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Preliminary Results from the Sci-SIP Project at NISTEP

Sources of Private and Public R&D Spillovers: Technological, Geographic and Relational Proximity

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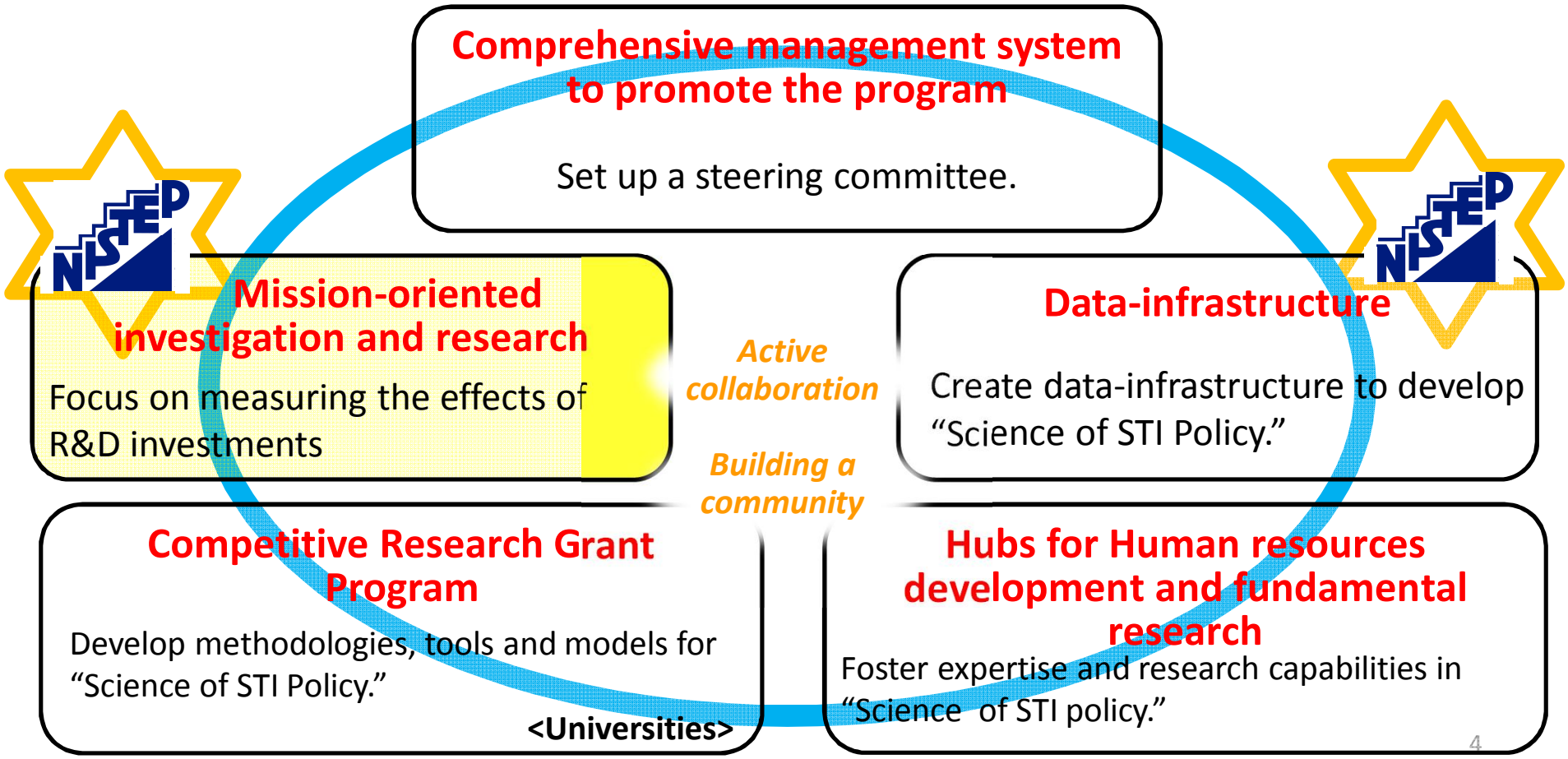
Outline

- Japan's Sci-SIP program: background and outline
- Current research & motivation
- Previous literature on spillovers and productivity at the firm level
- Data & variables
- Preliminary results
- Limitations and future research agenda

Japan's "Sci-SIP" Program

- Sci-SIP program:
  - Science of Science, Technology and Innovation Policy program
- Ultimate goal:
  - To facilitate the formation of **"objective evidence-based Science, Technology and Innovation (STI) policy"**
  - To make STI policies more effectively based on reliable data and analysis
- Approaches:
  - Development of a systematic and international comparable STI data infrastructure
  - Measuring the effects of public R&D investment with scientific methodologies: goal of the mission-oriented/competitive research grant
  - Securing and capacity-building of personnel for evidence-based policy-making, able to examine research questions from across the wide-ranging STI policy field

