Structure & Evolution of Regional Industrial Ecosystems

Case study of Barceloneta, Puerto Rico

Outline

- Objective – Inductive theory-building using case study research to understand how regional industrial systems function and change

- Approach – An integrative framework to study different elements of structure and their evolution in such systems
- Case study – Barceloneta, Puerto Rico 1950-2005
- Preliminary findings
- Summary

A framework for studying regional industrial ecosystems

- Region industrial systems can be studied using
  - Industrial ecology (community ecology concepts)
  - Economic geography
  - Organizational sociology
  - Complex systems theory
- This research integrated these approaches by first determining similarities and differences in how each field perceives system structure and evolution

System structure

- Three aspects to consider
  - Context in which the system exists, actors/components within the system, and interactions among the actors
- External forces determine conditions that act on the system
  - Biophysical resource availability and stochastic events
  - Social, economic and political conditions and changes
- Within system: structure results from patterns in relationships among actors
  - Diversity and dominance of different types of actors
  - Biophysical (material and energy) flows
  - Economic trade (buying and selling goods and services)
  - Social interactions, norms, culture

Structural components of integrative framework

Aspect	Ecological forces	Regional socio-economic forces	Industrial ecosystem measure
Context	Climate, biogeography	Institutional context	Climatic and biogeographic conditions Political, economic, social, cultural, and institutional conditions
		Factors of production	Stocks of natural (water, land use, air quality), financial, human, social and knowledge capital
Actors	Species	Industries	Identification of industrial sectors and firms present, diversity and dominance of industrial sectors
	Functional groups, trophic levels	Industrial sectors	Categorization of industrial firms into functional groups, including producers, consumers and recyclers; identification of specialization
Interactions	Energy flows		Energy supply and demand and the flow of energy among industries
	Material flows		Material use within region, with special attention to use of recycled materials and recycling loops
	Competition	Competition	Consumption of locally available resources, development of symbiosis
	Predation	Demand conditions	Supply chain, local and export markets
	Migration, colonization	Threat of substitutes or new entrants	Entrance of new firms and new industries
		Social networks	Inter-firm and inter-personal relationships

Puerto Rico context

- Climate and geography
  - Tropical climate, susceptible to hurricanes
  - Diverse island ecosystems
  - Area ~9000 km^2
  - Population ~3.9 million

- Political economy
  - US commonwealth territory with internal self government
  - Economy based on manufacturing and tourism
  - Island is politically stable but currently in economic recession

