The nature and direction of innovation in global value chains for wind energy technologies

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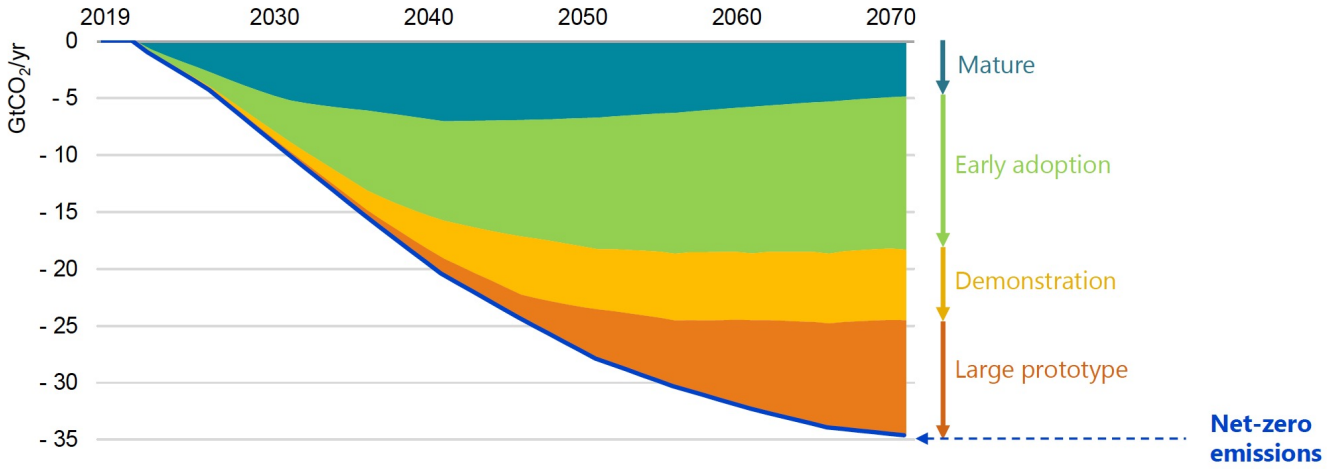
Meeting long-term decarbonization goals requires a time-horizon perspective for accelerating innovation

Net-zero emissions is not viable without a lot more innovation

Global CO_2 emissions reductions in the Sustainable Development Scenario, relative to baseline trends



Technologies at prototype or demonstration stage today contribute almost 35% of the emissions reductions to 2070; a further 40% comes from technologies that are at early stages of adoption.

Source: IEA, Global energy sector CO2 emissions reductions by current technology readiness category in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-2070, IEA, Paris

The direction of innovation in clean energy technologies depends on manufacturing locations in the GVC

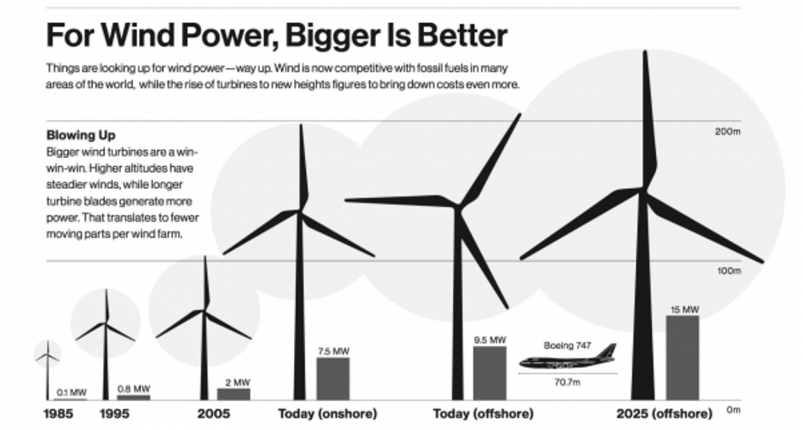
- measuring the direction of innovation: we develop a time-horizon perspective for when technologies would be needed and when to possibly expect outcomes (short-term, long-term)
  (extending beyond incremental vs. radical, product vs. process, high vs. low carbon etc.)

