros, A. (2022). Technology, resources and geography in a paradigm shift: the case of critical and conflict materials in ICTs. *Regional Studies* https://doi.org/10.1080/00343404.2022.2077326
  - Li, Y., Ascani, A. and Iammarino, S. (2024), The Material Basis of Modern Technologies - A Case Study on Rare Metals, *Research Policy* https://doi.org/10.1016/j.respol.2023.104914
  - Li, Y. and Iammarino, S. (2024). Critical Raw Materials and Renewable Energy Transition: The Role of Domestic Supply, GSSI WP #2024-04 https://www.gssi.it/images/discussion%20papers%20rseg/2024/DPRSEG_2024-04.pdf



General relevance of the topic







For example: the EU's worries

Critical Raw Materials are at the beginning of many industrial supply chains and their global demand is increasing:

Rare earths are key components of permanent magnets used in wind turbines motors

Lithium, cobalt and nickel are used in battery manufacturing

Silicon is used for semi-conductors

The demand of critical raw materials will increase in the next years:

EU demand for lithium batteries powering our electric vehicles and energy storage set to increase 12 times by 2030 (21 times by 2050)

EU demand for rare earth metals, used in wind turbines and electric vehicles set to rise 5 to 6 times by 2030 (6 to 7 times by 2050)

Source: https://ec.europa.eu/commission/presscorner/detail/en/fs_23_1663

The EU's dependence on CRMs

63% of the world's cobalt, used in batteries, is extracted in the Democratic Republic of Congo, while 60% is refined in China

97% of EU's magnesium supply is sourced from China

100% of the rare earths used for permanent magnets globally are refined in China

South Africa provides 71% of the EU's needs for platinum group metals

Türkiye provides 98% of the EU's supply of borate

SETTING 2030 BENCHMARKS FOR STRATEGIC RAW MATERIALS

EU EXTRACTION

At least **10%** of the EU's annual consumption for extraction

EU PROCESSING

At least **40%** of the EU's annual consumption for processing

EU RECYCLING

At least **15%** of the EU's annual consumption for recycling

EXTERNAL SOURCES

Not more than **65%** of the EU's annual consumption of **each strategic raw material at any relevant stage of processing** from a single third country

Source: https://ec.europa.eu/commission/presscorner/detail/en/fs_23_1663

Conceptual framework(s) in a nutshell

Innovation studies

- *Material-based technological regime* (following, e.g., Dosi 1988; Breschi et al. 2000; Dosi & Nelson, 2010)
- Material usage closely related to key properties of technological regimes (e.g. Renewable Energy industry):
  - Specific materials define the *knowledge base*, i.e. underpinning scientific axioms, strictly linked to material technologies (changing materials correspond to changes in scientific principles)
  - *Technological opportunities* emerging from new materials/new uses of old ones, enabling technological functions
  - *Appropriability* conditions shaped by the availability of the materials themselves

Supply chain management studies (e.g. Gaustad et al. 2018; Mouloudi & Evrard 2022)

- Supply chain risks due to geological scarcity, geographical concentration of reserves and production, political instability, geopolitical risks in global trade, low recycling and substitution rates
- Alternative strategy to global sourcing: diversification and increasing domestic supply of CRMs

International Business studies (e.g. Cantwell 1995. 2017)

- Strategic integration of geographically distinct paths of production and innovation
- Technological diversification and international expansion of MNE operations are both partly reflections of technological accumulation processes within the firm; technological innovation and internationalisation have become ever more interconnected over time

CRM and MNE strategies

- Technologies such as electric batteries, biofuels, fuel cells, wind and photovoltaic energy are at the core of decarbonisation and climate objectives. These technologies are mostly developed by large MNEs

Two broad research questions:

- ***Technological strategies:*** what/who are the trajectories, geographies and leaders in the emerging material-based technological paradigm?
- ***Internationalisation strategies:*** what are the location choices of CRM-user MNEs? Are they associated to their CRM-based technological strategies?

