The internationalization of industry supply chains and the location of innovation activities

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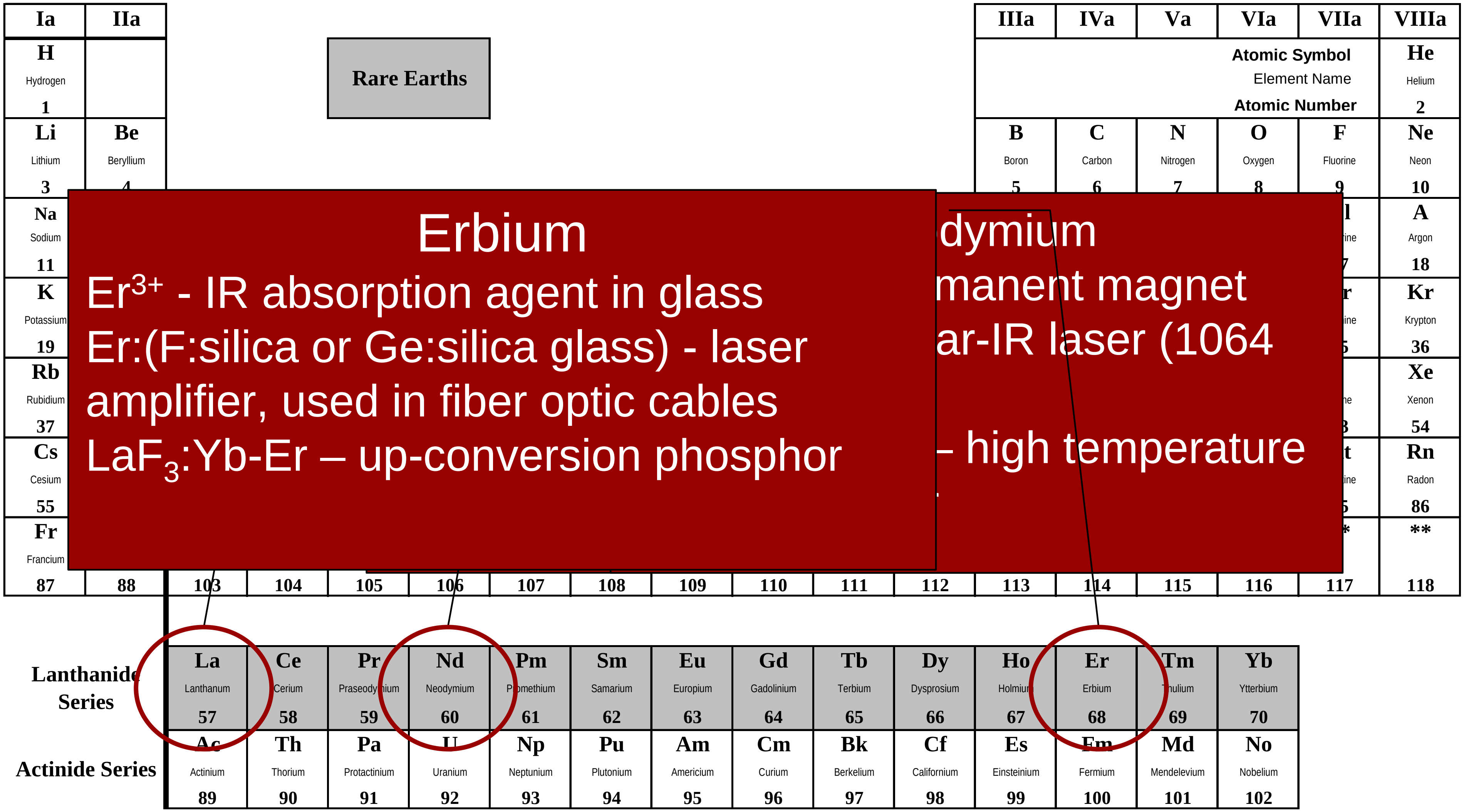
The Middle East has Oil, China has…

… Rare Earths

Deng Xiaoping, 1992

What is the Rare Earth Industry?