NISTEP's Missions in Sci-SIP program



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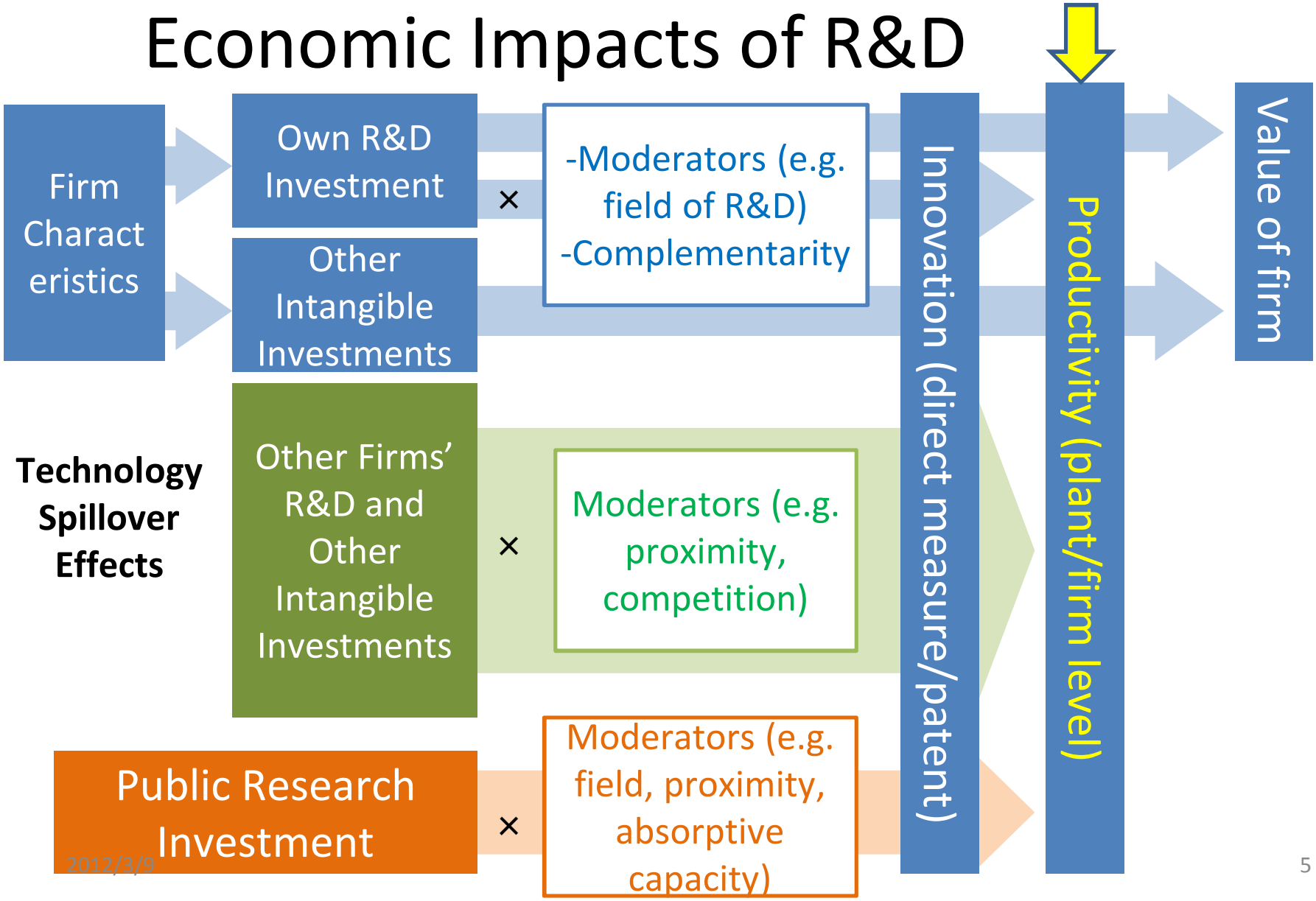
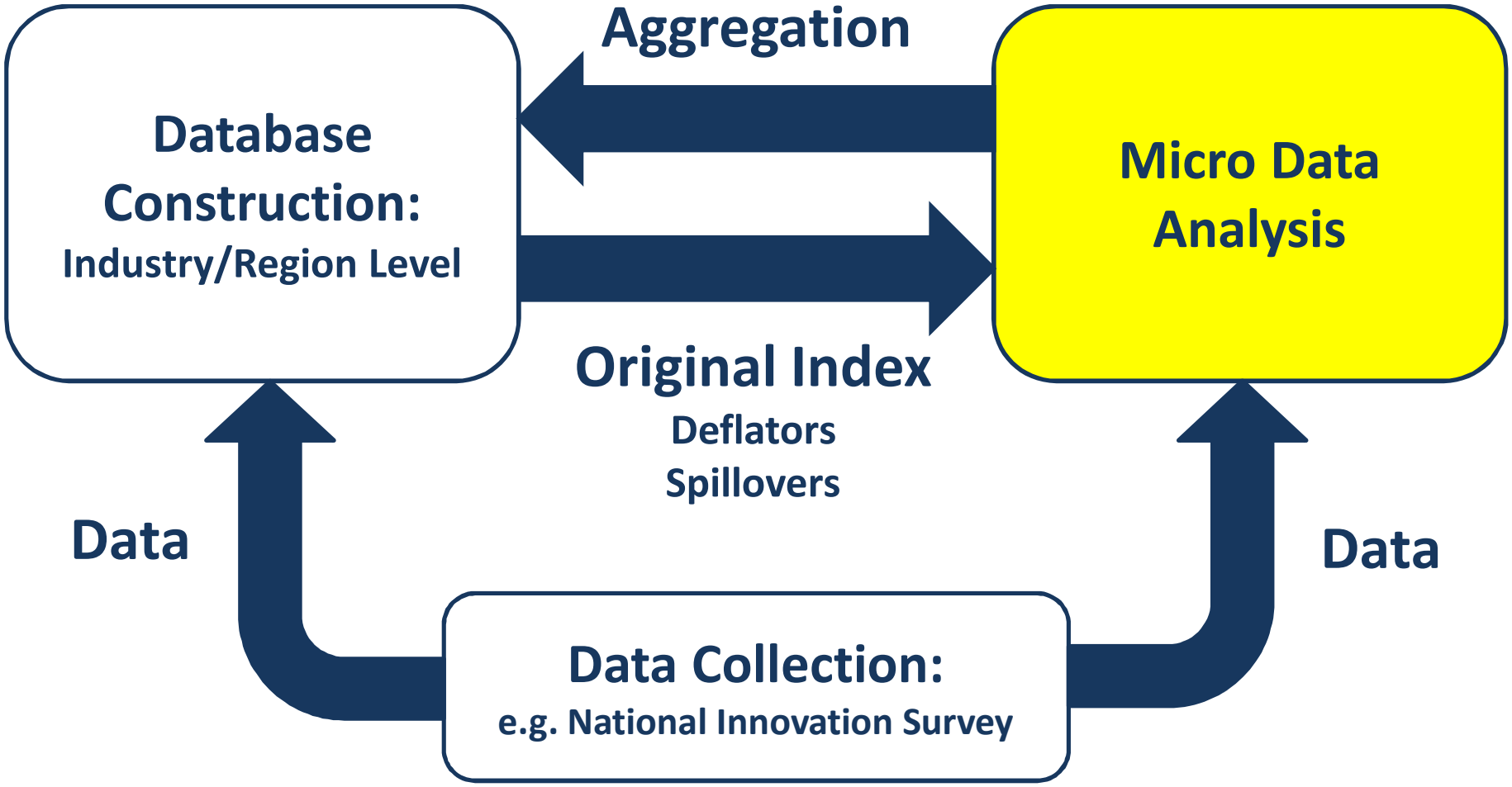
Framework for analysis of the Economic Impacts of R&D



