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Mapping Technological Trajectories in a mature TIS under pressure (work in progress)

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Introduction

- Markard (2018) introduces a new framework to outline the development of **Technological Innovation Systems (TIS)** over time: **TIS life-cycle**

Motivation:

- Sustainability transitions are not only concerned with the emergence of sustainable technologies but also with the **decline of un-sustainable ones.**

➢ Studies are needed which investigate the **central mechanisms of technology decline and the transition between the phases of the TIS life cycle.**

TIS life cycle framework (Markard 2018)

*"A **technological system** may be defined as a **network** of agents interacting in a specific economic/industrial area under a particular **institutional infrastructure or set of infrastructures** and involved in the generation, diffusion, and utilization of **technology**."* (Carlsson and Stankiewicz 1991: 111)

- A technological innovation system is situated in a larger **context:** actors, networks, institutions and technologies outside the TIS. (Bergek et al. 2015a, Markard et al. 2016)

TIS-Life cycle framework:

- 4 phases: formative, growth, mature and decline phase.
- **Transformational process between phases.**
- During transformation a **TIS is under pressure.**
- Transformation by means of **different dimensions** of the TIS

Transformation of the Technology Dimension in mature TIS

Focus: technological dimension – **changes in the direction of technological development**

- ***Technological trajectories (Dosi 1982) describe the direction of technological development in TIS.*** *(*Carlsson and Stankiewicz 1991, Hekkert and Negro 2009, Hekkert et al. 2011, Bergek et al. 2015b, Stephan et al. 2017)

Possible transformation pathways of **mature TIS** (Markard 2018):

- Novel technology dies out early, old technology prevails
- Old technology ceases to exists or survives in niche applications
- **Decline delayed or interrupted by re-configuration**
  - **Visible as changes in the direction of technological development?**

Empirical Case: internal combustion engine

For the empirical case we define the internal combustion engine (ICE) as the **focal technology** of our TIS

- Transformational pressure on the internal combustion engine TIS (Sushandoyo et al. 2012, Dijk et al. 2014)
  - Rising fuel prices and greenhouse gas regulation
  - Rise of competing TIS: fuel cell and electric battery powertrains

- Internal combustion TIS faces a **transformation from mature to decline phase**

Research Questions

1. What are the dominant technological trajectories in the internal combustion TIS?
2. Do we observe some kind of re-configuration in the technological development of ICE?

Methodology

Patent citation networks capture can capture the technological development in terms of knowledge creation and search processes (Verspagen 2007, Mina et al. 2007, Fontana et al. 2009)

Main Path analysis in patent/publication citation networks allows to reveal **technological trajectories** and changes thereof. (Hummon and Doreian 1989, Verspagen 2007, Mina et al. 2007, Fontana et al. 2009, Liu et al. 2012, Martinelli 2012, Ho et al. 2014, Kim and Shin 2018)

- **Main path algorithm** identifies the most important patents and **streams of knowledge** in the network
- Each citation link is weighted based on the number of citations and its position in the network
- **Search Path Count (SPC)** indicator is used for weighting the network. (Batagelj 2003)

Methodology

IPC codes can provide an overview of the underlying technology and its trajectories. (Hekkert et al. 2011)