Erbium

Er^{3+} - IR absorption agent in glass

Er:(F:silica or Ge:silica glass) - laser amplifier, used in fiber optic cables

LaF_3:Yb-Er – up-conversion phosphor

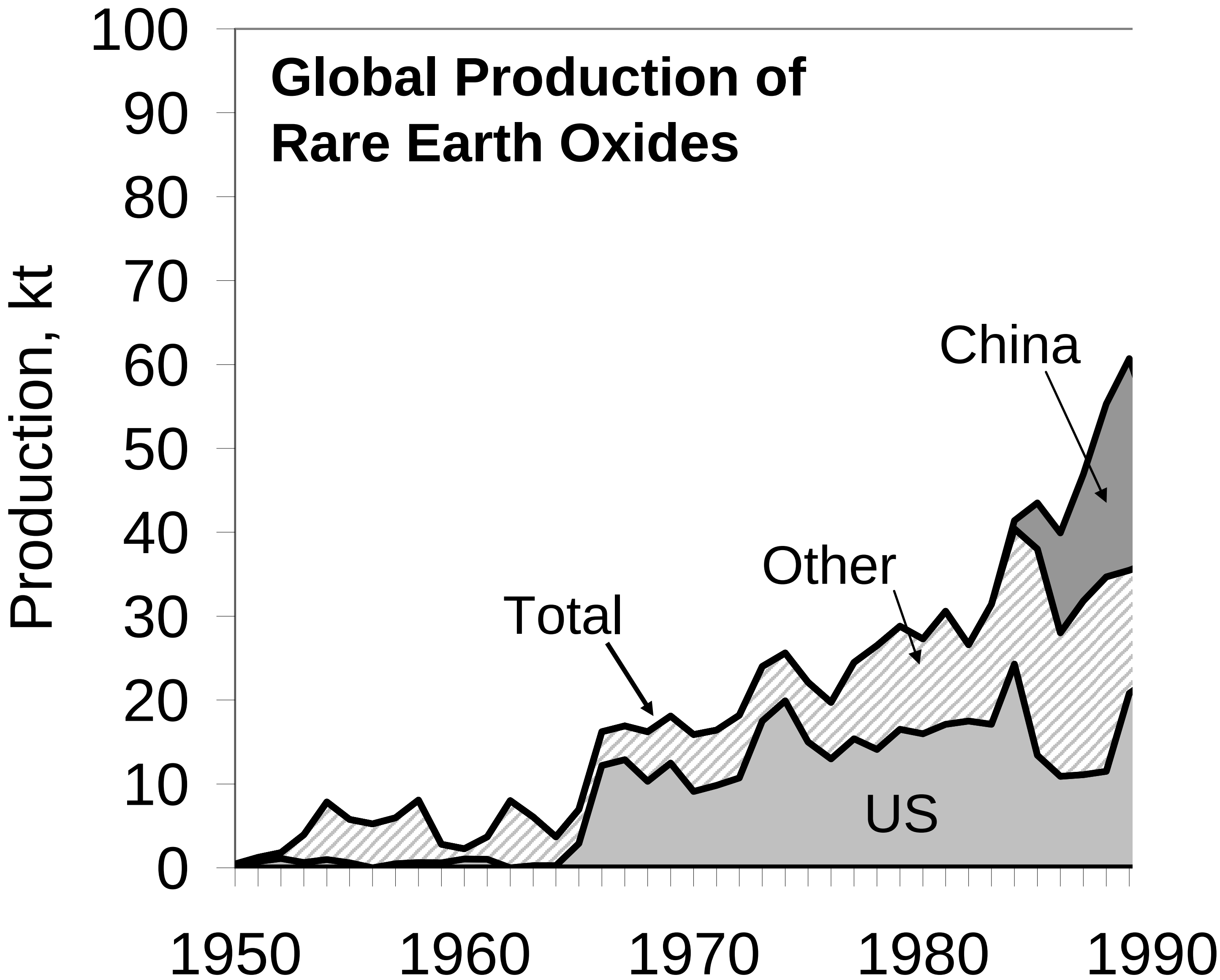
dymium

manent magnet

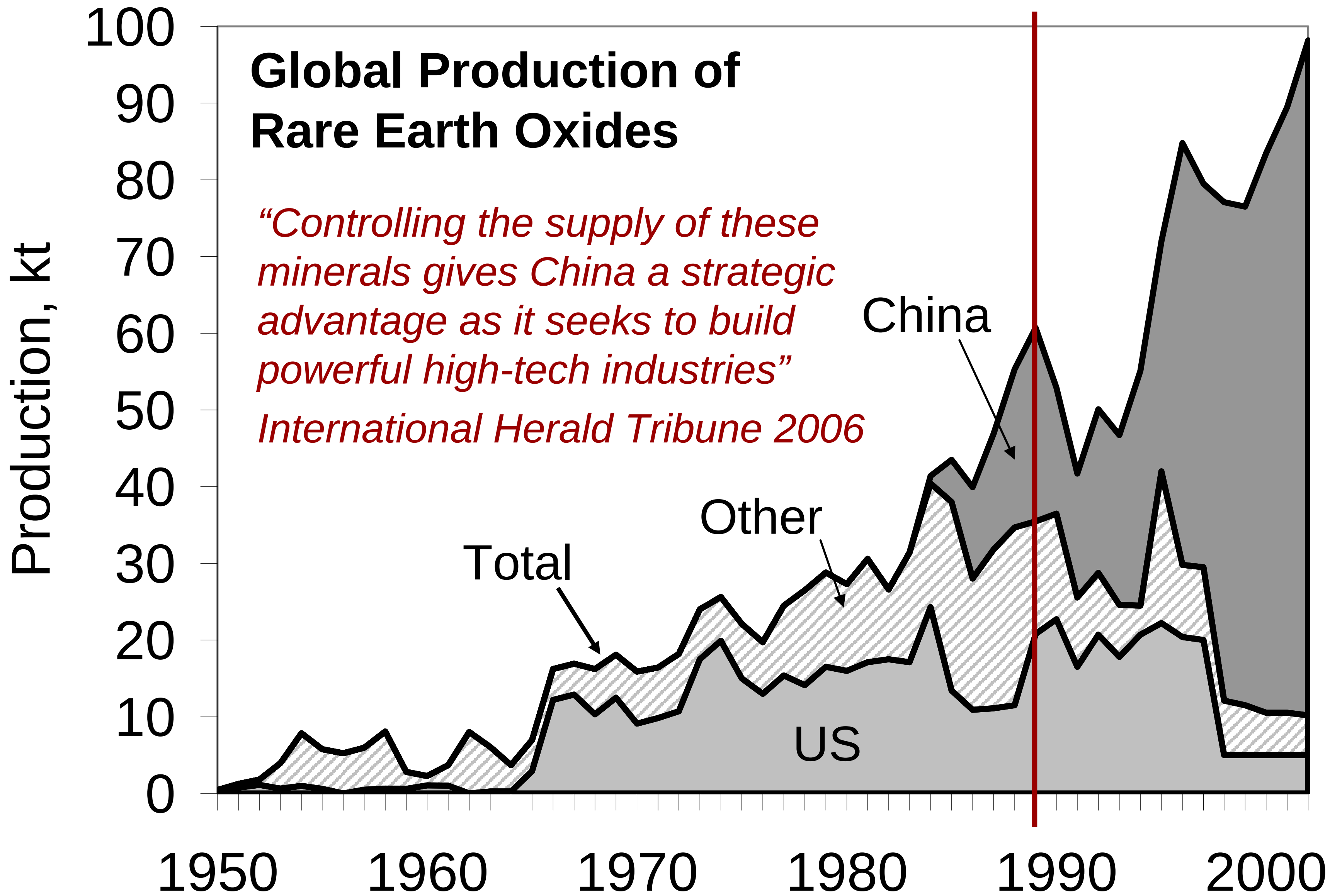