- where you manufacture may change the direction of innovation
  Manufacturing shifts to Asia (in automobiles and high-end optoelectronics) "may reduce innovation, domestically and globally, at least in the short to medium term" (Fuchs 2014, Science)

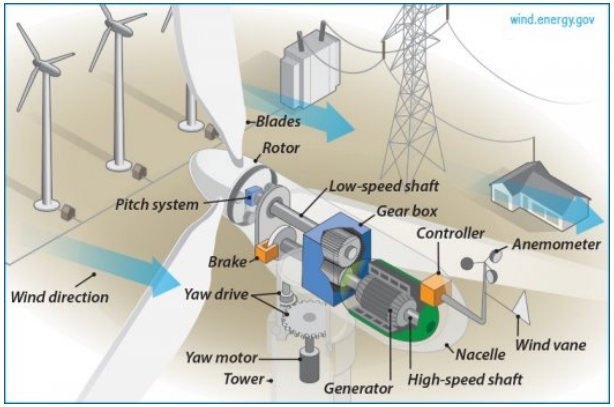
- manufacturing and innovation are globally dispersed (GVCs, global innovation systems)
  (e.g., Binz and Truffer, 2017, Pietrobelli and Rabellotti, 2011)

How does the location of suppliers in the global value chain impact the direction of innovation?

In the case of wind energy, technology innovation at the component level has led to bigger, better wind turbines



Source: MIT Technology Review, 2017



- **turbines**
- **OEMs** with large market shares
- **countries** and policies (EU and US -> China and India)

e.g., Lewis and Wiser 2007, Lewis 2012, Dai and Xue 2014, Qiu and Anadon 2012, Garud and Karnoe, Gosens and Lu 2014, Awate et al 2012

- **technology** characteristics
- **components** and **suppliers**
- **global value chain, global innovation system,** global industry

e.g., Binz and Truffer 2017, Pietrobelli and Raboletti 2011, Huenteler at al 2016, Haakonsson et al 2016, Jurowetzski et al 2018, Zhang and Gallagher 2016

Our approach: mapping GVCs and measuring the direction of innovation

- Mapping the global value chain for wind energy
- Analyzing the location of manufacturing in suppliers and OEMs
- Measuring the direction of innovation
- Analyzing the relationship between location and innovation in the GVC

Measuring and mapping the wind energy GVC

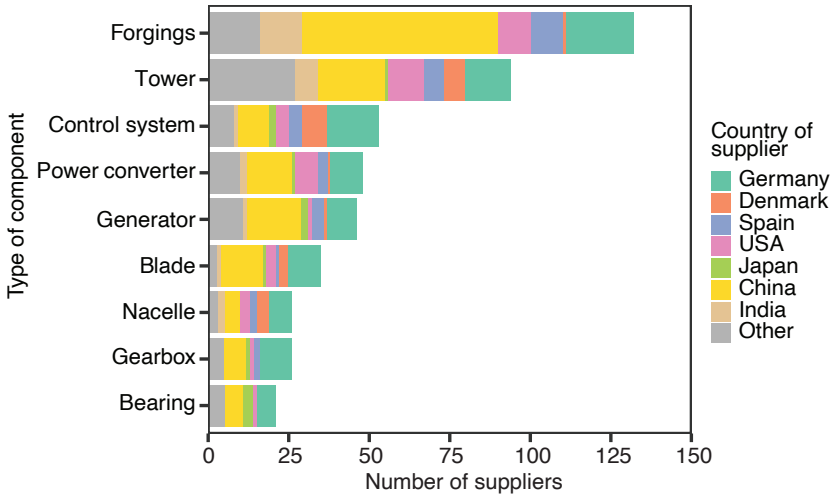
1. **Structuring GVC data** from unstructured wind industry reports*
   - 389 Suppliers
   - 9 Components
   - Over 1,000 relationships with 13 OEMs between 2006 and 2016

*Navigant Research. Supply Chain Assessment Reports

OEM	Supplier	In-house / Acquire / Outsource	Component	Origin Country of Supplier	Actual Location of Supplier	Start Year	End Year	Capacity (annual MW)
Vestas	Windcast	Acquire	Castings	Norway	Norway			
Vestas	VTC	Outsource	Castings	Germany	Germany	2013		
Vestas	Titan Wind	Outsource	Towers	China	Denmark			500
Vestas	Vestas	In-House	Nacelles	Denmark	Italy		2013	