Relationship among Projects



Collaboration

- Projects of the Research Institute of Economy, Trade & Industry (RIETI)
- OECD New Sources of Growth Project
  - NESTI (National Experts on Science and Technology Indicators)
  - WPIA (Working Party for Industry Analysis)

This Presentation

TFP and R&D spillovers: preliminary results

- TFP in an unbalanced panel of > 12,000 Japanese manufacturing plants (census data), 1984-2007
- Matched with firm-level R&D data from yearly R&D surveys
  - R&D distinguished by 30 fields: mapped to industries
  - Allows for approximation of R&D stocks by location and relevant field
    - But currently still limited correction for non-response and matching failures

Effects of R&D at the plant level

- Parent firm R&D stock: by field/industry
- R&D spillovers from other firms
  - By location (city, prefecture) and by field/industry
  - By buyer-supplier relationship and location (*only cross section*)

Motivation

- Discrepancy between the trends in R&D expenditures and TFP growth in Japan
  - Japan's total factor productivity growth has been declining since the mid 1980s (e.g. Fukao and Kwon, 2011).
  - R&D expenditure to GDP ratio has been steadily increasing to reach 3.1% in 2008.
  - ➢ Decline in aggregate returns to R&D
- One possible explanation: a decline in R&D spillovers
  - Loosening of traditional stable supplier-buyer relationships
  - Firms increasingly shield off their technologies, focus on intellectual property rights protection and appropriation
  - Relocation of increasingly sophisticated manufacturing plants abroad
  - Changing patterns of R&D agglomeration and R&D specialization
  - ➢ Examine patterns of R&D spillovers in Japanese manufacturing industries, and possible moderators

Literature on spillovers and productivity at the firm level

Two moderators have received most attention

- Geographic proximity attenuates the effectiveness of R&D spillovers (Jaffe et al, 2003; Keller, 2002)
  - E.g. Adams and Jaffe, 1996; Aldieri and Cincera, 2009; Orlando, 2004
- Spillovers more likely for related technologies: technological proximity matters
  - E.g. Orlando, 2004; Aldieri and Cincera, 2009; Bloom et al 2010; Jaffe, 1988

Approach in Previous Studies

1. Typically relied on:
   - ï Single industry empirical settings (Adams and Jaffe, 1996)
   - ï Smaller samples of publicly listed firms, using consolidated firm data (Orlando, 2004; Aldieri and Cincera, 2009)
     - ➢ No plant level data with detail on location/geography
2. Abstracted from the role of public research
   - ï Different research stream focusing on the role of knowledge spillovers from (proximate) public research (e.g. Jaffe, 1989; Adams, 1990; Anselin et al, 1997; Furman et al, 2006).
3. Limited attention to spillovers through supplier and client linkages: *'relational proximity'*
   - Goto and Suzuki (1989): R&D weighted with input-output tables (industry level analysis). Crespi et al, 2007: knowledge flows from suppliers increase productivity (UK)
   - Instead, supplier-buyer linkages have been the focus of the literature on FDI spillovers to local firms

Supplier-client Linkages and Spillovers

- Buyer-supplier relationships have been found to be a key channel of spillovers from foreign direct investments to local firms.
  - e.g. Haskel et al, 2007; Görg and Strobl, 2001; Javorcik, 2004; Kugler, 2006
  - Knowledge from suppliers and clients
  - Purposeful knowledge exchange to facilitate transactions
  - Quality demands & specifications of buyers
  - 'Pecuniary spillovers' (Hall et al, 2010) from suppliers: prices of intermediates do not reflect full value of embedded technology
- In the context of Japanese firms:
  - Stable supplier relationships (for instance those within vertical business groups) have been associated with knowledge sharing and technology spillovers (Suzuki, 1993; Branstetter, 2000)