ar-IR laser (1064

– high temperature

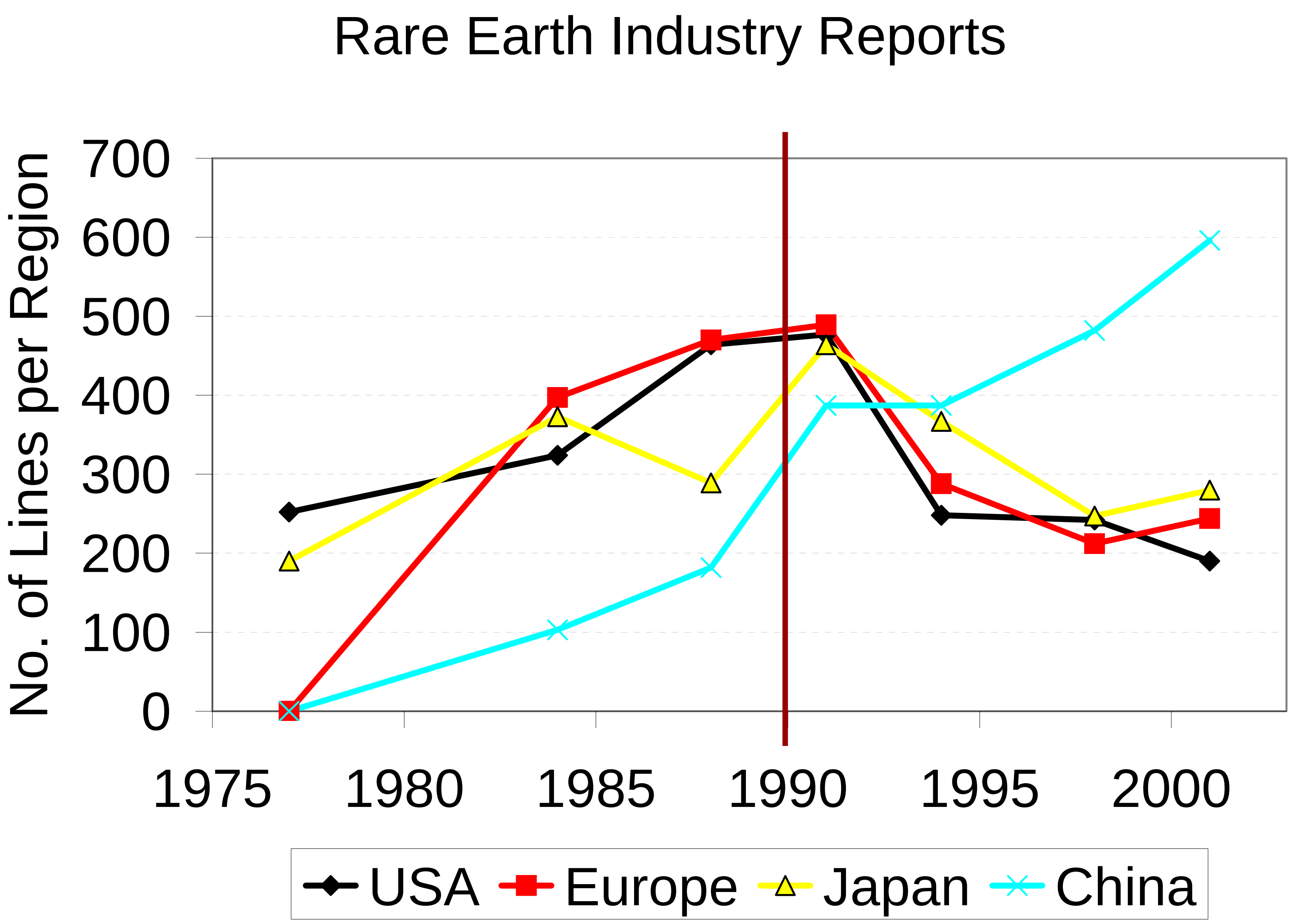
Development of a *growing* industry



The *emergence* and *domination* of China



China emerges as *critical* consumer



What is the impact of offshoring?