(Very) preliminary evidence

Data and method

- Text-mining CRM-related keywords in the descriptive text of USPTO patents from Orbis IP (for details Diemer et al. 2021, and Li et al., 2024): 2,150,070 patents granted to 153,545 firms globally during the period of observation 2013-2023
- Greenfield direct investment abroad (FDI) information obtained from Orbis Crossborder Investment dataset. 57,577 FDI projects (with positive investment values) from 19,853 MNEs (current direct owners) in 2013-2023. Link Orbis IP and Orbis greenfield investment datasets through firm ID
- Production* information for each CRM from British Geology Survey (BGS) and the United States Geology Survey (USGS): this includes both CRM minerals and metals (REE is reported as REE Oxide)
- CRM selection: all appearing on all the five lists published by some of the major world economies

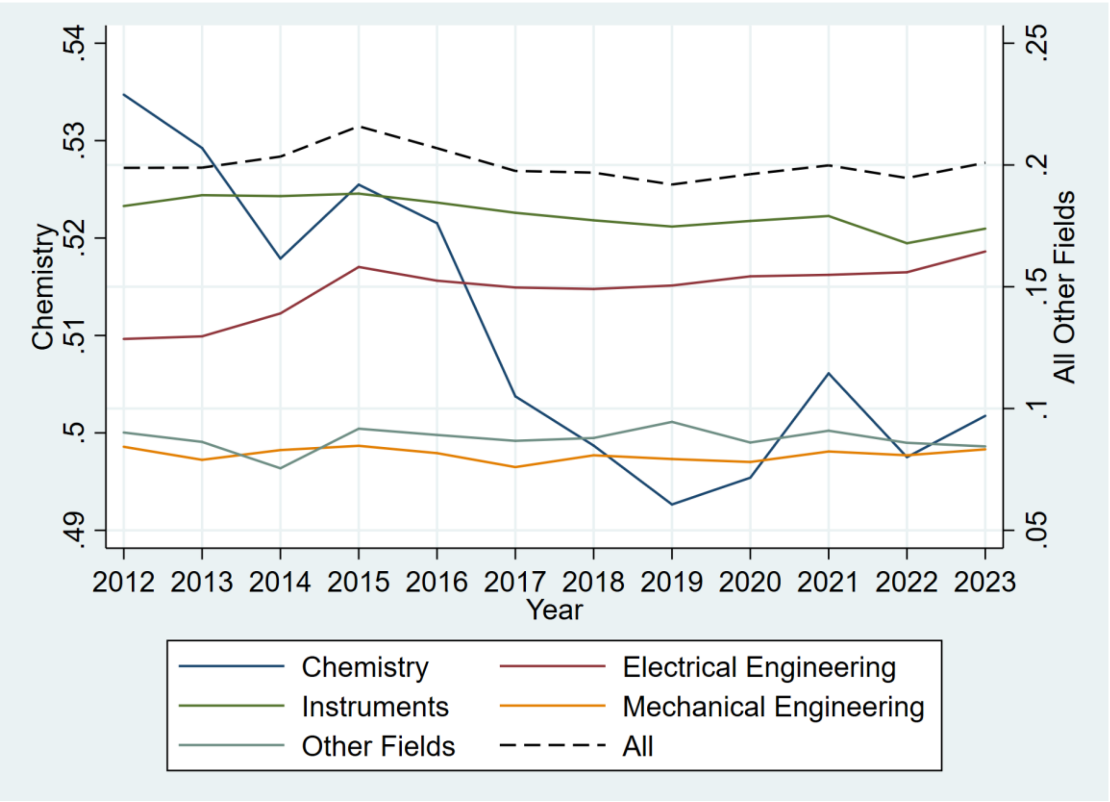
*Production is defined as domestic production of processed CRM materials after metallurgy and refining, independently from the source of raw minerals and ores

CRMs and patents

Table 1 - No. and share of USPTO patents mentioning each CRM (2013-23)

