From catching up to industrial leadership: Towards an integrated market-technology perspective

– An application of semantic patent-to-patent similarity in the wind and EV sector –

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Background & Motivation
what is catch-up in emerging economies?

Empirical context

- Emerging economies using industrial policy to catch up in green sectors [Capozza and Samson, 2019; D. Rodrik, 2014]
- China, the “green giant” [Jaffe, 2018][1]
- Yet: Surpassing incumbents in Solar PV [Fu and Gong, 2011], wind power [Lewis, 2012] and EV [Li et al., 2018]

What means leadership?

- Technological capability
- Existing literature: Market share
- but also novelty + impact

[1] higher greenhouse gas emission than EU + USA

Background & Motivation

Methodological novelty and contribution

Technological development

- Patent analysis has been around
- Counting exercises
- Citation based analysis has limited value

Overall contribution

- Patent quality indicators [Basberg, 1987]
- Integrated Market-Technology framework building on [Jung and Lee, 2010]
- EV & Wind Power in China vs. South Korea and Japan

The questions that we are trying to answer:

- What implications does sector-specificity have for market vs. technology catch-up and leadership?
- What should latecomers countries consider when entering a new sector?
- Which trajectories and detours can latecomers take to avoid market and technology traps?

From technological change to catch-up cycles

- Learning and capacity building (and risk taking)
- **Windows of opportunity** (WOO) represent time-anchored context structures within Sectoral Systems (SSI)
- WOOs are *Shifts in the techno-economic paradigm*: Leapfrogging opportunities [Lee and Malerba, 2017b]
- **Catch-up cycles**: Successive changes in industrial leadership → WOOs + Firm reaction [Lee and Malerba, 2017a]
- Motorola → Nokia → Samsung → Huawei (?)

WOOs?

- Initially: Significant technological innovation [Perez and Soete, 1988]
- Later: market demand
- institutional setting

Theoretical Background
Catch-up strategies

Strategies are not mutually exclusive [Malerba and Nelson, 2011].

Path Following

- adopting first generation technology
- risk of middle income trap
- not suitable in green-tech: path-dependency, asset-specificity, high upfront investment

Stage Skipping

- adoptiong up-to-date tech
- following incumbent but using new tech trough conventional tech-transfer
- IPR can make tech upgrading problematic

Theoretical Background

Catch-up strategies and SSI as context structure

Path Creating

- Leapfrogging [Perez and Soete, 1988]
- risky but untactful if it works
- overcoming the “catch-up paradox”

SSI - as an “enabling constraint”

- Catch-up more likely in sectors with predominantly explicit knowledge regimes
- electronics vs. automobile
- short life cycle

Theoretical Background
Measuring catching up and industrial leadership

Market-oriented view [Mowery, D., Nelson, 1999]

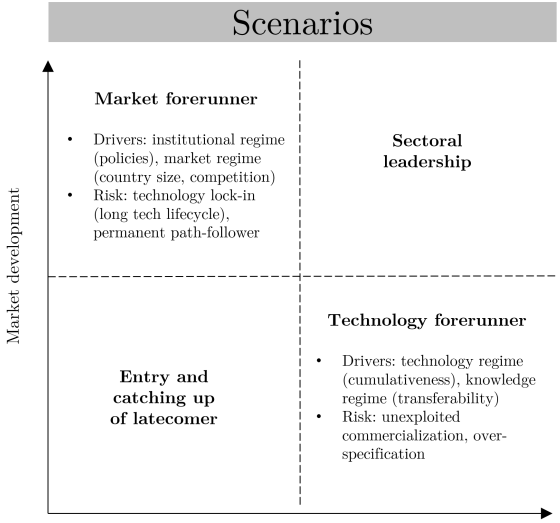
- superior production or marketing strategies
- global market/production shares of a country's lead firm

Technology-oriented view [Bell and Pavitt, 1993; Lall, 1992]