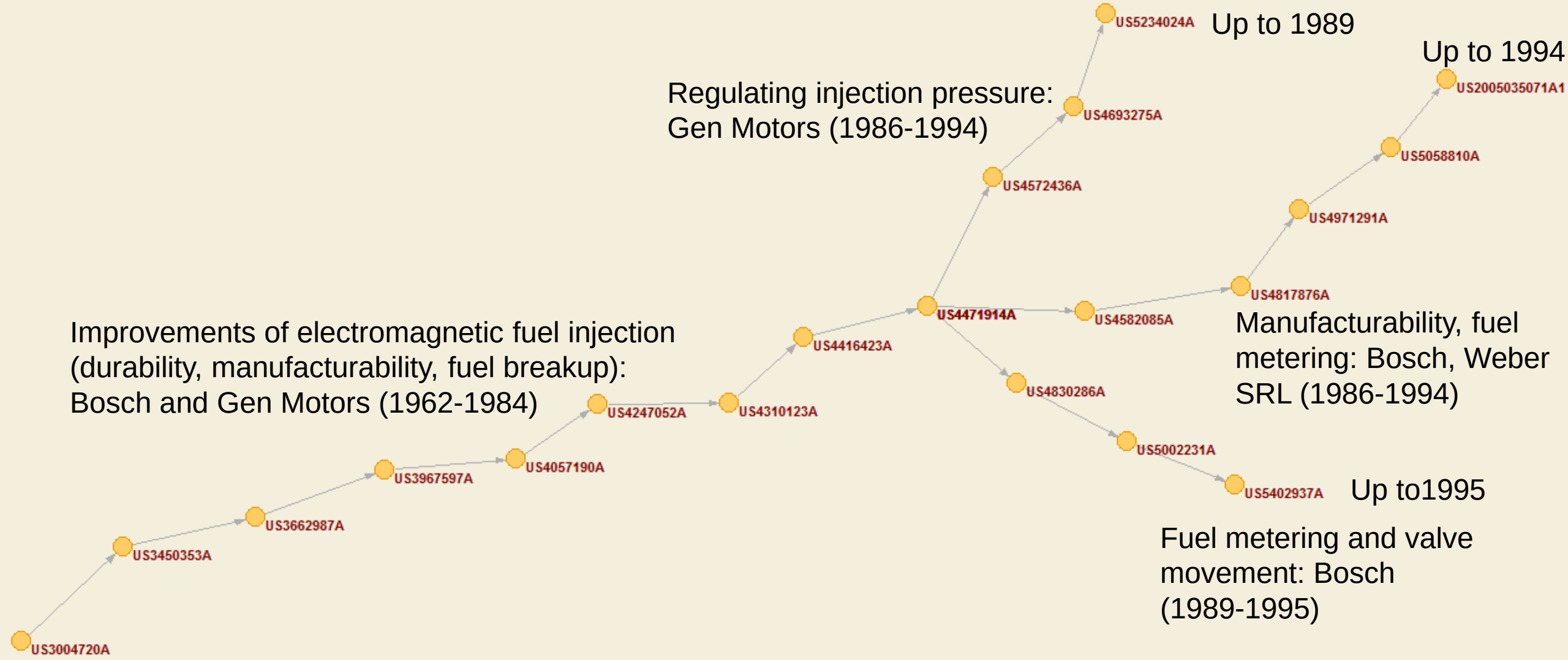
- F02B/D/F/M/N/P for internal combustion engine. (Aghion et al. 2016)
- Patent data retrieved from PatentInspiration with forward citations. (Hummon and Doreian 1989)
- 221700 patents with 323374 citations in the final dataset.

Development of the dominant Trajectories over time

- **Global Main Path**: Search for the path whose sum of SPC is the highest.
- Global Main Paths are calculated for subsequent time periods: (t, T), (t, T+1), ... , (t, T+n), t=1900. (Verspagen 2007, Mina et al. 2007, Fontana et al. 2009, Martinelli 2012)

➢ How has the dominant **direction of knowledge creation** developed over time?

Development of the dominant Trajectories over time: (1900, 1980) – (1900, 1995)



Development of the dominant Trajectories over time: (1990, 1996) – (1900, 2002)

Improvements of fuel tank filters: suction efficiency, manufacturability, effective filtering area: Nifco, Japan, Gen Motors (1957-1991)

