

# Key Inventors: A Comparison of Fuel Cell and Nanotechnology Firms and Inventors using Patent Analysis

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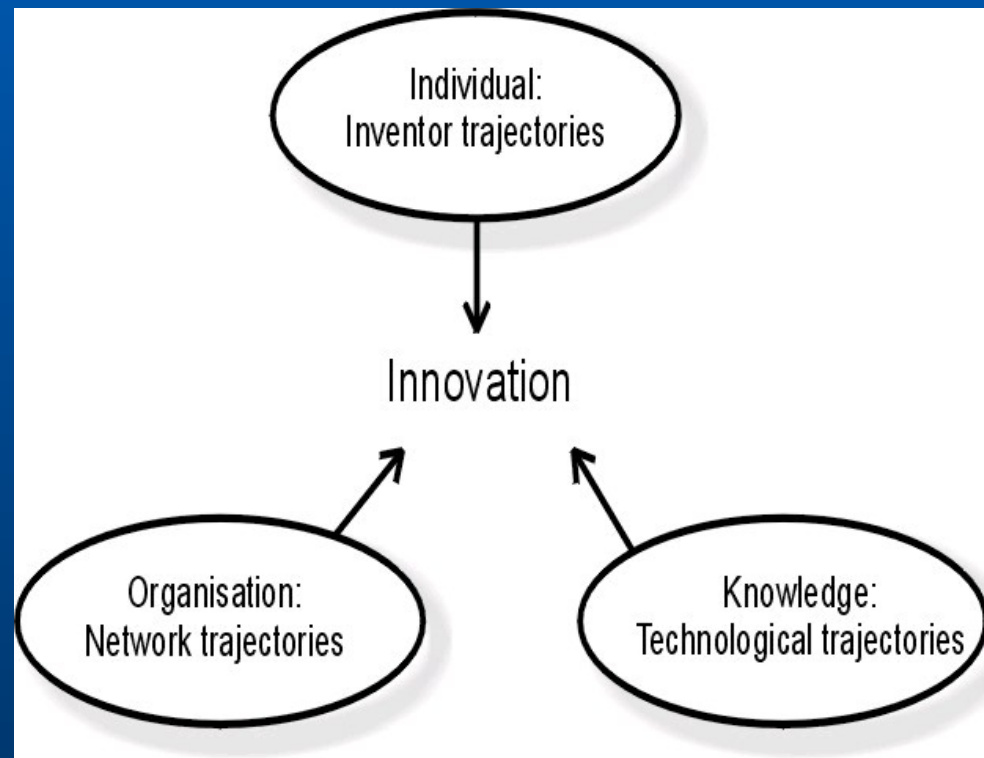
# Outline

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- MOT Study: Technological Trajectory Mapping
- Alternative Fuel Vehicle Project
- IP Analysis: plotting value and networks
- Key Inventor framework
- Cross industry Comparisons: nanotech
- Future work

# Research Outlook

- *Changes in Technology and Practice:*
  - Trajectories
  - Discontinuity
- *Players in Innovation:*
  - Individual: inventors
  - Organisation: networks
  - Technology: development



# AFV Study Programme

- Explore trajectories as theoretical issues in technology change
- Series of case studies:
  - Selected because “area of expertise”
    - Battery Electric Vehicles
    - Hybrid Technology
    - Fuel Cells
- Patent Analysis: “interesting data source”
  - Examination of firm and inventor networks
  - Technology Status Mapping
  - Portfolio Analysis: Identifying Interdependent Technologies

# Patents and MOT studies

- Limits:
  - National differences
    - Difficult for economic comparisons
    - US data seen as representative (or triad-patent)
  - Patent applications or patents granted?
    - Historical US application data not available
  - Cross-industry comparisons
    - Different technologies/industries = different strategies
  - Need to concentrate on technology not product
- Problems reduced for emerging technology fields with US focus

# Data Sources

- Raw Data
  - US Patent and Trademark Office
  - Delphion
  - NUS Patent Database
  - Specialised data extraction and manipulation methods
- Case 1: Fuel Cell
  - Patents with “fuel cell” in front page text: 6,272
  - Expanding area: 288 firms left, 788 entrants
- Case 2: Nano Technology (with NUS)
  - More refined search term needed: 4,865 patents

# Preliminary Study Results

Patents seem OK, because:

- Robust/independent means of identifying players
- Patents indicate technologies not products

Early explorations showed:

- Identifying imminent commercialisation
- Relationship between regulation and technological capability

# Key Inventor Method: Motivations

Theoretical views on innovation:

- “Social capital” or “Structural Holes”

Own questions:

- Which individuals lead innovation?
- Is this a personal or firm level effect?
- What distinguishes the best inventors?
- Can emulation promote innovation effectiveness?