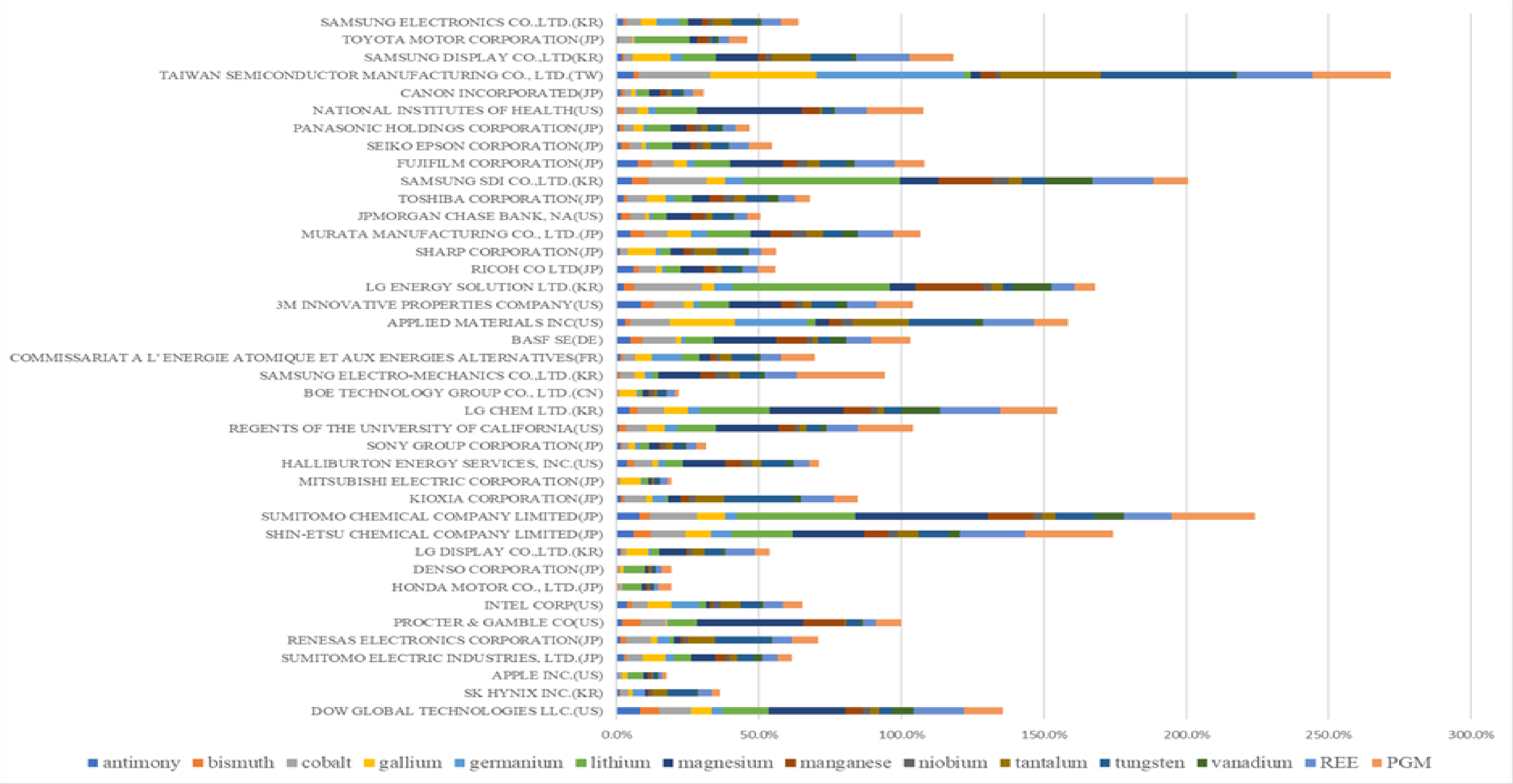
CRM	Patent number	Percent
antimony	26488	1.2%
bismuth	23605	1.1%
cobalt	79178	3.7%
gallium	60865	2.8%
germanium	45430	2.1%
lithium	125792	5.9%
magnesium	157385	7.3%
manganese	57248	2.7%
niobium	23659	1.1%
tantalum	48407	2.3%
tungsten	87667	4.1%
vanadium	30048	1.4%
REE	102975	4.8%
PGM	134508	6.3%
any CRM	428211	19.9%
Total patent no.	2150070	