2. Verification and additional data on **supplier firms****
   - Home location of firms
   - Size, founding year
   - M&A
   - Specialization in wind

**using Factset, Orbis, Bloomberg



Effects of technology complexity on the emergence and evolution of wind industry manufacturing locations along global value chains; Surana, Doblinger, Diaz Anadon, and Hultman, *Nature Energy*, 2020

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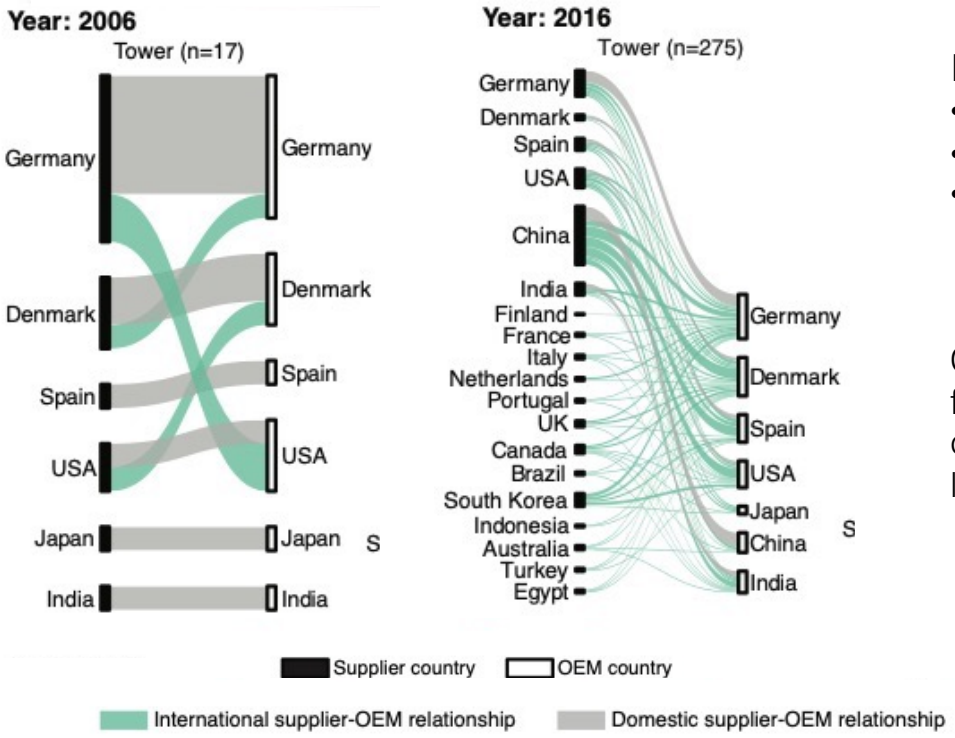
Analyzing the location of manufacturing: component suppliers increasingly work with OEMs from other countries: e.g., tower suppliers



Surana, Doblinger, Diaz Anadon, and Hultman, *Nature Energy,* 2020

Increase in:

- Number of **suppliers** (over x15)
- **Countries** with suppliers (x3)
- **International relationships** of suppliers (with foreign OEMs)

Countries and institutions, supplier firms, and component **technology** characteristics/**complexity** shape location in GVC