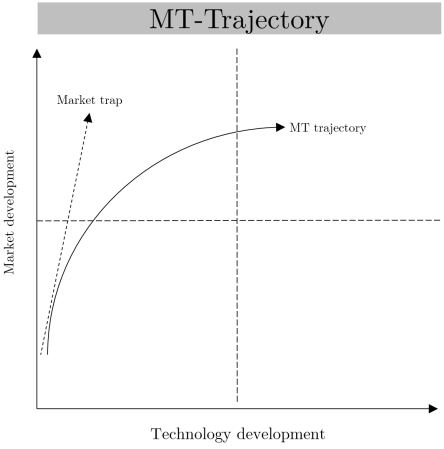
- superior tech. and innovation capabilities
- basic, intermediate, advanced, world-leading
- often firm-level but acknowledgement of external sources

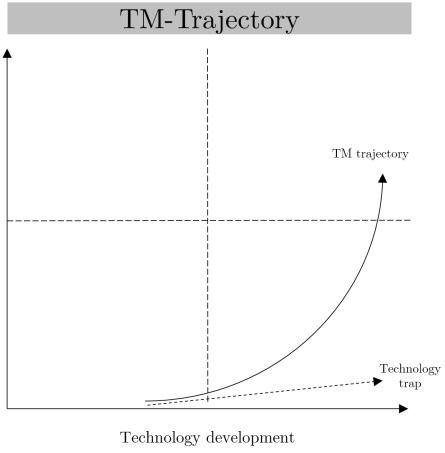
In the case of India and China having large domestic market shares $\neq$ developing novel tech
Korea and Japan have tech but not the same conditions to scale up

The market-technology matrix
Towards an integrated perspective



Trajectories and traps
in the market-technology matrix





Analysitical approach
What we do, how, and why

Patents & innovation performance: What we know...

- Technological & economic significance of patents varies broadly [Basberg, 1987].
- Consequently, the quality rather than number of patents more informative.

Patent Quality: What's been done so far

- Number/composition of IPC assignments [Lerner, 1994].
- Backward [Shane, 2001] & forward [Trajtenberg et al., 1997] citations.
- Lately, first attempts to introduce text (keyword) based indicators [Arts et al., 2017].

Methodological approach
What we do, how, and why

What we do instead...

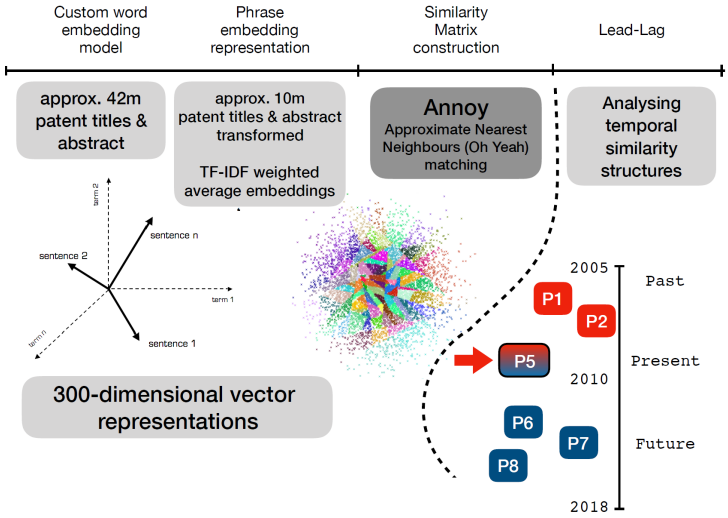
1. Exploit rich textual information with semantic embedding techniques to capture technological signatures.
2. *Relational mapping* of similarity structures between patents (network analysis).
3. Temporal mapping of technological similarity between patents (lead-lag analysis).

The details

1. EPO's Patstat autumn 2018 edition
2. 1980 - 2017
3. Only priority filings; One patent per extended (INPADOC) patent family
4. earliest granted filing with English abstract available
5. $\rightarrow$ 12 million observations
6. inventor level rather than applicant

Methods: Pipeline Overview

Our Approach in a Nutshell



Methodological approach

Semantic search – a non-EV and non-wind example

Search for “bad horror”

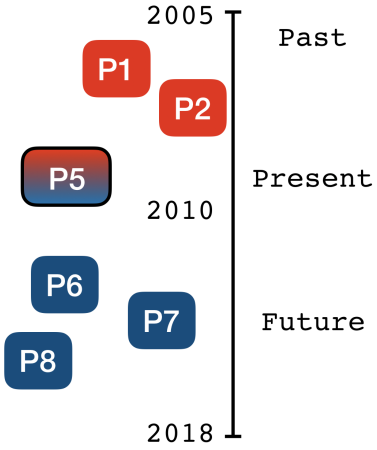
One of my best friends brought this movie over one night with the words ’Wanna watch the worst horror movie ever?’ I always enjoy a good laugh at a bad horror flick and said yes. I had expected your typical cheesy b-slasher but this was beyond B. This is Z-slasher, the lowest of the low.