R&D and Spillovers: other issues

- Absorptive capacity (Cohen and Levinthal, 1989): firms' own R&D stock enhances benefits of spillovers (e.g. Aldieri and Cincera, 2009; Lokshin et al. 2008; Griffith et al, 2004)
  - In particular in case of public R&D spillovers from universities (e.g. Cockburn and Henderson, 1998; Cassiman and Veugelers, 2006).
- Market spillovers: fewer productivity benefits expected of other firms' R&D if these firms are direct market competitors, due to compensating 'business stealing' effect of rivals' R&D
  - Bloom et al, 2010; Branstetter and Sakakibara, 2002
- International knowledge spillovers, e.g. through trade or FDI (e.g. Branstetter, 2001; Keller, 2002; Griffith et al. 2004)
- Role of multinational firms:
  - 'Reverse knowledge transfer' from overseas R&D laboratories (Griffith et al., 2008; Todo and Shimizutani, 2008; Iwasa and Odagiri, 2004): spillovers from foreign R&D stocks
  - Affiliates of foreign multinationals tend to have higher TFP levels (e.g. Criscuolo and Martin, 2009; Doms and Jensen, 1998)

Our Research Ambition

Simultaneous consideration of all potential spillovers

Current approach (presentation)

- Technological proximity (R&D by field)
- Geographic proximity (prefecture & city)
- Relational proximity (main buyers and suppliers of firms) (very preliminary)

Future Plans

- Public R&D spillovers (local university R&D)
- Competition effects
- Identification of multinationals and overseas R&D (matching with Basic Survey data)
- Business group spillovers

Data & Sample

Main data sources

- Census of Manufacturers (CM)
  - > 240,000 plants yearly
  - After 2000, only plants > 30 employees with capital stock data; 40,000 plants
  - TFP of manufacturing plants available (JIP productivity project)
- Survey of R&D (SRD)
  - Mandatory yearly survey, ca. 9000 responding firms, response rate > 90%

Database matching

- Matching keys: firm name, address and capital (no firm codes available)
- On average > 90% of total R&D expenditures by manufacturing firms linked to census plants: allocate to fields and locations
- But >50% of SRD respondents (often small firms) could not be matched (yet)
- ➢ Remains unclear if any specific unmatched plant in the CM is owned by a R&D conducting firm

Preliminary sample:

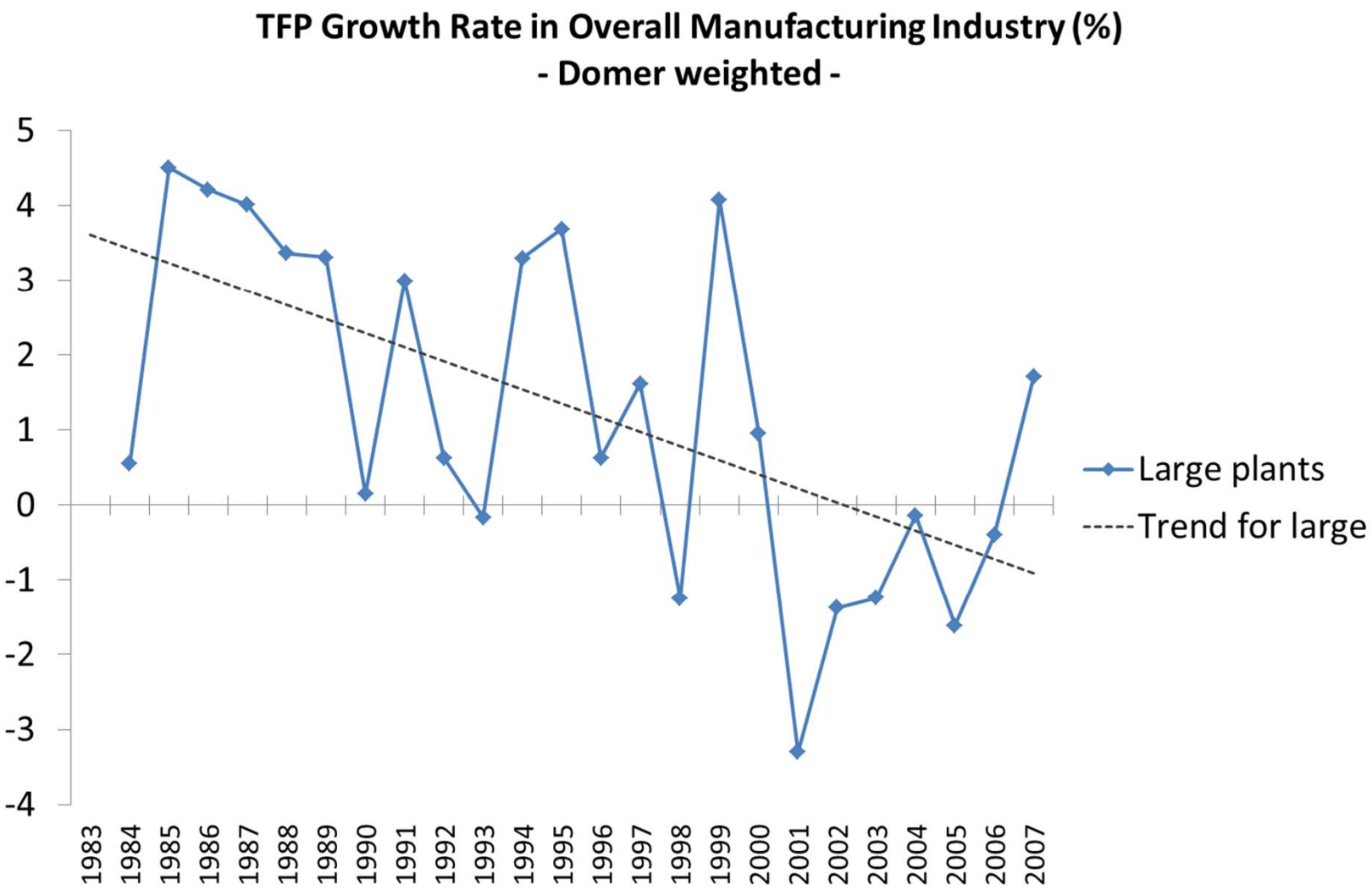
- Focuses on plants owned by firms with matched (positive) R&D data
- ➢ Unbalanced panel of 12317 plants owned by 4824 parent firms, 1984-2007