CRM Patent Share Over Time by WIPO Field



CRMs and MNEs

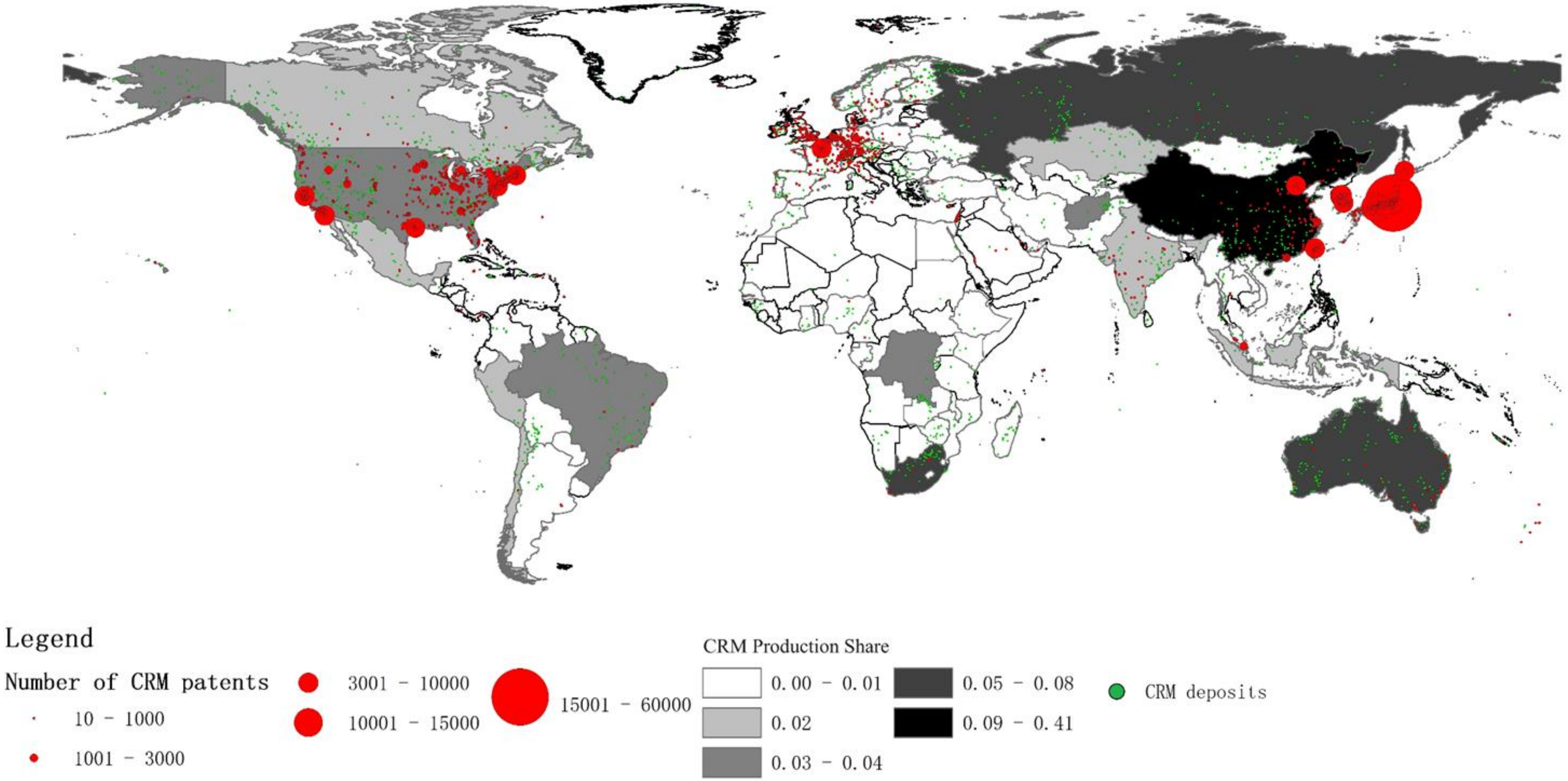
Share of patents using CRMs for the top 40 firms with highest number of CRM-based patents