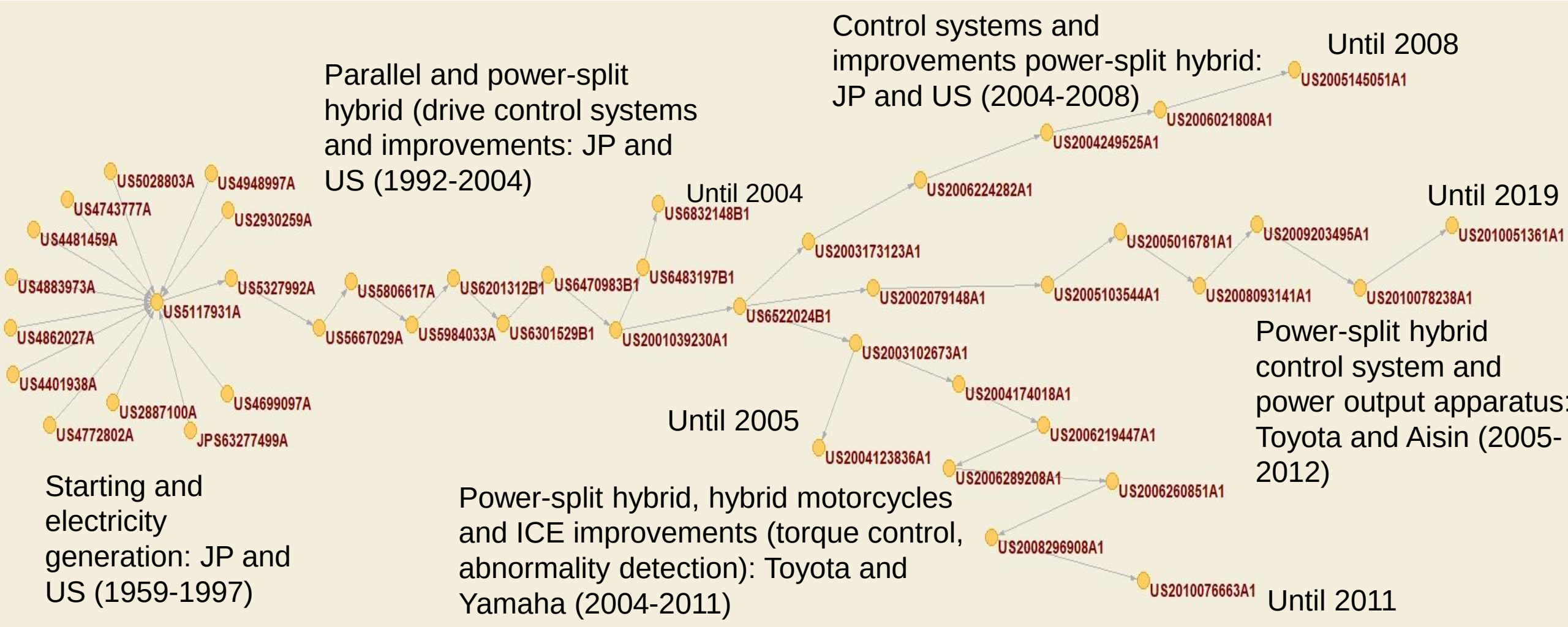
Filter for in-tank fuel pump: Aisin, Nifco (1996-2002)

Until 2002

Until 1997

Filtration media improvements: Kuss Corp. (1996-1997)

Development of the dominant Trajectories over time: (1990, 2003) – (1900, 2019)



Dominant Trajectories over time

Trajectory	Main Topic	Main Aim	Main Players
1950/55	Fuel delivery system (carburetor)	Performance	-
1960/65/70/75	ICE fuel injection valves	Performance and fuel consumption	US
1980 - 1995	ICE fuel injection and metering (electromagnetic)	Performance and fuel consumption	Bosch (DE), Gen Motors (US)
1996 - 2002	ICE fuel tank filters	Prevent damage to injection system	Nifco (JP), Gen Motors (US), Kuss Corp. (US)
2003 - 2019	Hybrid powertrain/propulsion	Fuel consumption/Emission	Toyota (JP), Aisin (JP), US

- Direction of search changes notably: development of new (dominant) trajectories
- Different main actors across trajectories

Outlook

(Preliminary) conclusion:

- Due to rising pressure, the internal combustion engine TIS changed/is changing its technological search process.
- The recent trajectory in knowledge development suggests that incumbent firms are increasingly interested in hybrid powertrain technologies (at least in Japan and USA).
- Decline of TIS could be delayed by an increasing use of the hybrid powertrain.

Next steps:

- Testing robustness of the trajectories (local main paths, key-route paths, different weighting indicator)
- Extend qualitative analysis of trajectories: competencies needed, perceived barriers, engineering heuristics (Martinelli 2012)
- Historical analysis to link trajectories to key changes in context and/or competitive pressures

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THANK YOU!