Plant TFP and R&D stocks

- TFP levels of each plant
  - Taken from JIP project
  - Calculated for 58 manufacturing industries
  - Non-parametric factor share method (Good et al, 1997) : TFP index
  - Dependent variable: 100* ln (tfp index)

- R&D stock at the plant level
  - Parent firm R&D distributed over 30 fields: mapped into 25 (2-digit) industries
  - Distinguish R&D stock in the plant's 2-digit industry and parent R&D stock in other industries (e.g. Adams and Jaffe, 1996)
  - Stocks calculated with perpetual inventory method, using 15% depreciation rate and industry deflators

TFP Growth Rate



R&D fields and R&D stock per industry

Industry (R&D field)	Total R&D stock (billion yen)	Total # of plants
Information & communication electronics	9,725	1,214
Automobile	6,631	867
General machinery	3,130	1,548
Drugs and medicine	2,979	477
Electrical machinery	1,614	840
Chemical fertilizers and industrial chemicals	1,566	678
Other chemicals	1,439	722
Household machinery	1,085	102
Precision instruments and machinery	646	308
Food	578	1,550
Iron and steel	565	322
Rubber	510	223
Ceramic, stone and clay	418	766
Other transportation equipment	409	136
Non-ferrous metals	329	331
Fabricated metal	296	828
Miscellaneous manufacturing	260	425
Textile mill	235	299
Pulp and paper	122	361
Petroleum and coal	85	95
Printing	60	104

Private R&D Spillover Pools

Parent R&D and Technological proximity: 2 variables

- Total parent R&D
- Share of the parent's R&D in the 2-digit industry of the plant (tech proximity)

R&D spillovers

Technological proximity

- R&D of plants in the same 2-digit industry versus R&D of plants in other industries
- (Only parent R&D in the matching 2-digit industry taken into account)