Estimating long-term and short-term innovation activity

Measuring the **direction of innovation** from the **content** of patents

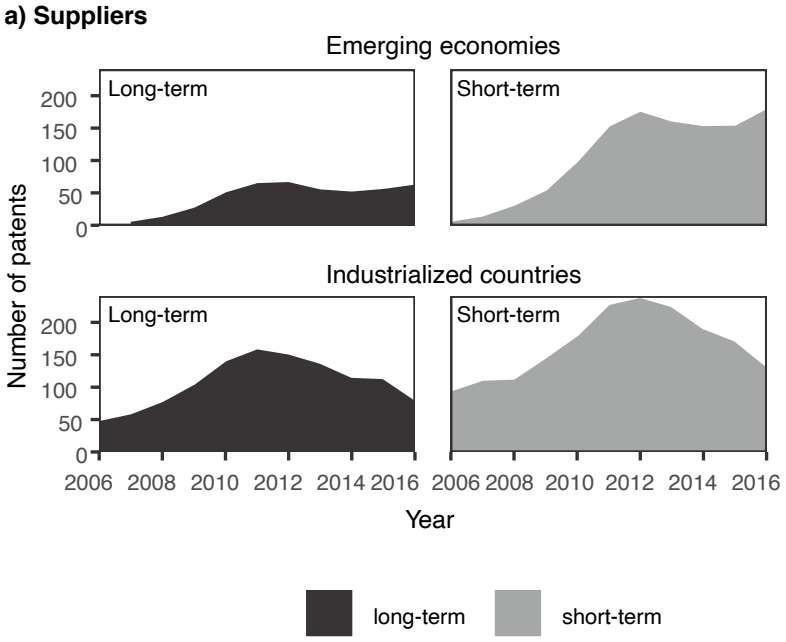
- >12,000 patents from suppliers and OEMs in our dataset
- clustering **patents** into what component / technology / improvement they refer to
  - Cooperative patent classification (CPC)
  - Topic modeling and Latent Dirichlet Allocation (LDA)
  - Term frequency
- identifying **short-term (and mid-term) and long-term** needs from International Energy Agency wind R&D reports and mapping them to patent content
  - short term/mid term examples: installation, assembly, adapting to environment conditions
  - long term examples: offshore

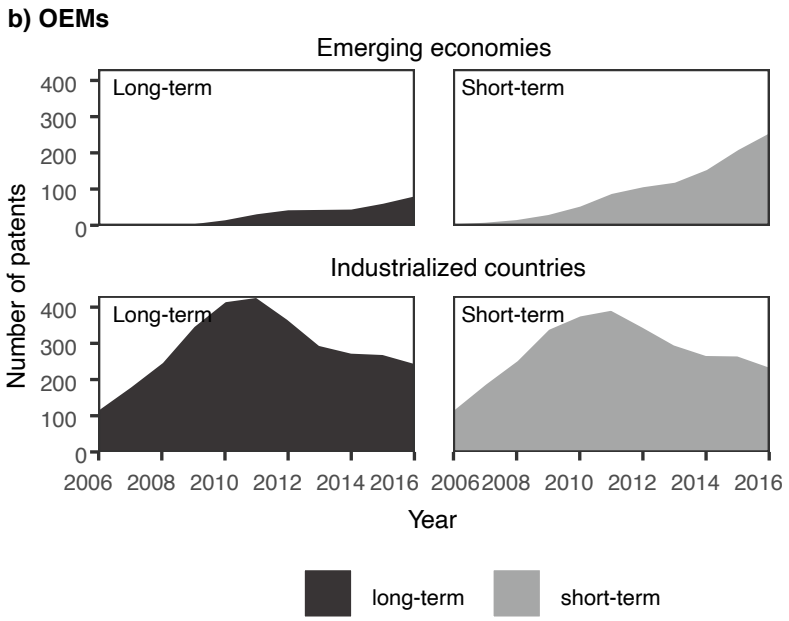
Research Topic	Description	Time-frame	Keywords searched in patent text	Patent title	OEM / Firm
Source: IEA			Source: Investigators' preliminary analysis		
Floating Offshore Wind Plants	Examine diverse system architectures and novel designs that may result in cost effective deployment of floating offshore wind plants in deep waters; studies should Include industrialization analysis and standardized load analyses.	2030 Long-term	float (word count: 11)	Method for operating safety system in floating wind turbine on sea bed, involves altering operational parameter of floating wind turbine based on either or both of fore-aft inclination signal and side-to-side inclination signal	Vestas

CPC: F03D13/25 Arrangements for mounting or supporting wind motors; Masts or towers for wind motors - specially adapted for offshore installation

Both component suppliers and OEMs can shape the direction of innovation

- Both component suppliers and OEMs contribute to shaping the direction of innovation
- Patenting activity **increased or stabilized** in component suppliers from emerging economies