As long as you go into this movie knowing that it’s terrible: bad acting, bad "effects," bad story, bad... everything, then you’ll love it. This is one of my favorite "goof on" movies; watch it as a comedy and have a dozen good laughs!

Methods: Similarity-to-Quality

Temporal similarity: Intuition

- Semantic similarity independent of time.
- Temporal similarity distribution can be exploited
- Inspired by the lead-lag approach of Ramage et al. [2010]; Shi et al. [2010].



Methods: Similarity-to-Quality

Temporal similarity: Types

Similarity to past: Novelty

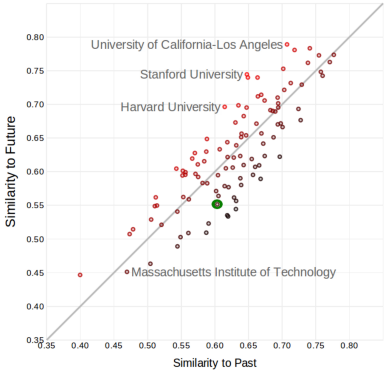
- Exploitation of existing knowledge.
- High values might indicate backward orientation, low values indicate novelty.

Similarity to present: Popularity

- “Riding the wave”, indicates activity in a trending area.

Similarity to future: Impact

- Shaping the agenda, indicator of future impact.
- Also: Indicator of “Window-of-Opportunity”, high growth technological field.



Technology cases
Wind & EV - mutual WOOs?

IPC classes for selection of relevant patents

Wind

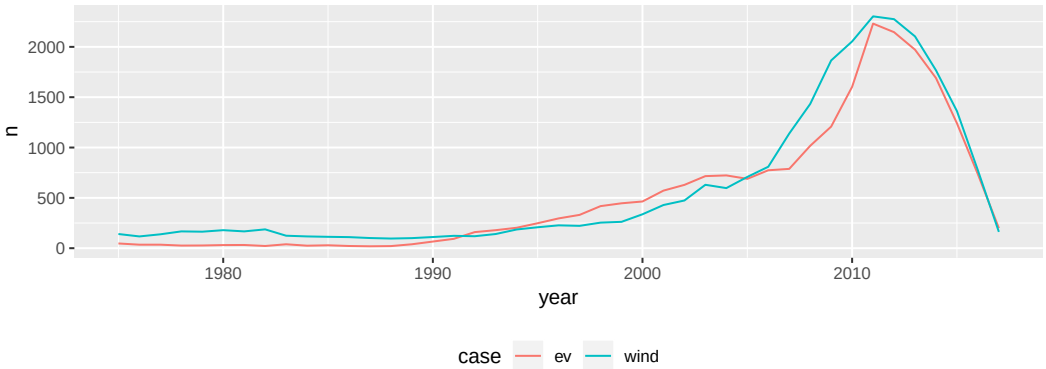
- Relatively mature second-generation technology
- offshore / onshore / hybrid
- wind tech class `F03D-*` but also `B63B` for maritime techologies
- overall 25k patent families