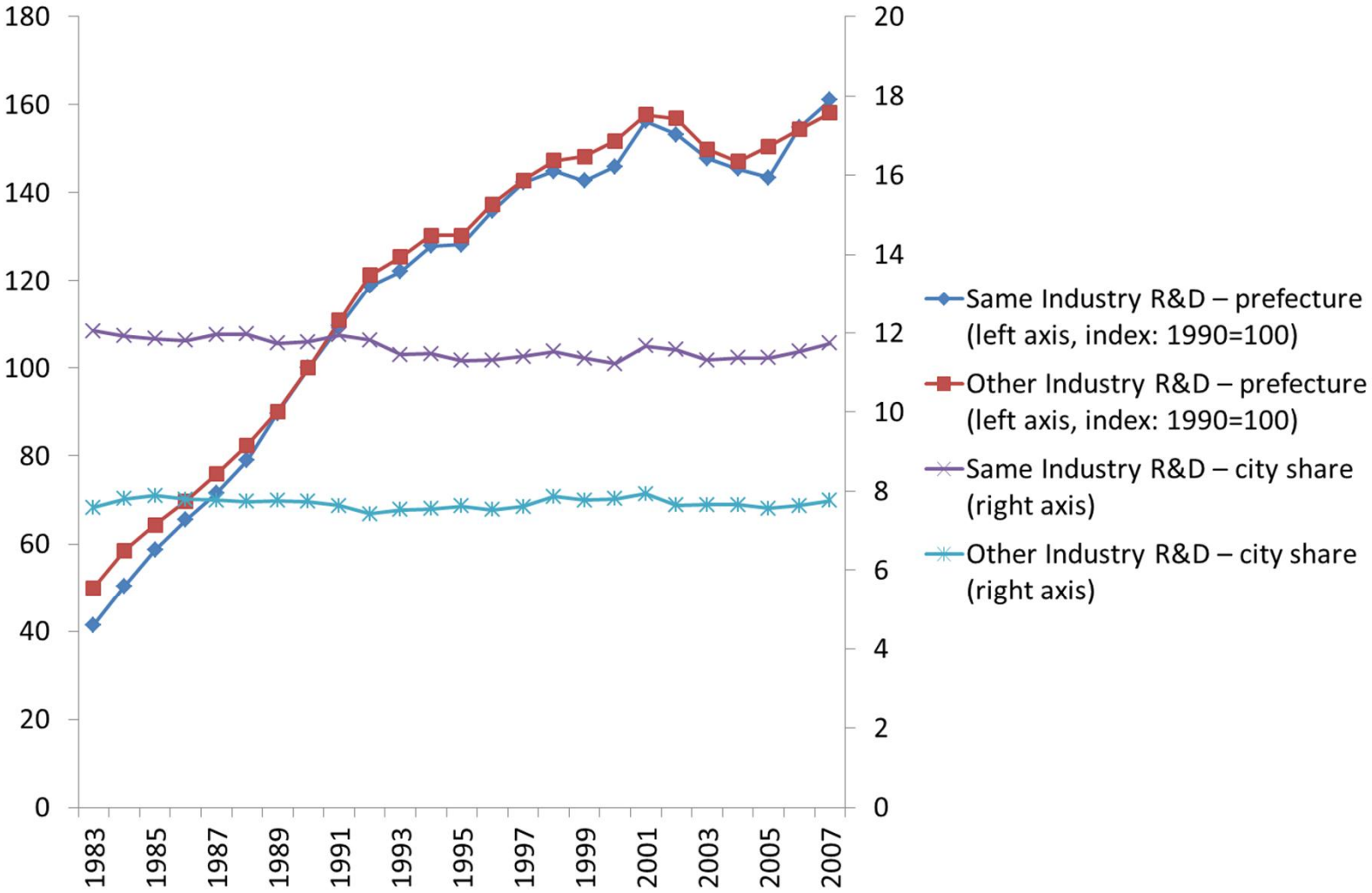
Geographic proximity

- Prefectural R&D stocks versus R&D stocks in the city of the plant

Combining Geographic & technological proximity: four variables

- Prefectural R&D stock in the same industry
- Share of the city in the 'same-industry' R&D stock (proximity)
- Prefectural R&D stock in other industries
- Share of the city in the 'other-industries' R&D stock (proximity)

R&D Spillover Pools



Relational proximity and spillovers

- R&D stock of the firm's main suppliers and customers
- Derived from detailed data on the (10) largest suppliers and customers of each firm collected by Tokyo Shoko Research (2006-2007)
- Potential effect of geographic proximity to suppliers & customers. Compare effects of:
  - Total relational R&D stock
  - R&D stock of suppliers & buyers with plants in the prefecture
  - Share of supplier & buyer plants in the city
- Current data only allow cross section analysis (2007)

Methods

- Fixed effects model regressing ln (tfp) on ln(R&D stock) variables and proximity ratios
  - FE controls for plant unobserved heterogeneity
- Full set of industry-year dummies to control for industry specific shocks
- Time-variant control variables (age of plant, just established plant, size of plant, exiting plant)
- Error terms clustered at the firm level

Fixed effects panel analysis of plant-level TFP: Parent R&D

	[1]	[2]
Parent R&D	0.832**	0.803**
	[0.407]	[0.409]
Parent R&D – same industry share		2.214**
		[0.898]
plant age	10.878***	10.858***
	[1.123]	[1.123]
new plant	7.647***	7.631***
	[1.316]	[1.316]
exiting plant	-1.535**	-1.538**
	[0.625]	[0.625]
Industry-year dummies	Included	Included
# observations	140,685	140,685
# plants	12,317	12,317
# parent firms	4,824	4,824
R-squared	0.277	0.278
F test	28.59***	28.51***
F test (extended vs basic model)		6.08**

Fixed effects panel analysis of plant-level TFP: R&D and regional spillovers

	[1]	[2]	[3]
Parent R&D	0.803**	0.816**	0.828**
	[0.409]	[0.405]	[0.403]
Parent R&D – same industry share	2.214**	2.175**	2.207**
	[0.898]	[0.898]	[0.904]
Same Industry R&D - prefecture		0.318	0.423**
		[0.199]	[0.201]
Same Industry R&D – city share		-0.399	-0.442
		[1.096]	[1.095]
Other Industry R&D - prefecture			1.659**
			[0.676]
Other Industry R&D – city share			-0.840
			[2.513]
Plant and indutry-year controls	Included	Included	Included
R-squared	0.278	0.278	0.278
F test	28.51***	28.60***	28.53***
F test (extended vs basic model)		1.33	3.16**

Fixed effects panel analysis of plant-level TFP: Structural Change (time trend)

	[1]	[2]	[3]
Parent R&D	0.464	0.819**	0.822**
	[0.474]	[0.404]	[0.403]
Parent R&D – same industry share	2.252**	2.212**	2.215**
	[0.906]	[0.904]	[0.904]
Same Industry R&D - prefecture	0.415**	0.705**	0.365*
	[0.201]	[0.289]	[0.202]
Same Industry R&D – city share	-0.415	-0.421	-0.467
	[1.091]	[1.096]	[1.093]
Other Industry R&D - prefecture	1.648**	1.469**	2.105***
	[0.675]	[0.679]	[0.721]
Other Industry R&D – city share	-0.794	-0.877	-0.722
	[2.509]	[2.516]	[2.524]
Time trend x Parent R&D	0.023		
	[0.016]		
Time trend x Same Industry R&D		-0.023	
		[0.016]	
Time trend x Other Industry R&D			-0.067**
			[0.029]
Plant and indutry-year controls	Included	Included	Included
R-squared	0.278	0.278	0.278
F test	29.02	28.70	28.43
F test (extended vs basic model)	2.03	2.07	5.34**

Fixed effects panel analysis of plant-level TFP: Structural Change (post 2000)

	[1]	[2]	[3]
Parent R&D	0.752*	0.817**	0.821**
	[0.413]	[0.405]	[0.402]
Parent R&D – same industry share	2.213**	2.211**	2.217**
	[0.904]	[0.904]	[0.904]
Same Industry R&D - prefecture	0.419**	0.529**	0.382*
	[0.201]	[0.212]	[0.201]
Same Industry R&D – city share	-0.433	-0.423	-0.473
	[1.093]	[1.095]	[1.093]
Other Industry R&D - prefecture	1.648**	1.502**	1.703**
	[0.674]	[0.673]	[0.679]
Other Industry R&D – city share	-0.823	-0.897	-0.767
	[2.513]	[2.517]	[2.522]
Post 2000 x Parent R&D	0.155		
	[0.189]		
Post 2000 x Same Industry R&D		-0.365**	
		[0.184]	
Post 2000 x Other Industry R&D			-0.899***
			[0.330]
Plant and indutry-year controls	Included	Included	Included
R-squared	0.278	0.278	0.278
F test	28.55	28.62	28.46
F test (extended vs basic model)	0.67	3.91**	7.43***