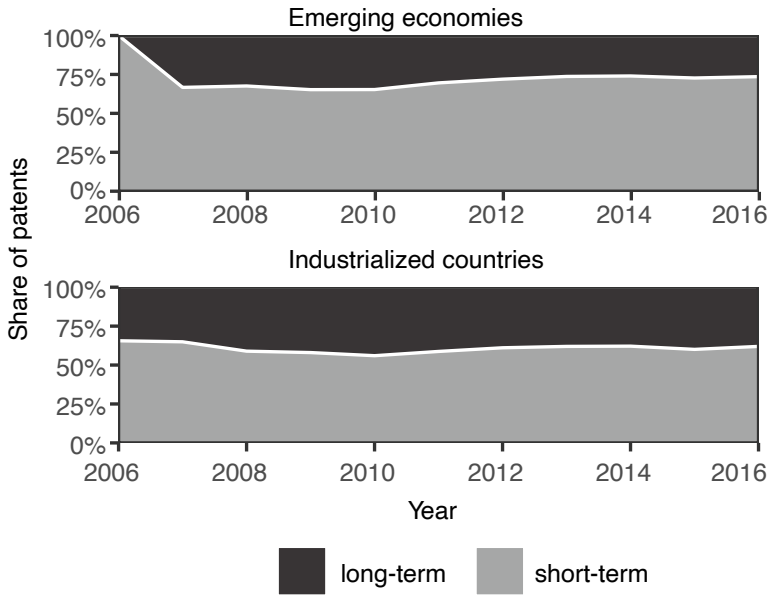


3 year moving averages

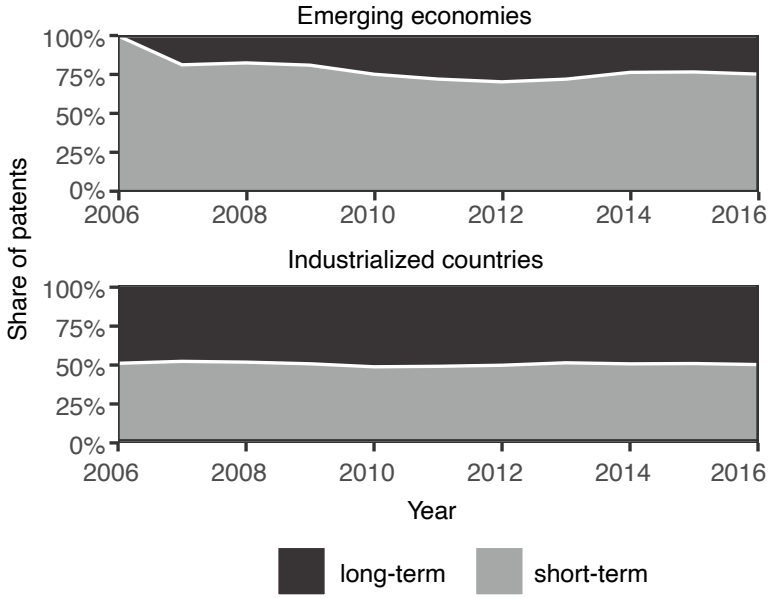
The share of long-term innovation in industrialized countries did not decrease over time

- Both types of component suppliers have similar shares of short- and long-term patents
- Emerging economies somewhat behind on long-term innovation, especially from OEMs

c) Share of long-term and short-term patents for suppliers



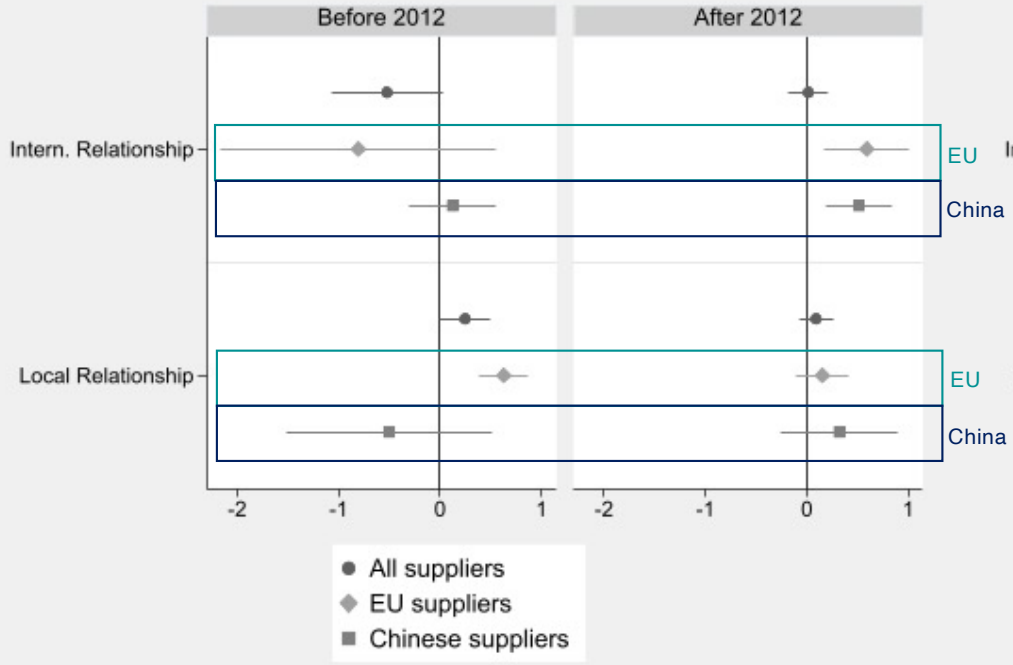
d) Share of long-term and short-term patents for OEMs