EV

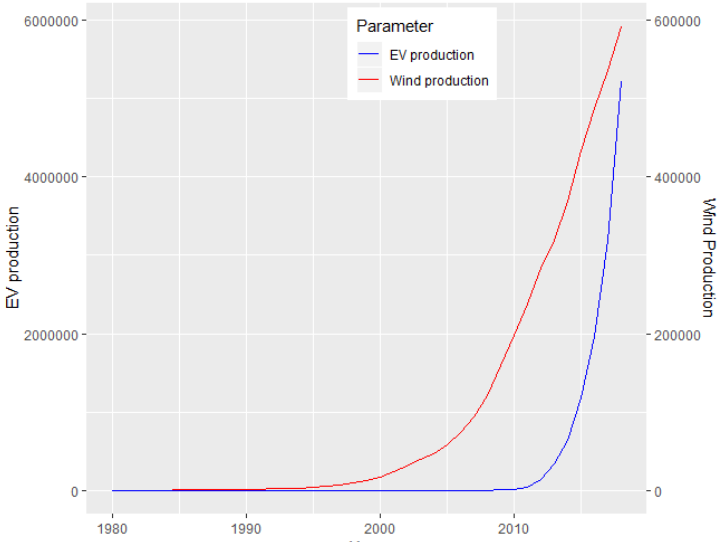
- Diversity of technologies: Battery-electric, hybrid-electric, range-extended electric, fuel-cell
- Focus: electric propulsion
- Class: `B16L11/-` – “Electric propulsion with power supplied within the vehicle”
- `B16L11/00` were used to exclude marine vehicles – likely home for EVs
- 22.285 patent families

Industrial Evolution

Number of patents by technology over time



Industrial Evolution
Cumulative production



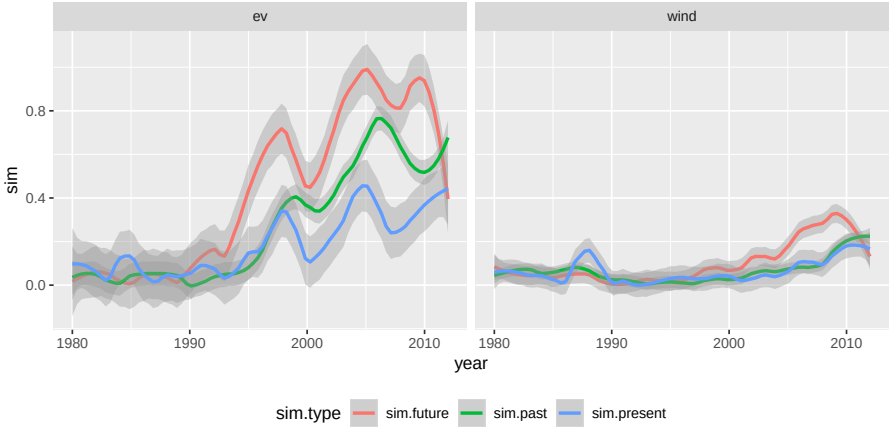
- EV: *science-based* innovation mode vs. early wind DUI
- R&D with the automotive sector: Exploration but no exploitation
- Diversity in designs - variation in ratios across countries

Industrial Evolution
Novelty and Impact

- EV patents more similar in general than wind
- Breakthrough inventions – down-right?