Cross section analysis of plant-level TFP (2007): Relational spillovers

	[1]	[2]	[3]	[4]
Parent R&D	2.341***	2.281***	2.313***	2.318***
	[0.267]	[0.268]	[0.267]	[0.268]
Parent R&D – same industry share	2.504	2.752	2.708	2.724
	[1.730]	[1.755]	[1.744]	[1.744]
Same Industry R&D - prefecture	-0.239	-0.233	-0.381	-0.388
	[0.423]	[0.423]	[0.429]	[0.431]
Same Industry R&D – city share	6.256***	6.180**	6.161**	5.957**
	[2.415]	[2.423]	[2.419]	[2.485]
Other Industry R&D - prefecture	1.232	1.247	0.996	1.015
	[0.811]	[0.810]	[0.827]	[0.831]
Other Industry R&D – city share	-1.990	-1.794	-1.858	-2.058
	[5.079]	[5.078]	[5.057]	[5.105]
Supplier&Buyer R&D - all		0.229		
		[0.174]		
Supplier&Buyer R&Dï prefecture			0.149*	0.141*
			[0.082]	[0.085]
Supplier&Buyer R&D – city share				0.800
				[1.988]
Plant and indutry controls	Included	Included	Included	Included
# observations (plants)	3,431	3,431	3,431	3,431
R-squared	0.465	0.466	0.466	0.466
F test	10.05***	9.11***	9.30***	8.45***
F test (extended vs basic model)		1.74	3.33*	0.16

Preliminary Results

- Positive effect of parent firm R&D stock on plants' TFP, with larger effects of parent firm R&D in the same industry/field
- Positive effects of R&D spillovers in the same industry in the prefecture, no further city proximity effect
- Positive effects of other industry spillovers at the prefecture level, no further proximity effects
- Weakly positive effects of relational spillovers

- Effects work *simultaneously*
- Spillover effects substantial compared to own R&D effects
- Spillover effects are *declining* over time
  - Challenge for future research is then to find out why
  - First steps: are results robust to better specified and inclusive models

Limitations and Future Research I

- **Include public R&D spillovers**
  - R&D by universities and research institutes in relevant fields for the industry
  - Examine role of absorptive capacity (interaction with plant/firm R&D stock)
- **Spillover disaggregation in more detail**
  - Calculate R&D stocks a the 3- digit level
  - Examine role of competition (negative market spillovers) at the 4-digit level
  - Improve R&D stock calculation correcting for no-matching and non-response
- **Improve binary representation of related and unrelated R&D**
  - Apply weighting scheme for relatedness of the R&D fields, to calculate a relevant R&D stock.
    - E.g. Based on joint occurrence of R&D in firms (Bond et al, 2010), or citation-based measure of relationships between technologies (Leten et al., 2007)
- **Geographic proximity ignores spillovers from other (adjacent) prefectures**
  - Use distance weighted proximity measures (latitude & longitude of plants)

Limitations and Future Research II

- **We assume that all parent R&D is available at each plant and that spillovers occur at the plant location**
  - Control for location of parent firm laboratories (Adams and Jaffe, 1986): using R&D facility directories
  - Public spillovers, in particular, may occur at the laboratory level
- **Business group effects**
  - Include business group/ capital ownership ties: match with Basic Survey
- **Control for international spillovers and overseas R&D**
  - Use Basic Survey information on overseas activities and foreign ownership (Japanese affiliates of foreign firms)
- **Buyer supplier relationships**
  - Examine feasibility of extending the data to a panel
  - Take R&D field of buyers and suppliers into account as well
- **Improve data & methods**
  - Consider GMM analysis; IV analysis using (changing) R&D policies as instruments; long difference analysis
  - Deal with attrition/exit in the sample