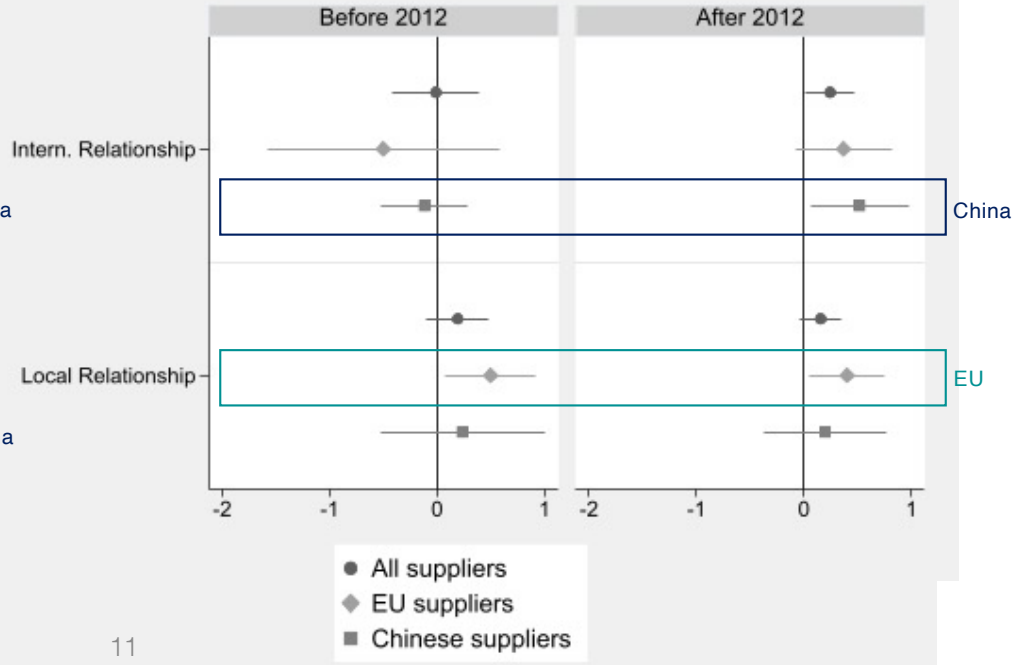
Shifts of market growth and manufacturing to emerging economies (primarily China) did not reduce long-term innovation

- Long-term innovation outcomes depend on where demand is growing (comparing sample splits before and after 2012)
- Negative binomial regressions: international relationships did not decrease long-term innovation in the EU after 2012
- International relationships linked to demand matter more for long-term innovation, rather than the country of origin of the component supplier

a) Drivers of long-term patenting



b) Drivers of short-term patenting



Takeaways on the location of manufacturing and the direction of innovation in wind energy GVCs

- Innovation in clean energy has a time horizon: new approaches combining data science and technology specific insights can help analyze the direction of innovation

- Innovation occurs in the GVC, with suppliers and OEMs: mapping GVCs is essential for approaches to accelerate clean energy innovation

- Changes in the direction of innovation with changes in the location of manufacturing: Manufacturing shifts to the 'east' did not directly translate to decrease in long-term innovation in the wind energy industry, in the study period

- Future research:
  - improving measurement of the direction of innovation using machine learning and data science
  - analyzing the relationship between location and direction of innovation using regressions
  - assessing the importance of demand at the regional level in China
  - tracing knowledge flows between OEMs and suppliers and their impact on long-term innovation

Thank you for your attention

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