Note: share of patents using each CRM. The sum of the shares can exceed 100% because a single patent can involve multiple CRMs

The geography of CRMs

Geographical distribution of CRM patent assignees, production shares and deposits (data sources: USPTO, BGS and USGS)



CRMs and MNE strategies

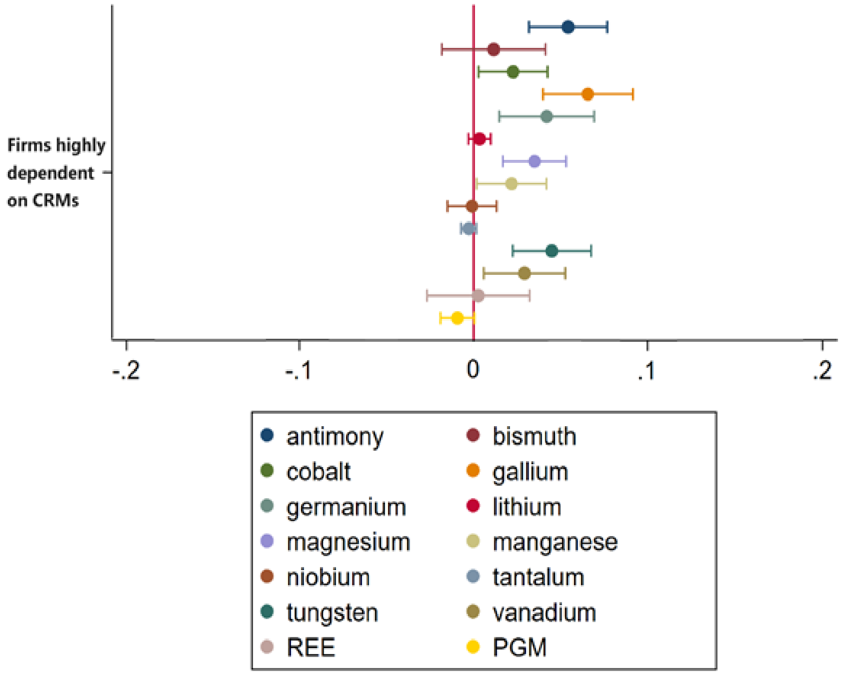
Average FDI value (total and by business function) for MNEs in Orbis IP (USD mil.) by technological CRM-dependence

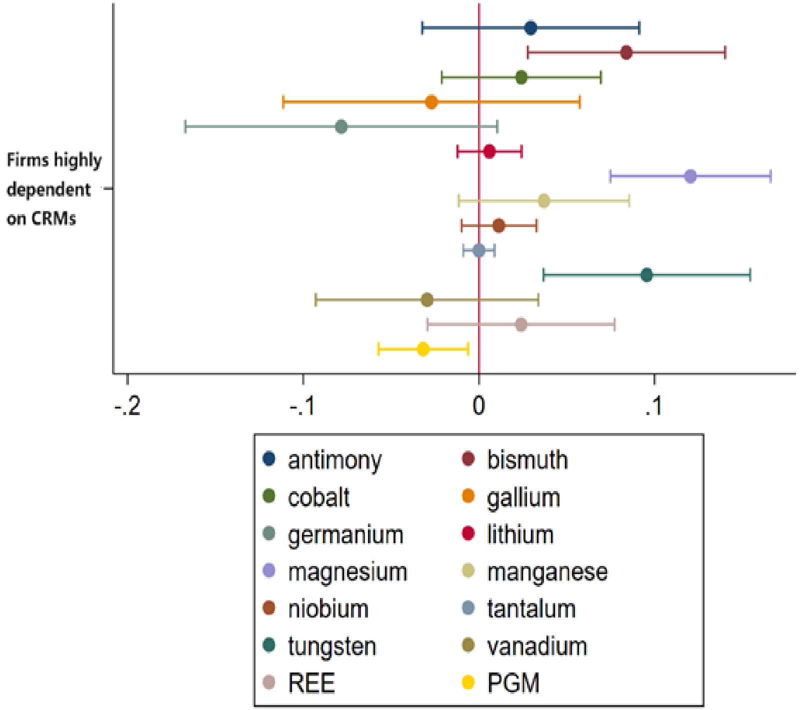
MNEs more technologically dependent on CRMs are more likely to engage in greenfield investment abroad