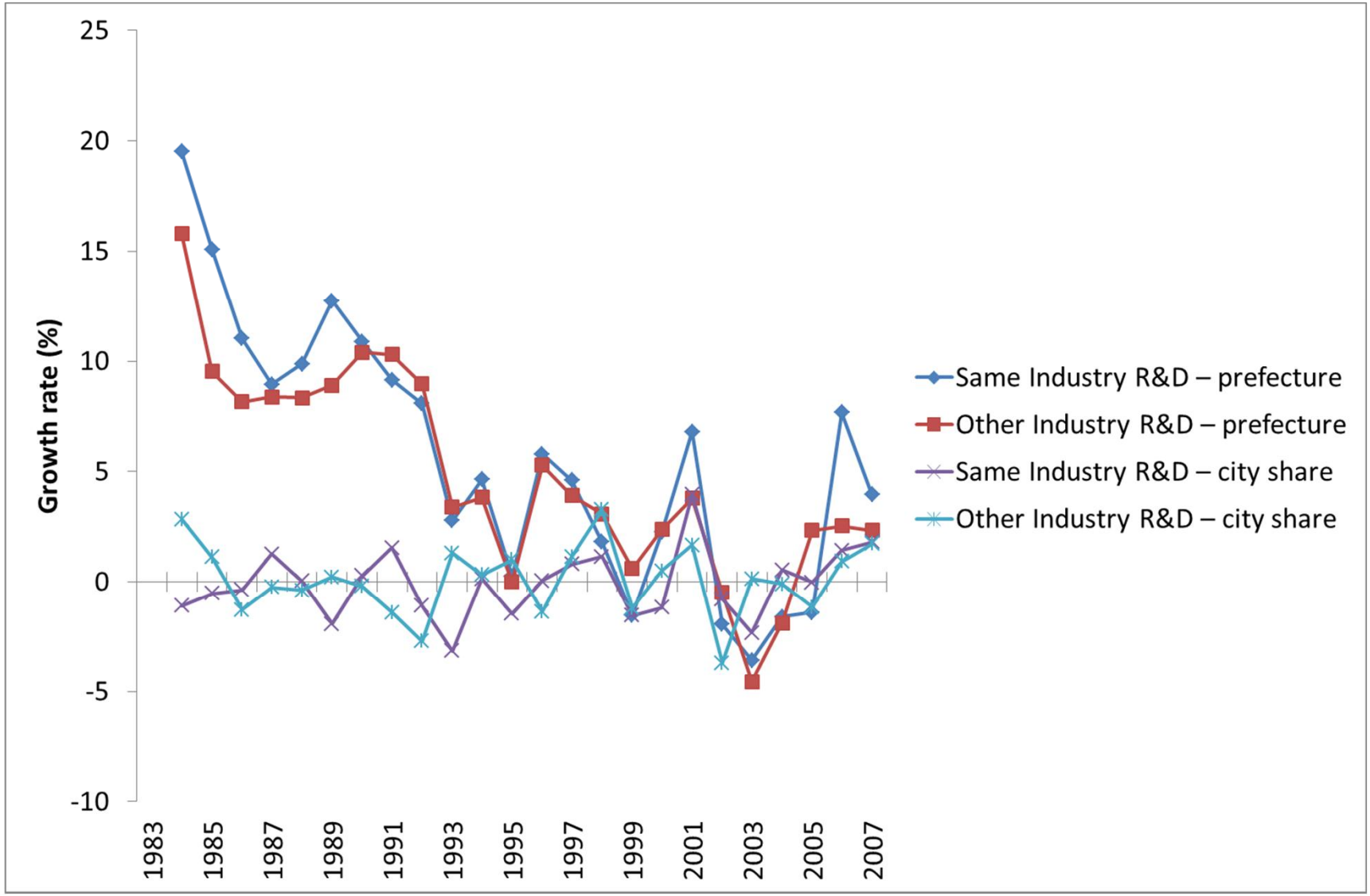
Other Future Research Plans

- Replicate this as firm-level analysis
  - ï Inter-firm spillovers moderated by plant locations and R&D fields
  - ï Compare laboratory co-location with plant co-location effects
- Analysis of firms in non-manufacturing industries
- R&D spillovers, intangibles, innovation output, and market value a the firm level
  - Match data with results 2012 innovation survey

Fixed effects panel analysis of plant-level TFP: all census plants with TPF data (including non-matches with R&D survey)

	[1]	[2]	[3]
Parent R&D	0.298***	0.300***	0.302***
	[0.088]	[0.088]	[0.088]
Zero R&D - R&D survey respondent firm	2.082***	2.079***	2.112***
	[0.730]	[0.730]	[0.729]
Zero R&D - R&D survey non-respondent firm	2.034***	2.036***	2.070***
	[0.637]	[0.637]	[0.636]
Parent R&D – same industry share	0.810	0.794	0.805
	[0.806]	[0.805]	[0.806]
Same Industry R&D - prefecture		0.167***	0.255***
		[0.045]	[0.046]
Same Industry R&D – city share		-0.180	-0.150
		[0.258]	[0.262]
Other Industry R&D - prefecture			1.229***
			[0.162]
Other Industry R&D – city share			-0.202
			[0.595]
Plant and indutry-year controls	Included	Included	Included
# observations	2,139,069	2,139,069	2,139,069
# plants	196,402	196,402	196,402
# parent firms	168,549	168,549	168,549
R-squared	0.191	0.191	0.191
F test	147.21***	146.69***	146.33***
F test (extended vs basic model)		7.24***	28.72***

Growth Rate of R&D Spillover Pools



Correlation of Variables

	Mean	Std. Dev.	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
[1] TFP of the plant x 100	20.05	41.58	1.000									
[2] Parent R&D ï total	12.98	2.37	0.208	1.000								
[3] Parent R&D ï same industry share	0.64	0.40	0.019	-0.254	1.000							
[4] Same Industry R&D ï prefecture	4.77	1.86	0.212	0.125	0.033	1.000						
[5] Same Industry R&D ï city share	0.12	0.23	-0.004	0.027	0.017	-0.029	1.000					
[6] Other Industry R&D ï prefecture	8.18	1.02	-0.032	0.001	-0.008	0.323	-0.092	1.000				
[7] Other Industry R&D ï city share	0.08	0.12	0.008	0.027	0.047	-0.098	0.257	-0.143	1.000			
[10] plant age	2.49	0.67	0.132	-0.040	0.073	0.102	-0.003	0.214	0.004	1.000		
[12] new plant	0.01	0.10	-0.013	0.010	-0.019	0.007	-0.002	0.005	0.000	-0.389	1.000	
[13] exiting plant	0.02	0.13	0.020	0.028	-0.017	0.024	-0.004	0.034	-0.004	0.036	0.011	1.000