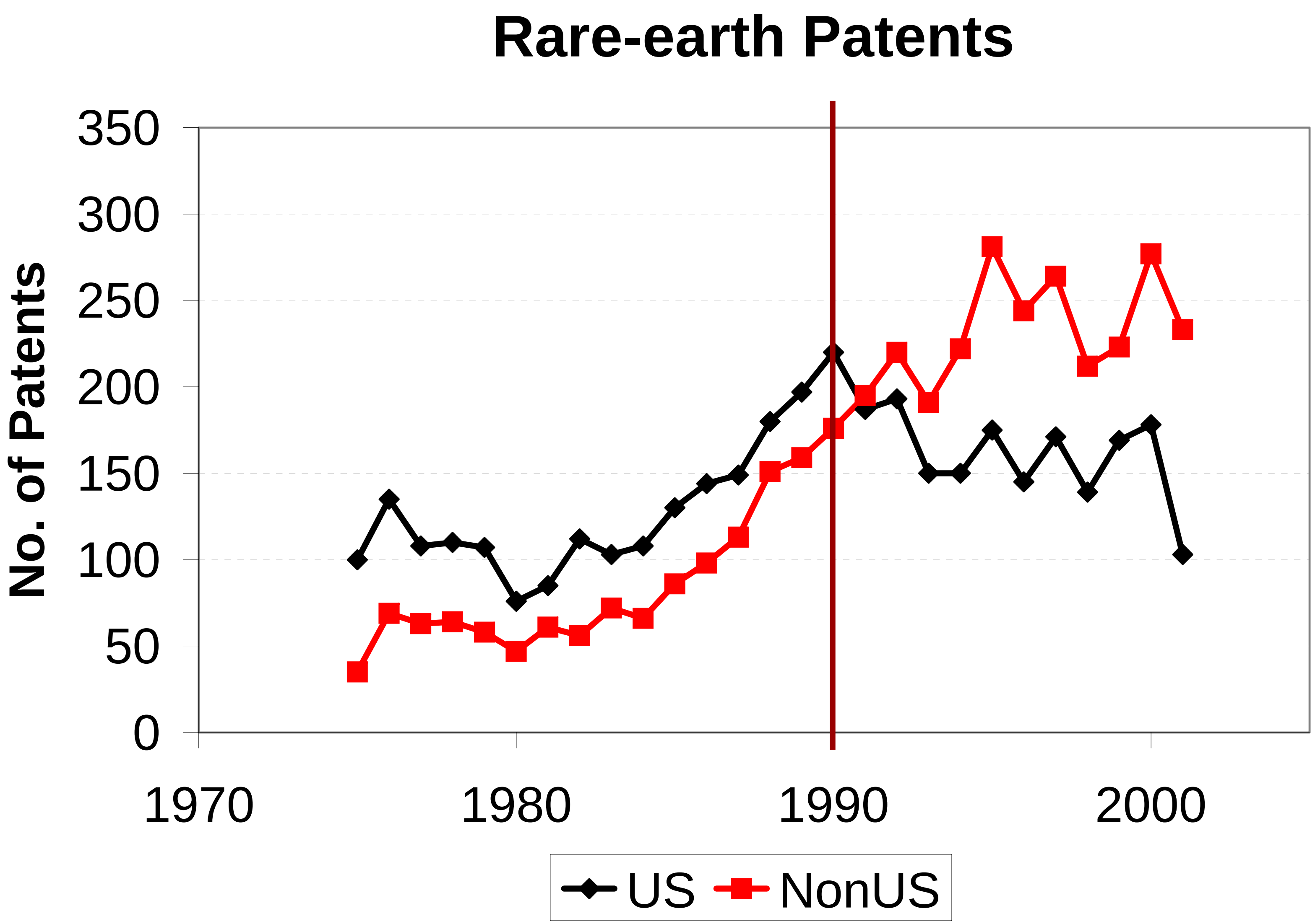
- Internationalization can benefit individual firms as well as regional economies (Mann, 2003; Farrell, 2003)
  - Reduces costs and expands markets (Aron & Singh, 2005)
  - Greater scale to exploit high technology innovation developed in home region (Shan and Song, 1997)
  - Increase innovation by augmenting knowledge base (Florida, 1997; Quinn, 1999, 2000)
- Manufacturing matters (Cohen & Zysman, 1987; Hira & Hira, 2005)
  - Manufacturing and high value added services are complements
  - As manufacturing moves, engineering and R&D will follow

Magnequench offshoring path

World leader in rare earth magnet powder metallurgy

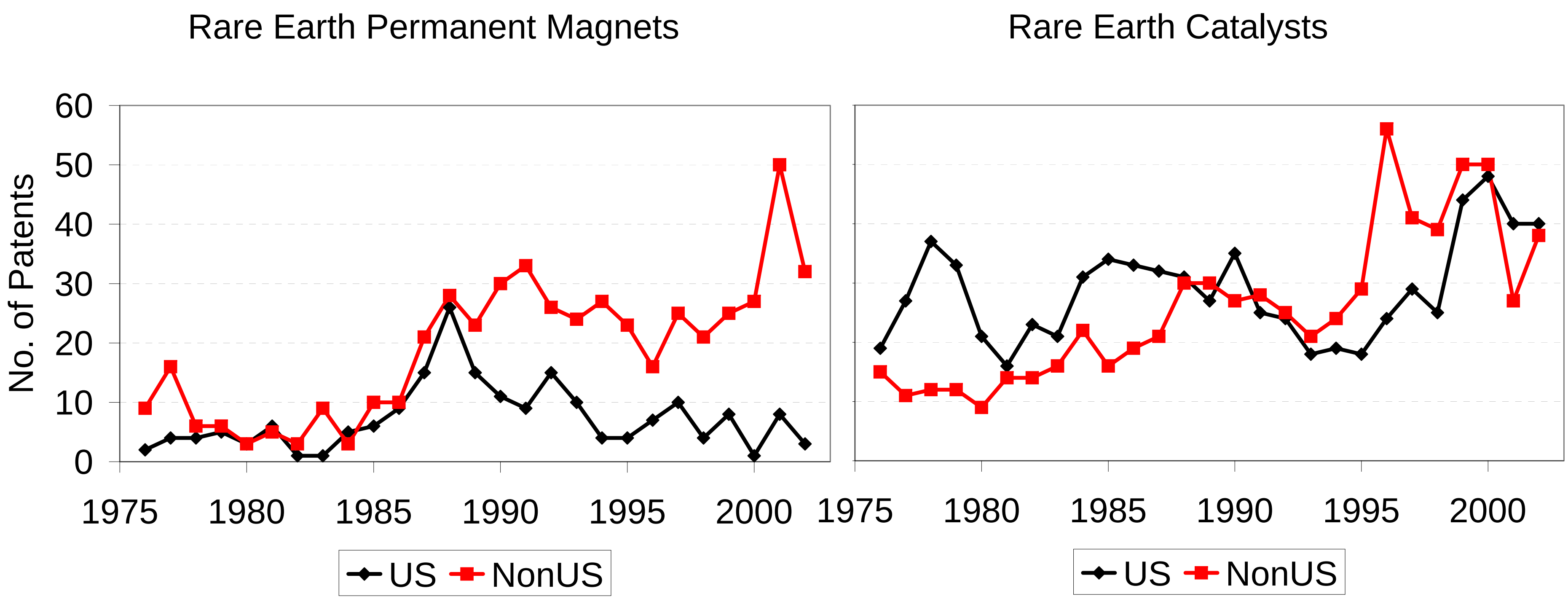
- 1982 – Files exclusive patent on NdFeB permanent magnet composition
- 1986 – Opens $70 million magnet facility in Indiana
- 1998 – Begins production in China
- 1999 – Opens R&D center in Research Triangle Park
- 2002 – Closes Indiana production facility
- 2004 – Moves R&D center to Singapore