Fuel Cell Questions

- Are firm technology foci converging?
- Is this a valid use for patent data?

# Key Inventor Method

- Measure inventors/firms using two dimensions:

- Productivity:
  - number of patents
- Quality:
  - the patents are significant
  - highly cited

Patent  
Quality

Talented	Key
Low	Industrious

Productivity

- Key inventors exhibit both high patenting activity and high quality
- Based on ideas of Ernst: ranked inventors in a firm
- Extension is to examine whole technology field

# Quality – Quantity Dimension:

## Most cited not always most productive

Inventor	No. of Patents	Citations per Patent
Isenberg; Arnold O.; (US)	26	16
Reichner; Philip; (US)	10	14
Reiser; Carl; (US)	16	11
Baker; Bernard S.; (US)	15	11
Watkins; David S.; (Ca)	14	9
Ruka; Roswell J.; (US)	24	9
Maricle; Donald L.; (US)	14	9
Maru; Hansraj C.; (US)	12	9
Marianowski, Leonard G.; (US)	24	9
Schroll; Craig R.; (US)	12	8
Breault; Richard D.; (US)	38	8
Cable; Thomas L.; (US)	11	8
Dempsey; Russell M.; (US)	11	8
Hsu; Michael S.; (US)	24	7
Iacovangelo; Charles D.; (US)	11	7
Mcelroy; James F.; (US)	12	7
Bloomfield; David P.; (US)	17	7
Bushnell; Calvin L.; (US)	10	7
Buswell; Richard F.; (US)	13	7
Tamura; Kohki; (Jp)	14	7

# Results: Fuel Cell Key Inventors

Quality  
2 x average = 3.1 citations  
per patent

Talents (n=498)	Key Inventors (n=624)
Low Performers (n=5,534)	Industrious Inventors (n=607)

Productivity  
Average = 1.9 patents per inventor

Correlation:  $R = 0.728$ , significant at the 0.01 level.

# Locations of the Key Inventors

Country	Key Inventors
US	106
JP	29
DE	3
GB	3
NL	1
CH	1
IL	1
AU	1
Grand Total	145

Reject alternative hypothesis:

Observed performance not due to geographic difference

# Industry Impact: Key Firms

Extended the method to look at firms

Quality  2 x average = 0.23 citations per patent per firm	Talents (n=134)	Key Firms (n=64)
	Low Performers (n=915)	Industrious Firms (n=107)

Productivity  
Average = 5.09 patents per firm

# Leading Key Firms

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Key Firm	No. of Patents
United Technologies Corporation	216
International Fuel Cells	187
Westinghouse Electric Corp.	155
United States Department Of Energy	142
General Electric Company	128
The Dow Chemical Company	94
Hitachi, Ltd.	80
E. I. Du Pont De Nemours And Company	76
Mitsubishi Denki Kabushiki Kaisha	63
Ballard Power Systems Inc.	62
NGK Insulators, Ltd.	59
Energy Research Corporation	58
Fuji Electric Co., Ltd.	56
Institute Of Gas Technology	52
Diamond Shamrock Corporation	41
Engelhard Corporation	39
The Regents Of The University Of California	38

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# Second Study: NUS Enterprise: Nano Technology

Patenting Quality 2x average = 6.7 citations per patent	high	<b>Talents</b> (n=397)	<b>Key Inventors</b> (n=33)
	low	<b>Low Performers</b> (n=2145)	<b>Industrious Inventors</b> (n=329)
		low	high

Patenting Activity  
2x average = 4.8 patents per assignee

Figure 5. Distribution of inventors by patenting activity and patenting quality.