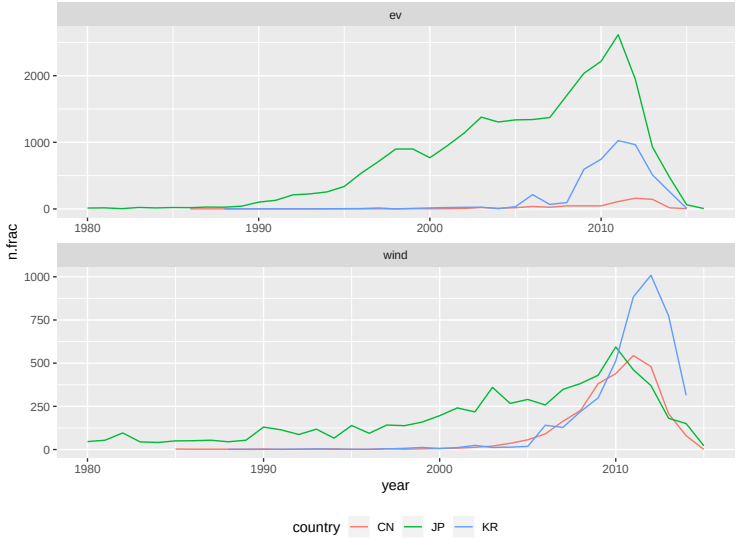
Industrial Evolution

Over time similarity



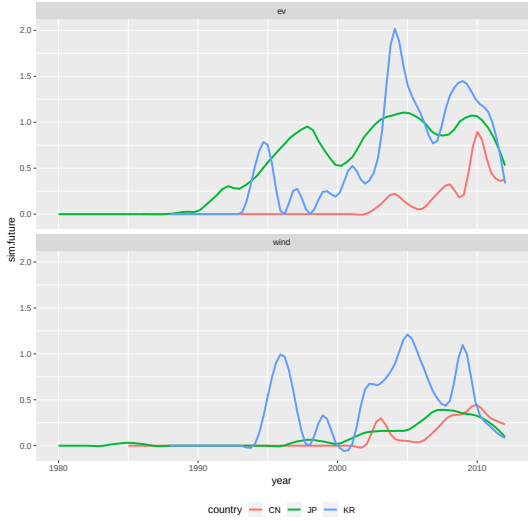
Industrial Evolution

Patenting per country



Industrial Evolution

Over time similarity per country



Market development
Wind & EV - Exploitation

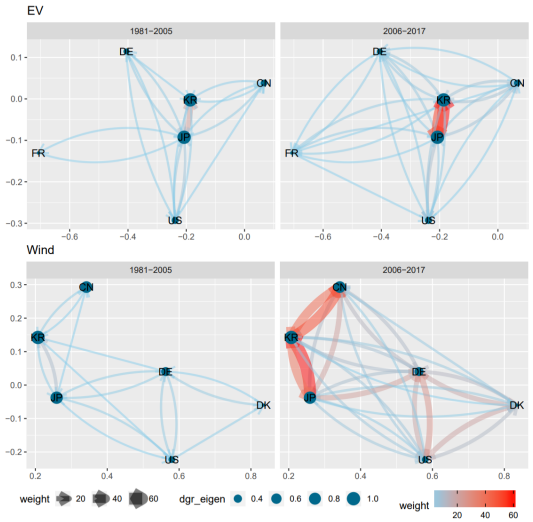
EV

- Japan and Korea had strong technological impact but did not realize market impact
- from 2009 slow market build up (second WOO)

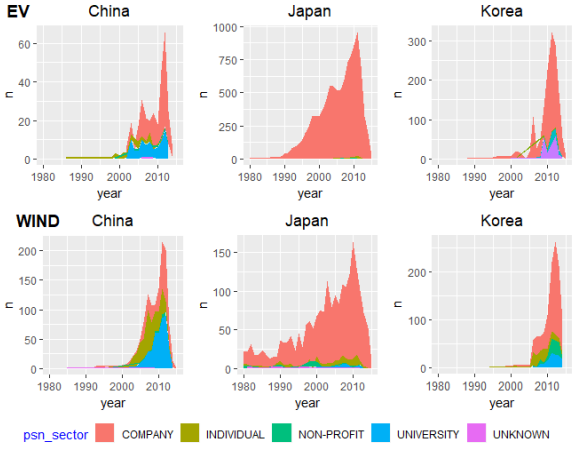
Wind

- Japan and Korea cannot manage to create same level of impact as in EV
- among the slowest growing countries despite high levels of patenting and impact
- China: market growth with little high-value knowledge creation (patenting)

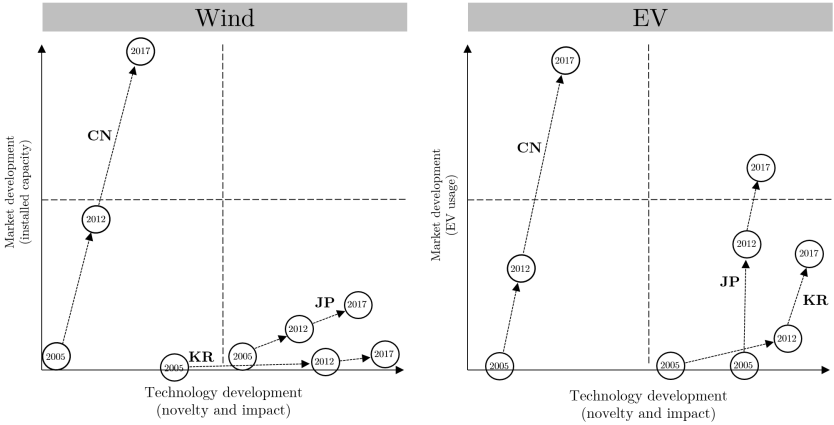
Knowledge flows
Similarity vs. Geography



Knowledge development
applicant type over time



Catch-up pathways



The End

Fin.