Magnequench as part of a *broader* trend



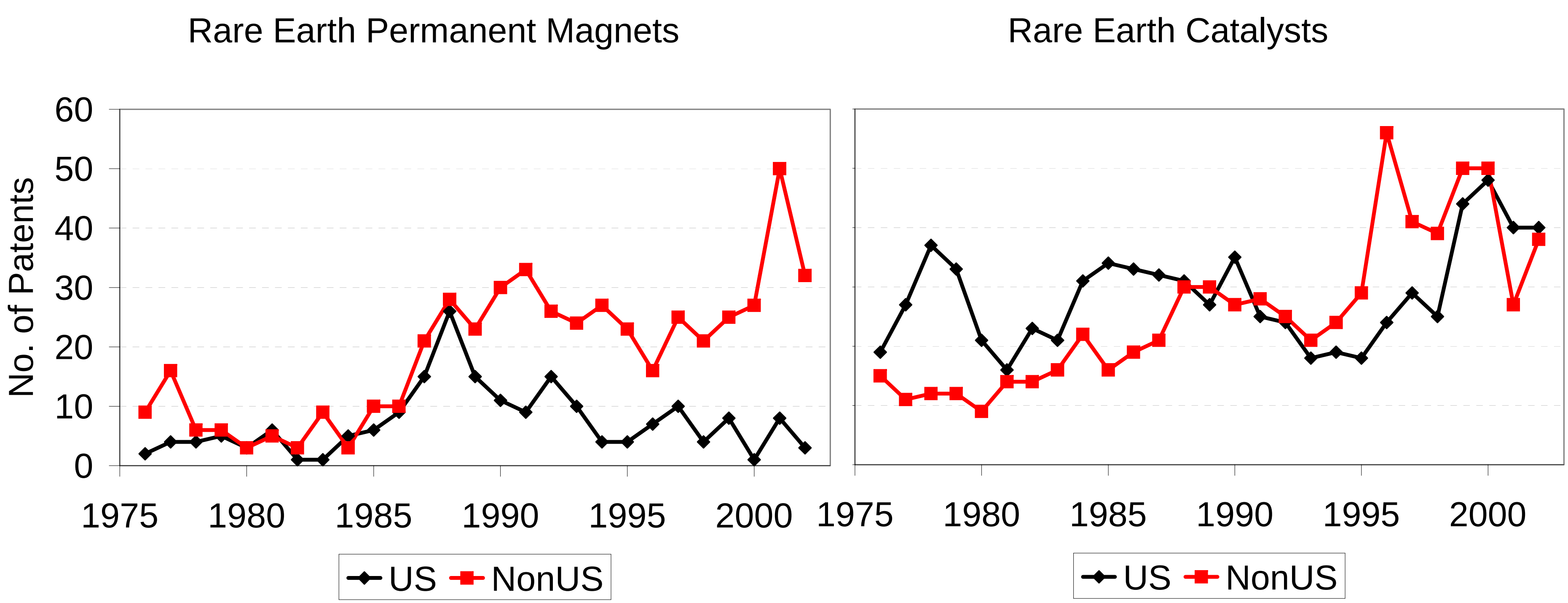
Rare earth technology differences

- US rare earth patenting has been declining since 1990
- But this trend is not uniform across rare earth technologies



Research question

- When does innovation follow the internationalization of upstream supply chain activities and when does it not?
- What are critical drivers of co-location of innovation and production?



Knowledge spillovers as a *critical* driver

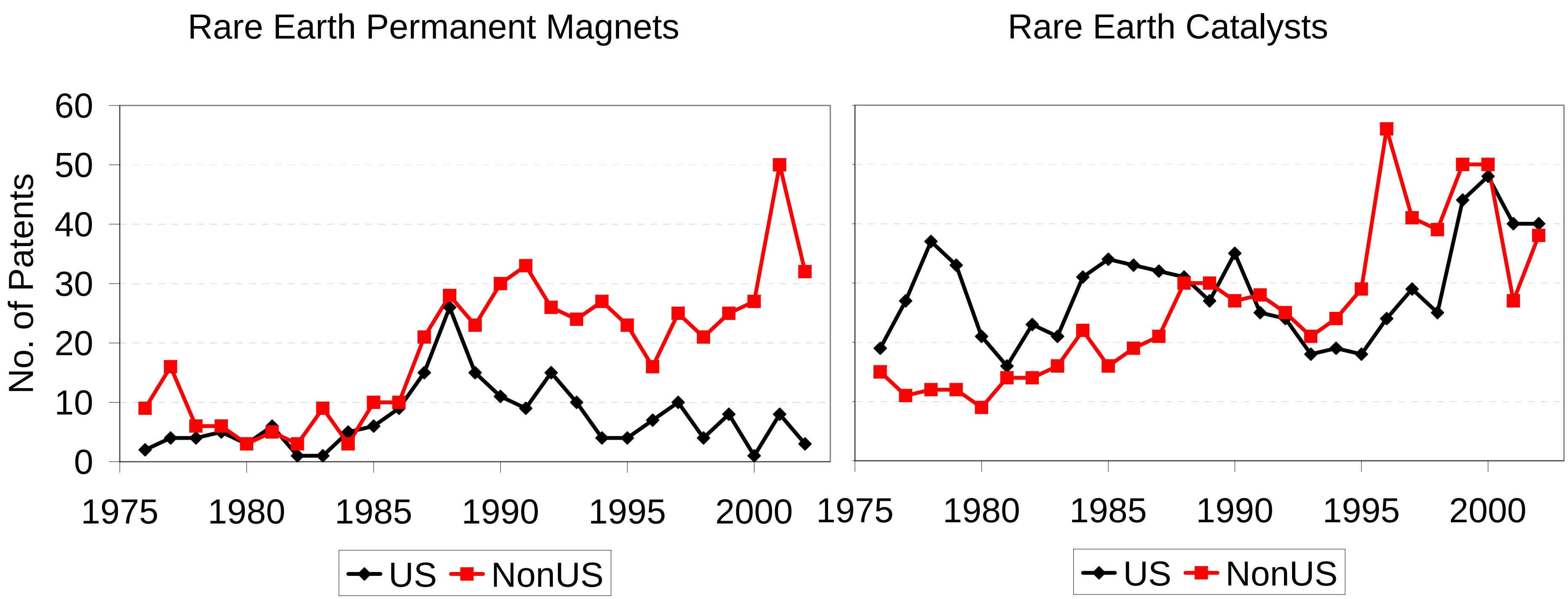
- Knowledge spillovers
  - Spillovers geographically localized (Jaffe et al., 1993; Audretsch and Feldman, 1996; Thompson and Fox-Kean, 2005)
  - Codified vs. tacit knowledge