# Nano Technology: Results

Table 6. Top ten key assignees.

<b>Key Assignee (&gt;average # of patents and &gt;average citations/patent)</b>	<b># of patents</b>	<b>citations per patent</b>	<b>Key Index</b>
University of California	136	4.91	136.09
Massachusetts Institute of Technology	52	5.13	52.25
3M Innovative Properties Company	40	2.73	40.09
Hyperion Catalysis International	33	8.30	34.03
President and Fellows of Harvard College	32	7.94	32.97
Toshiba Corporation	32	3.19	32.16
NEC Corporation	31	4.74	31.36
Leland Stanford Jr. University	30	5.23	30.45
Nanosphere, Inc.	30	3.23	30.17
AlliedSignal Inc.	28	2.86	28.15

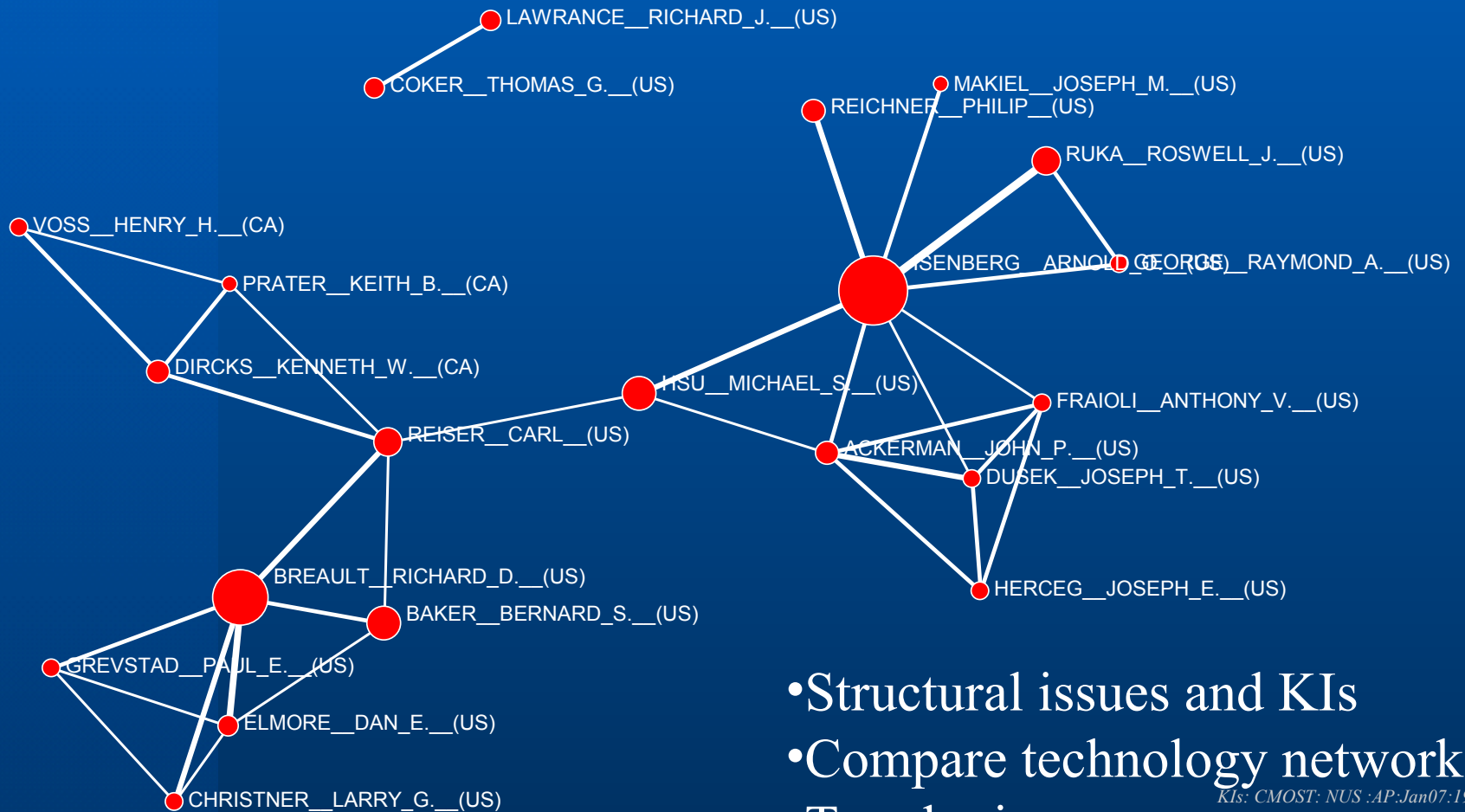
# Results: Comparisons

- Both show growing importance and activity
- Age of citations: Fuel cell citations older (= more developed?)
- Concentrations can be plotted:
  - Fuel cell focus in US industry
  - Nano features many Universities
  - Nano KIs are more international
- Nature of technology:
  - Fuel cell has clear product focus: vehicle or powergen
  - Nano is technology focus: applications widespread

# Future Analysis: Aims

- Who are these people?
- Theoretical review:
  - What makes good inventors
  - Education/OB/Individual factors
  - Social capital
  - Organisational structural factors
  - Structural holes

# Current focus: Citation Network Analysis



- Structural issues and KIs
- Compare technology networks
- Typologies

# Future Analysis 1: Technology Lifecycle - Trajectories

- Group firms by profile:
  - Similar technology portfolios
  - Factor analysis using patent class data
- Compare early and late data
- Is there evidence of convergence?
- Are key inventors just in the right area?

	Component				
	1	2	3	4	5
Fuji Electric Co., Ltd.	.945				
Engelhard Corporation	.909				