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Table: IPC-classes EV

IPC class	Level	Description
B60L 11/00	Subgroup	Electric propulsion with power supplied within the vehicle
B60L 11/02	Subgroup	Using engine-driven generators
B60L 11/04	Subgroup	Using dc generators and motors
B60L 11/06	Subgroup	Using ac generators and dc motors
B60L 11/08	Subgroup	Using ac generators and motors
B60L 11/10	Subgroup	Using dc generators and ac motors
B60L 11/12	Subgroup	With additional electric power supply, e.g. accumulator
B60L 11/14	Subgroup	With provision for direct mechanical propulsion
B60L 11/16	Subgroup	Using power stored mechanically, e.g. in flywheel
B60L 11/18	Subgroup	Using power supplied from primary cells, secondary cells, or fuel cells

Table: IPC-classes Wind

IPC class	Level	Description
F03	Class	Wind energy
H02K 7/18	Subgroup	Structural association of electric generator.
B63B 35/00	Subgroup	Structural aspects of wind turbines.
E04H 12/00	Subgroup	Structural aspects of wind turbines.
F03D 11/04	Subgroup	Structural aspects of wind turbines.
B60K 16/00	Subgroup	Propulsion of vehicles using wind power.
B60L 8/00	Subgroup	Electric propulsion of vehicles using wind power.
B63H 13/00	Subgroup	Propulsion of marine vessels by wind-powered motors.

Backup
slides

Table: EV Market figures

	EVs stock			EVs sale			EVs share		Trade in 2018*		
	2009	2012	2018	2009	2012	2018	2012	2018	Im	Ex	Net EX
China	0.48	16.88	2306.30	0.48	9.90	1078.53	0.16%	4.74%	$1200	$129.8	$-1070.2
Japan	1.08	40.58	255.10	1.08	24.44	49.75	0.58%	1.13%	$69.8	$389.4	$319.6
Korea	NA	0.85	59.60	NA	0.51	33.68	NA	2.21%	$231	$1100	$869
World	7.48	182.82	5122.46	2.32	118.68	1975.18	0.09%	1.21%			

In thousand EVs. * In million USD Source: [Bunsen et al., 2019; Workman, 2019]

Table: Wind Market figures

	Installed Capacities (MW)			Global share		
	2006	2012	2018	2006	2012	2018
China	2599	75564	211392	3.5%	26.8%	35.7%
Japan	1309	2614	3661	1.8%	0.9%	0.6%
Korea	176	483	1302	0.2%	0.2%	0.2%
World	74151	282482	591549			

Source: [EPI - Earth Policy Institute, 2016; GWEC, 2019]

Backup
slides

Table: Comparing market regimes

Sector	Country	# OEMs	Lead firms	Cumulative capacity (GW/stock in k)	Top-1 market share (% domestic)
Wind	CN	19	Goldwind, Envision, Mingyang, Guodian United Power, CSIC Haizhuang	188.3 GW	26 %
	KR	4	Doosan, Unison, Hanjin, Hyundai	1.1 GW	58%
	JP	2	Hitachi, Mitsubishi	3.5 GW	37%
EV	CN	16	BYD, Geely, Jiangang, BAIC, SAIC	1227.7k	30%
	KR	<5	Hyundai, Kia, RSM	25.9k	40%
	JP	<5	Toyota, Mitsubishi, Nissan, Honda	205.3k	NA

Source: FTI [2018]; GWEC [2018]; Ou et al. [2017]. Note: Data as in 2017. No exact data available for OEMs EV in JP and KR as EV is not listed separately. Market share of largest KR wind turbine OEM Hyundai is <10%; listed share by Danish Vestas. In Japan, the largest local wind OEM Mitsubishi accounts for <15%, yet formed a joint venture with Vestas in 2013. Listed share by MHI Vestas.