- Knowledge Spillovers and Co-location of Production and Innovation (Macher and Mowery, 2004)
  - When spillovers matter, innovation follows the movement of the value chain
  - When spillovers do not matter, the location of segments of the value chain do not impact the location of innovation activities

- Industry interviews suggested spillovers important for permanent magnets but not catalysts

Knowledge spillovers and innovation offshoring in 2 rare earth technologies

- Are knowledge spillovers important?
- Do they play a role in the movement of innovation activities?



Methods: Empirical testing

- Patent citations
  - Citations identify "prior art" of relevance to the focal patent
  - Citations are one of the most traceable records to understand critical knowledge flows (*Jaffe et al., 1993, 2000; Stuart and Podolny, 1996*)
  - Preponderance of local citations is indication of knowledge spillovers (*Jaffe et al., 1993, 2000*)

- Take a US perspective
- Measure percent of US citations by focal patents

$$perus = \frac{US\ citations}{Total\ citations}$$

Methods: Variables

- Independent variables
  - US dummy (*US*)
    - US versus NonUS location
  - Time period dummy (*d*)
    - Before and after 1990
  - Interaction
- Control variable
  - Random expected percent of US citations per focal patent
    - Use algorithm to identify complete set of patents containing relevant and available prior art
    - Controls for time trends

Regression Results

Dependent Variable: **ln(perus/(1-perus))** *Logistic transform of percent US citations*				
	Catalysts		Magnets	
Model	1a	1b	1a	1b
US *0-1 dummy for location*	+***	+***	+***	+**
d *0-1 dummy for time period*	+***	+**	-	-**
US*d *US after 1990*		+		+**
** p < 0.05; *** p < 0.001				

Understanding regression results

- For both technologies
  - Local knowledge spillovers matter in both time periods (*US* = +*** in all models)
- For Catalysts after 1990
  - US knowledge <u>more</u> important for all innovation activities (*d* = +*** in Model 1a and 1b)
- For Magnets after 1990
  - US knowledge <u>less</u> important for innovation activities abroad (*d* = -** in Model 1b)
  - US knowledge <u>more</u> important for US innovation activities (*US**d* = +** in Model 1b)

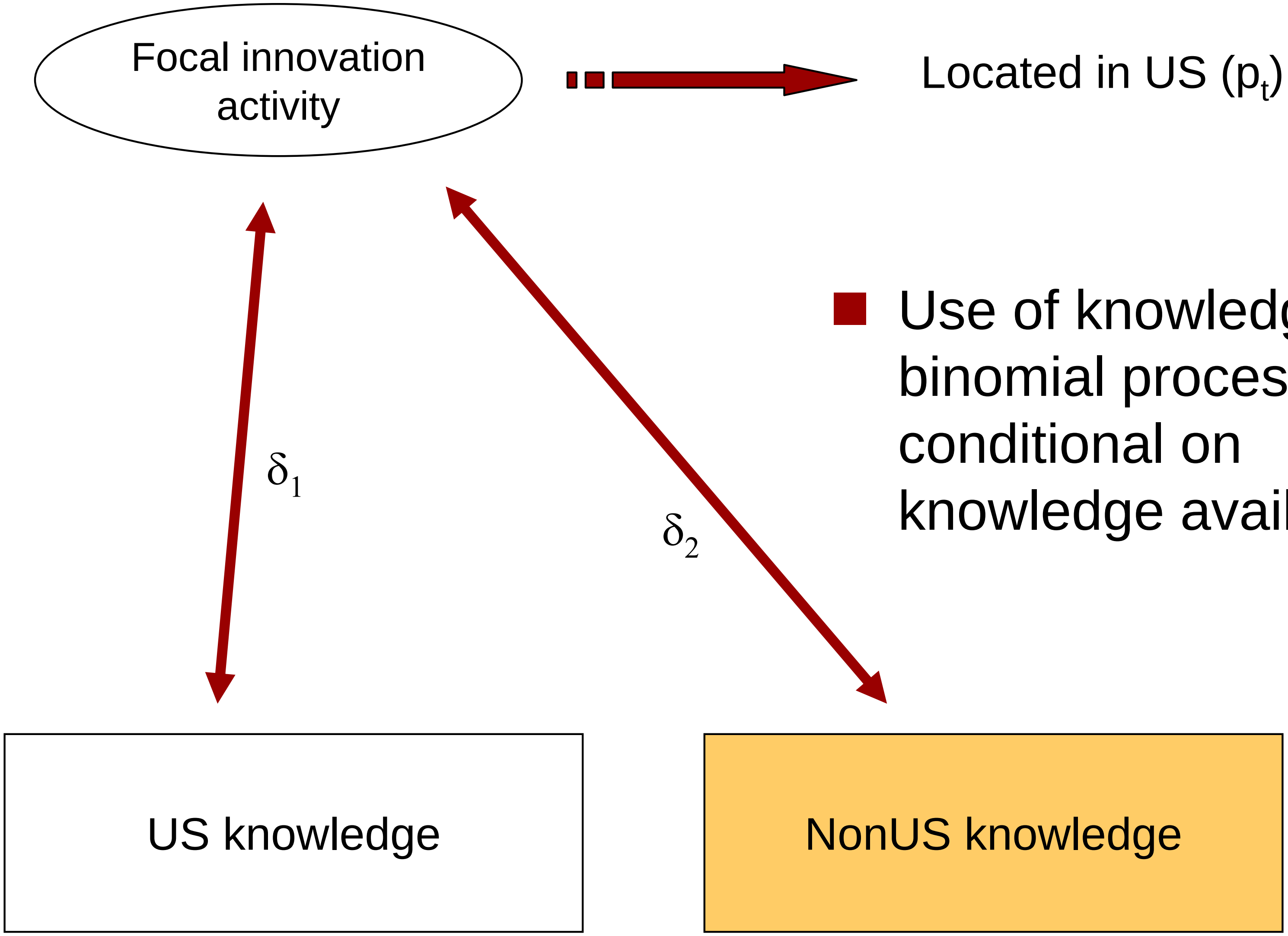
Interpreting role of knowledge spillovers