Energy Research Corporation	.906				
Sanyo Electric Co., Ltd.	.903				
Toyota Jidosha Kabushiki Kaisha	.889				
International Fuel Cells	.886				
Daimler-Benz Ag	.871				
Ballard Power Systems Inc.	.860				
Siemens Aktiengesellschaft	.823				
United Technologies Corporation	.687				
Mitsubishi Denki Kabushiki Kaisha	.662			.547	
General Motors Corporation	.649				
Hitachi, Ltd.	.593			.573	
Exxon Research & Engineering Co.	.409				
NGK Insulators, Ltd.		.877			
The University Of California		.780			
BASF Aktiengesellschaft		.724			
Westinghouse Electric Corp.		.661			
The US Army		.658			
Matsushita Electric Industrial Company		.656		.403	
Gas Research Institute		.623			
Allied Signal Inc.		.554			
California Institute Of Technology		.501			
E. I. Du Pont De Nemours and Company			.779		
Imperial Chemical Industries Plc			.770		
Asahi Glass Company Ltd.			.760		
The Dow Chemical Company			.755		
Diamond Shamrock Corporation			.751		
Hooker Chemicals & Plastics Corp.			.614		
Olin Corporation			.608		
Institute Of Gas Technology				.911	
Kabushiki Kaisha Toshiba	.450			.715	
US Dept. Of Energy	.425	.517		.555	
Prototech Company					.826
Tanaka Kikinzoku Kogyo K.K.					.739
Hoechst Aktiengesellschaft					.612
Union Carbide Corporation					.502
United Aircraft Corporation					
Robert Bosch Gmbh					
General Electric Company			.444		

# Rotated Component Matrix

Extraction Method: Principal  
Component Analysis.  
Rotation Method: Varimax with  
Kaiser Normalization.  
Rotation converged in 15 iterations.

# Interpretation: What do the factors mean?

Factor 1:

Fuel cell system integrators

Factor 2:

The development and production of solid electrolytes

Factor 3:

Membrane technology and stack assembly

Factor 4:

The development and manufacture of fused electrolytes

Factor 5:

Electrode and catalyst development

# Comparing Early and Late Data

## Early Clusters

	1	2	3	4	5	6	7						
Fuji	0.845	Electrochem Energie	0.833	Diamond Shamrock	0.712	Gas Research Inst	0.741	Occidental	0.758	BASF	0.789	USAF	0.792
Energy Research	0.812	Allied Signal	0.712	Uop	0.667	Varta	0.697	Toshiba	0.751	MIT	0.782	Inst Francais Du Petrole	0.497
Mitsubishi	0.750	EPRI	0.539	Kurcha Kagaku	0.483	US Navy	0.542	United Aircraft	0.498	Standard Oil	0.564	Siemens	0.438
Sanyo Electric	0.638	Hitachi	0.392	Union Carbide	0.452	Int Fuel Cells	0.476	US Dept Energy	0.433			Engelhard	0.437
Int Fuel Cells	0.579	Robert Bosch	0.368	Prototech	0.417	United Technologies	0.420					Sanyo	0.401
Engelhard	0.571												
Hitachi	0.502												
United Technologies	0.471												
US Dept Energy	0.458												
Inst Francais Du Petrole	0.454												
Westinghouse	0.365												

## Late Clusters

	1	2	3	4	5				
Siemens	0.818	Tanaka Kikinoku	0.842	Rockwell	0.757	Permelec	0.852	Cal Tech	0.778
Int Fuel Cells	0.813	Osakak Gas	0.595	Energy Research	0.727	Lynntech	0.791	Johnson Matthey	0.752
Ballard Power	0.746	NGK	0.585	Hughes Aircraft	0.600	Du Pont	0.784	Minnesota Mining & Manuf	0.535
GM	0.694	Dow	0.561	Toyota	0.478	United Technologies	0.666	Matsushita	0.399
Daimler-Chrysler	0.688	Allied Signal	0.532	Forschungszent Julich	0.452	MIT	0.415		
Fuji	0.678	Gas Research Inst	0.360	H Power	0.417				
Ztek	0.663	Matsushita	0.359						
Honda	0.378								

# Future Analysis 2: Tracking Key Inventors

- Are these people more valuable to the firms?
- Do they move more?
- Do they have a high market value?

*Key inventors*

Average companies cited with 1.6

*Industrious inventors*

Average companies cited with 1.3

*t-test (assuming independent variances) 7.786, significant at 0.1%*

Assignee of Patent	Sum of Attraction Index
INTERNATIONAL FUEL CELLS	37
SIEMENS AKTIENGESELLSCHAFT	7
BALLARD POWER SYSTEMS INC.	5
ELECTRIC POWER RESEARCH INSTITUTE, INC.	4
ELTECH SYSTEMS CORPORATION	4
ENERGY PARTNERS, INC.	4
KABUSHIKI KAISHA TOSHIBA	4
ALLIED SIGNAL INC.	3
ORONZIO DE NORA IMPIANTI ELETTROCHIMICI S.P.A.	3
H POWER CORPORATION	2
UNIVERSITY OF CHICAGO	2
CERAMATEC, INC.	-2
COMMUNICATION SATELLITE CORPORATION	-2
ENGELHARD CORPORATION	-2
LEESONA CORPORATION	-2
SOUTHERN COUNTIES GAS	-2
THE OHIO STATE UNIVERSITY	-2
UNITED STATES DEPARTMENT OF ENERGY	-2
WESTINGHOUSE ELECTRIC CORP.	-2
UOP INC.	-3
CANADA MINISTER OF NATIONAL DEFENCE	-4
INSTITUTE OF GAS TECHNOLOGY	-4
PERRY OCEANOGRAPHICS, INC.	-4
TOKYO SHIBAURA DENKI KABUSHIKI KAISHA	-4
DIAMOND SHAMROCK CORPORATION	-5
GENERAL ELECTRIC COMPANY	-8
UNITED TECHNOLOGIES CORPORATION	-20
UNITED AIRCRAFT CORPORATION	-22

Effect of Key  
Inventor  
Movement on  
Key Firms

Firm  
Performance?

# Help Needed



## 1. Theoretical basis for classification

Currently use:

> 2x Average Quality

> Average Productivity

❖ Could use Lotka, Bradford, Zipf rules...any other suggestions?

## 2. What other industries are close to commercialisation and so valid for use of patents?

# Future Research

- £0.5m ESRC Grant application
  - Revise and improve data
  - Identify theoretical frameworks to test
  - Survey key inventors
  - Offer advice: how to be a key inventor
  - UK support:
    - DTI
    - Cabinet Office
    - Low Carbon Vehicle Project
  - International collaboration: Hamburg, Singapore, US



Thank you.

Questions?