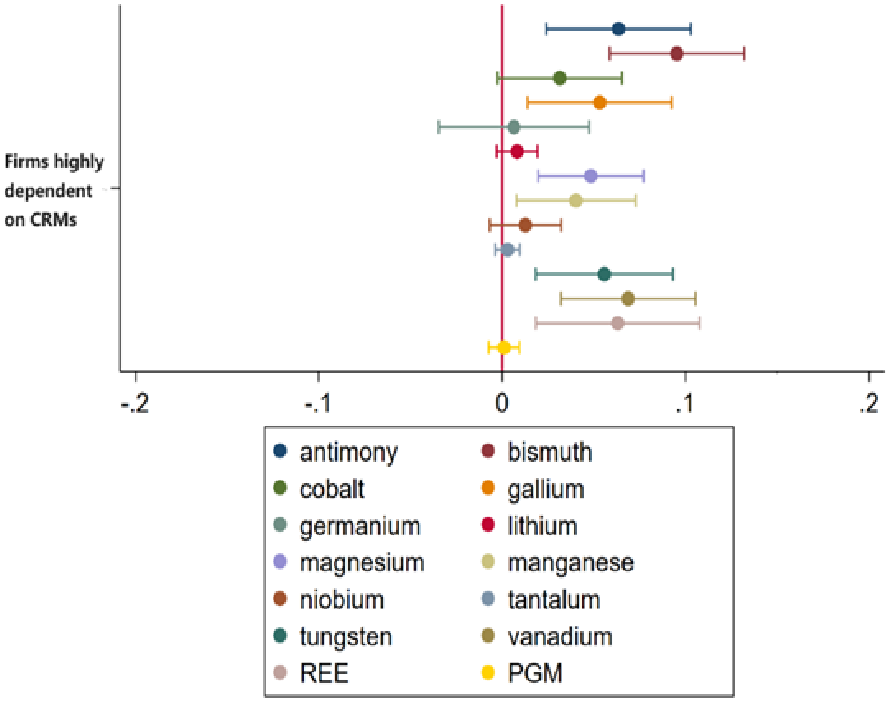
CRMs and MNE strategies (2)

For each CRM, how a firm's technological reliance on CRMs influences FDI location choices
Cross-firm and cross function comparison

Estimated coefficients for technological dependence on a CRM and preference for investing in countries producing this CRM: FDI in Production, Retail and R&D investments







Key messages and ongoing research

- Many industries important for the dual technological transition respond to a material-based technological regime; current changes in CRM-based GPTs can be overall conceptualised as a CRM-based paradigm shift
- Reinstating the importance of some strategic tangible assets in explaining MNE choices and behaviours
- MNEs with heavier technological reliance on CRMs (than the global average) seem not only more likely to engage in greenfield FDI abroad – thus implementing more complex internationalisation strategies – but they also choose to locate in the major producers of the CRMs they depend upon

Some ongoing research focusses on:

- different MNE strategies of sourcing CI … s in different institutional settings and by CRM
- competition for the same CRMs betwe … nd across (fine-grained) geography