- Patent counts suggest
  - Innovation activities in <u>magnets moving away</u> from the US
  - Innovation activities in <u>catalysts remain</u> in the US
- Citation regressions suggest
  - For catalyst innovation, US knowledge remains important for domestic and foreign activities
  - In magnet innovation, domestic and foreign activities increasingly rely on respective local knowledge
- When spillovers matter for innovation activities these will be located where relevant knowledge is

Understanding the Process

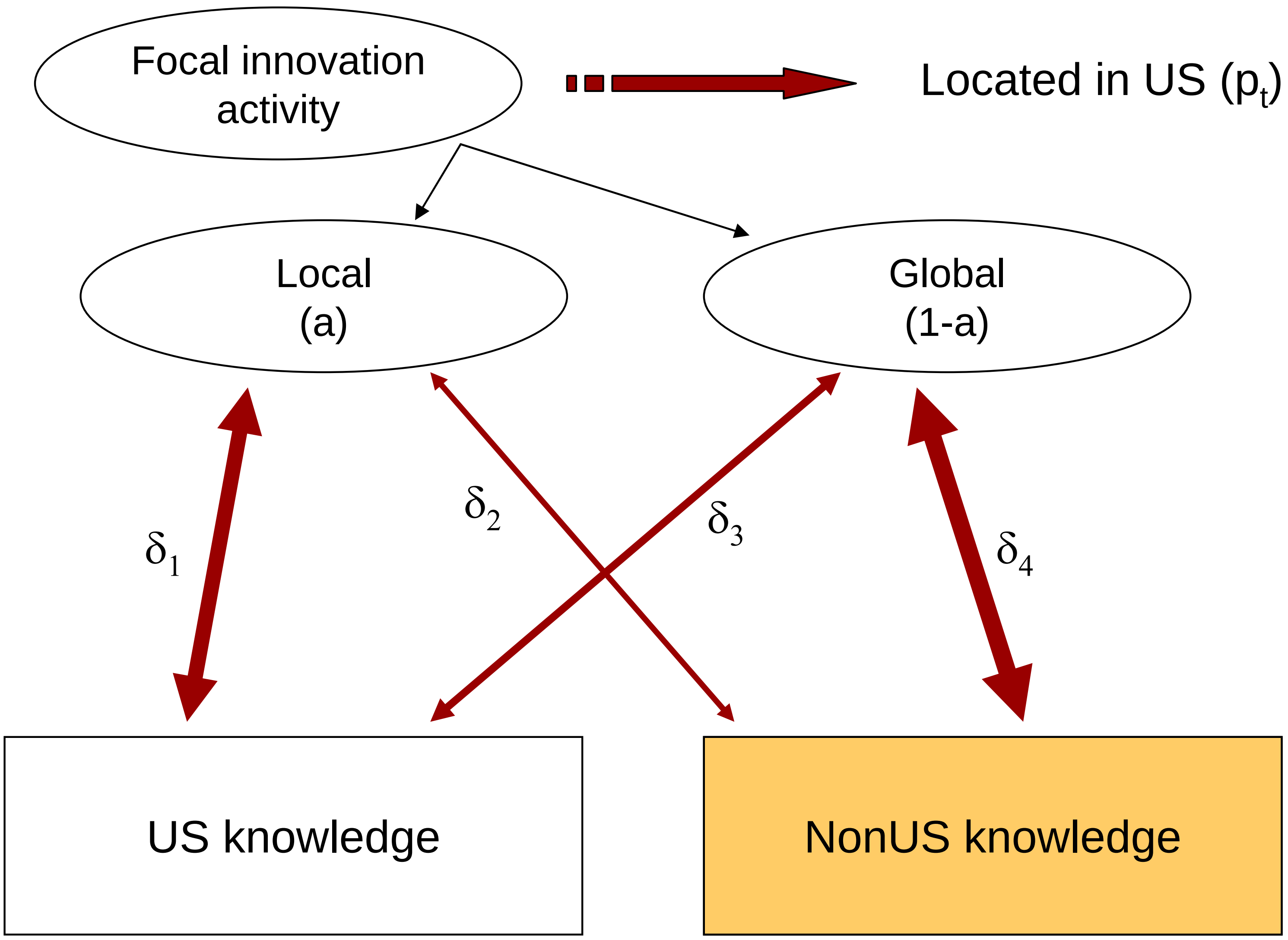
- Testing for competing explanation
  - Nature of innovation process changed after 1990
    - unobserved heterogeneity
- Model underlying structure for innovation processes
  - Capture the role of knowledge spillovers
  - Control for the nature of innovation processes
  - Replicate key regression results

Understanding knowledge use in innovation

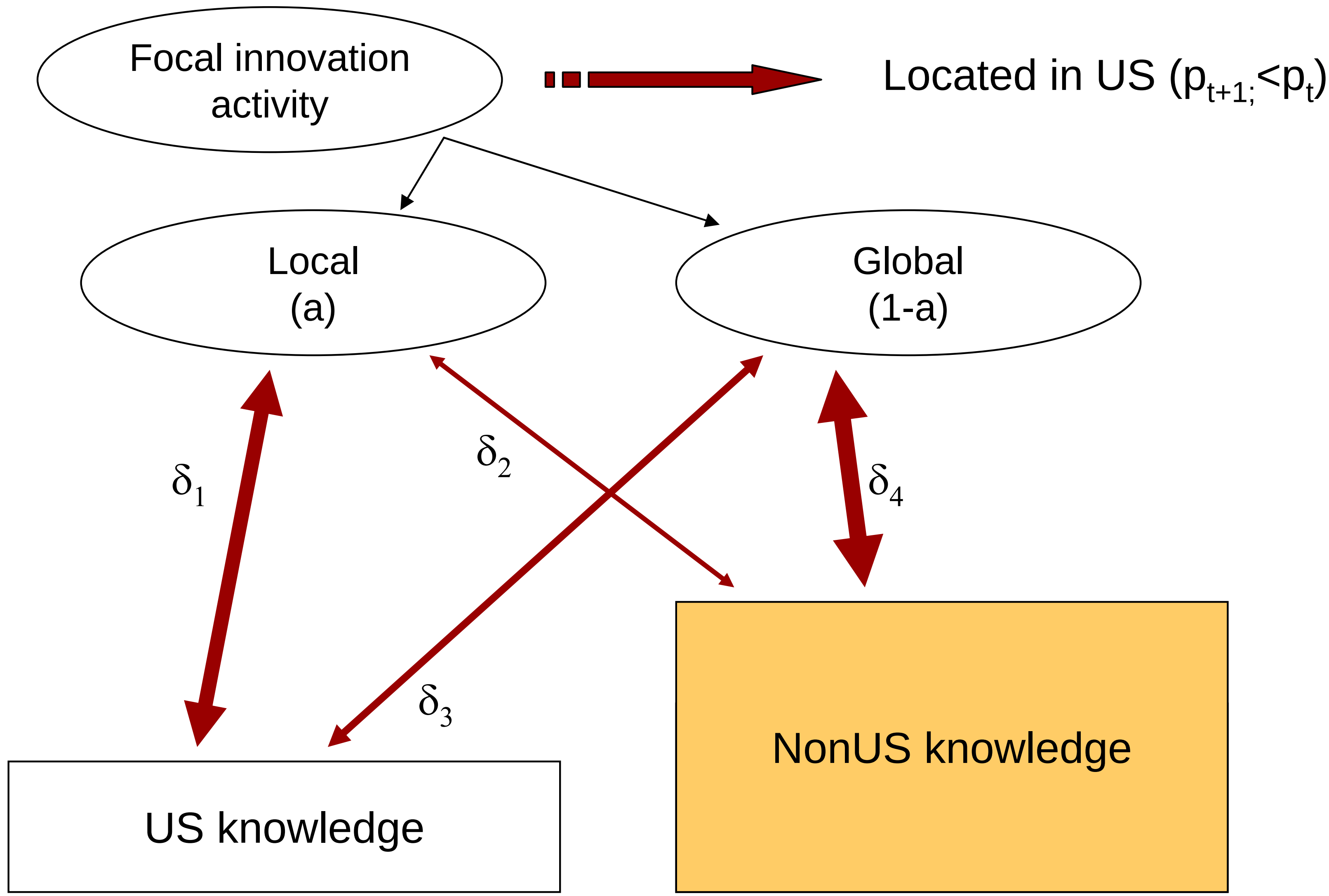


- Use of knowledge is binomial process conditional on knowledge availability

Assume two classes of innovation activity



What changes in time period t+1?



Results of model

US Magnet Innovation Activities				
	Before 1990		After 1990	
	Local	Global	Local	Global
Local Knowledge	51%		64%	

- For magnets after 1990,
  - US knowledge more important for US innovation activities (Percent increase = 13%)
  - US knowledge more important for US innovation activities (*US*d* = +** in Model 1b)

Process behind the results

US Magnet Innovation Activities				
	Before 1990		After 1990	
	Local	Global	Local	Global
% innovation activities	39%	61%		
Local knowledge	98%	35%		
Global knowledge	2%	65%		

Conclusions

- What innovation will stay and what will go?
  - Knowledge spillovers play a role in determining location
  - Need to understand changing nature of innovation activities
- What tasks will stay and what will go?
  - Codifiable and tacit information (*Leamer and Storper, 2001*)
  - “Routine” and “nonroutine” tasks (*Levy and Murnane, 2004*)
  - Electronic and nonelectronic tasks (*Blinder, 2006*)
- Need to reframe discussion on appropriate responses to movements offshore
  - View that solution is just to upgrade to higher value-added (innovation) jobs may be incorrect – some of these will go

Questions?

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