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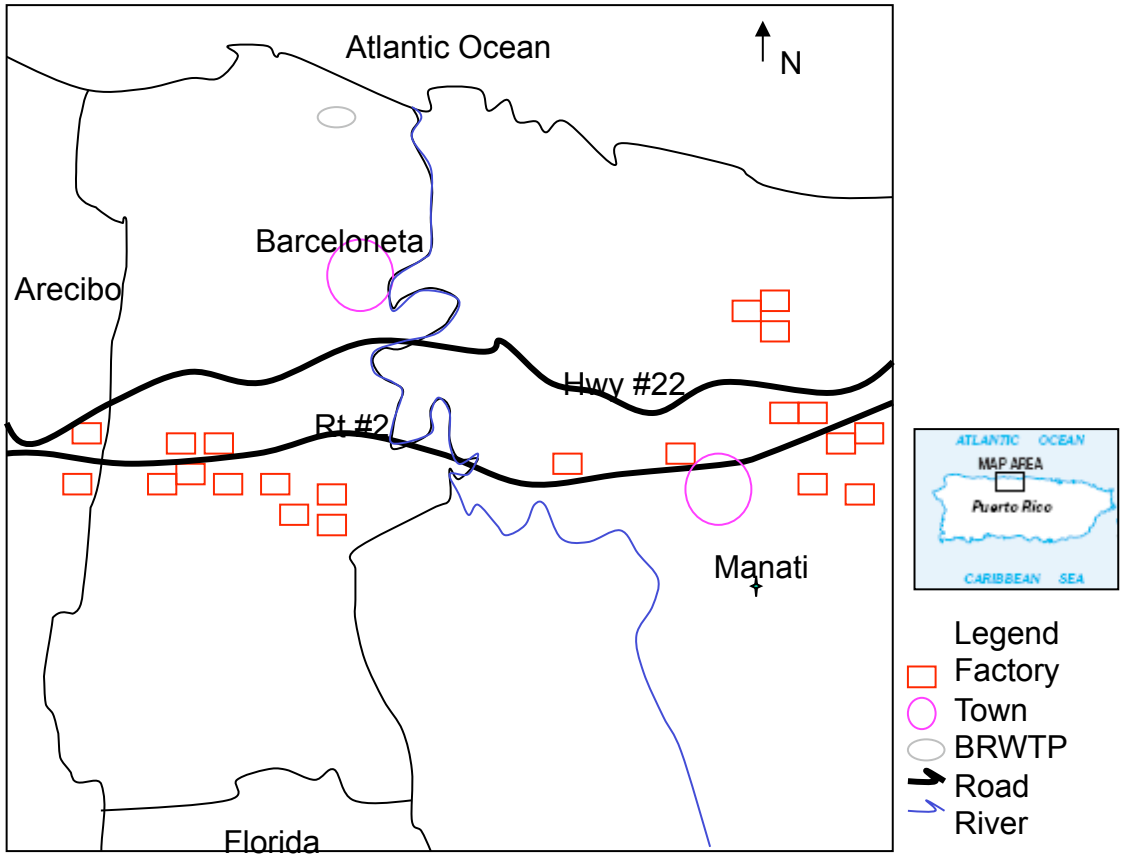
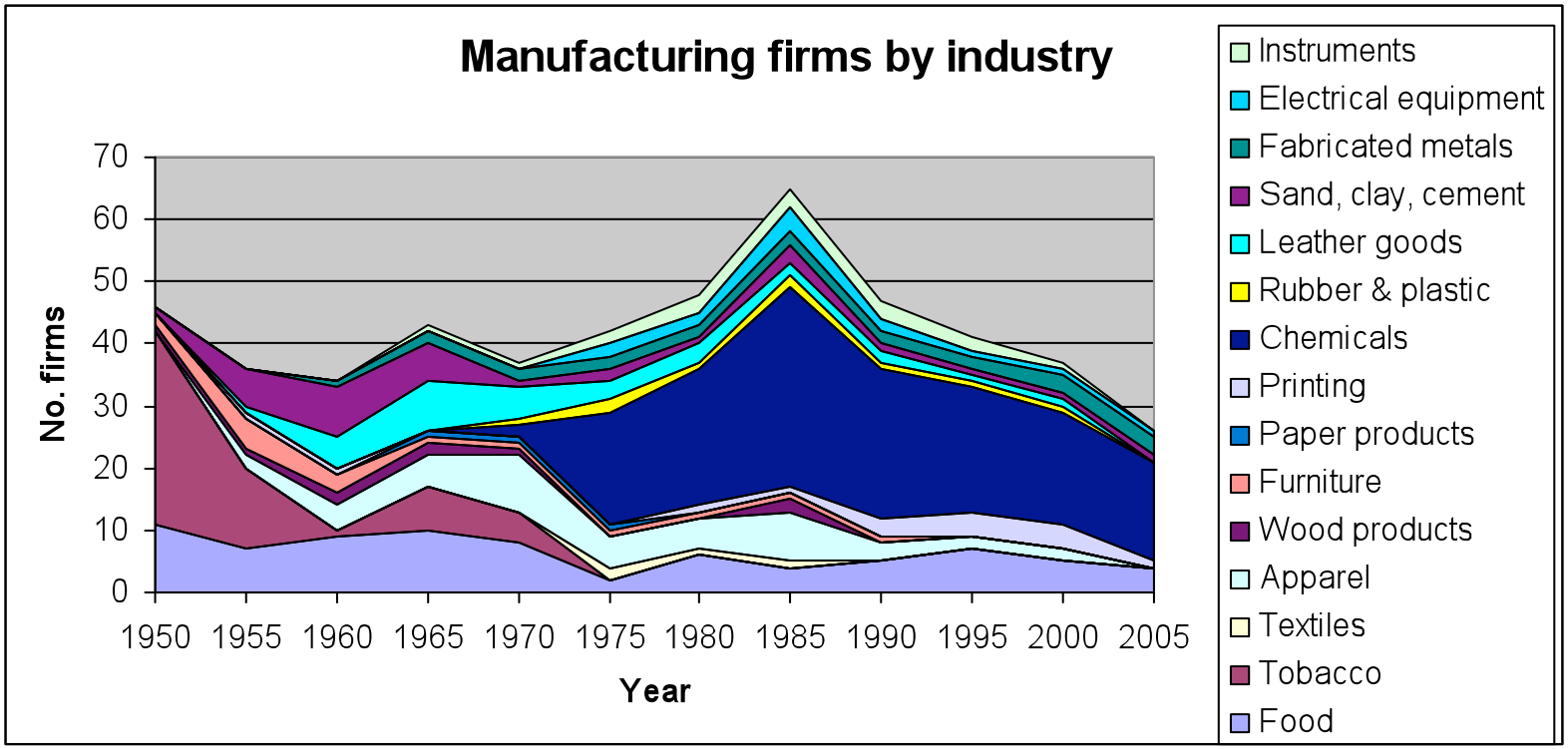
Barceloneta Resource availability

- Natural resources
  - Zone of highest permeability in vast north coast aquifer system
  - 30km proximity to San Juan and its ports
  - Proximity to ocean for treated wastewater discharge



Barceloneta industrial evolution



Pre-1950:	Rural, agricultural region, sugar cane plantations
1960s:	Labor intensive manufacturing industry – food, textiles, footwear
1970-2000:	Capital intensive manufacturing – pharmaceuticals
Post-2000:	Decline of manufacturing, rise of services

Industrial structure diversity & dominance

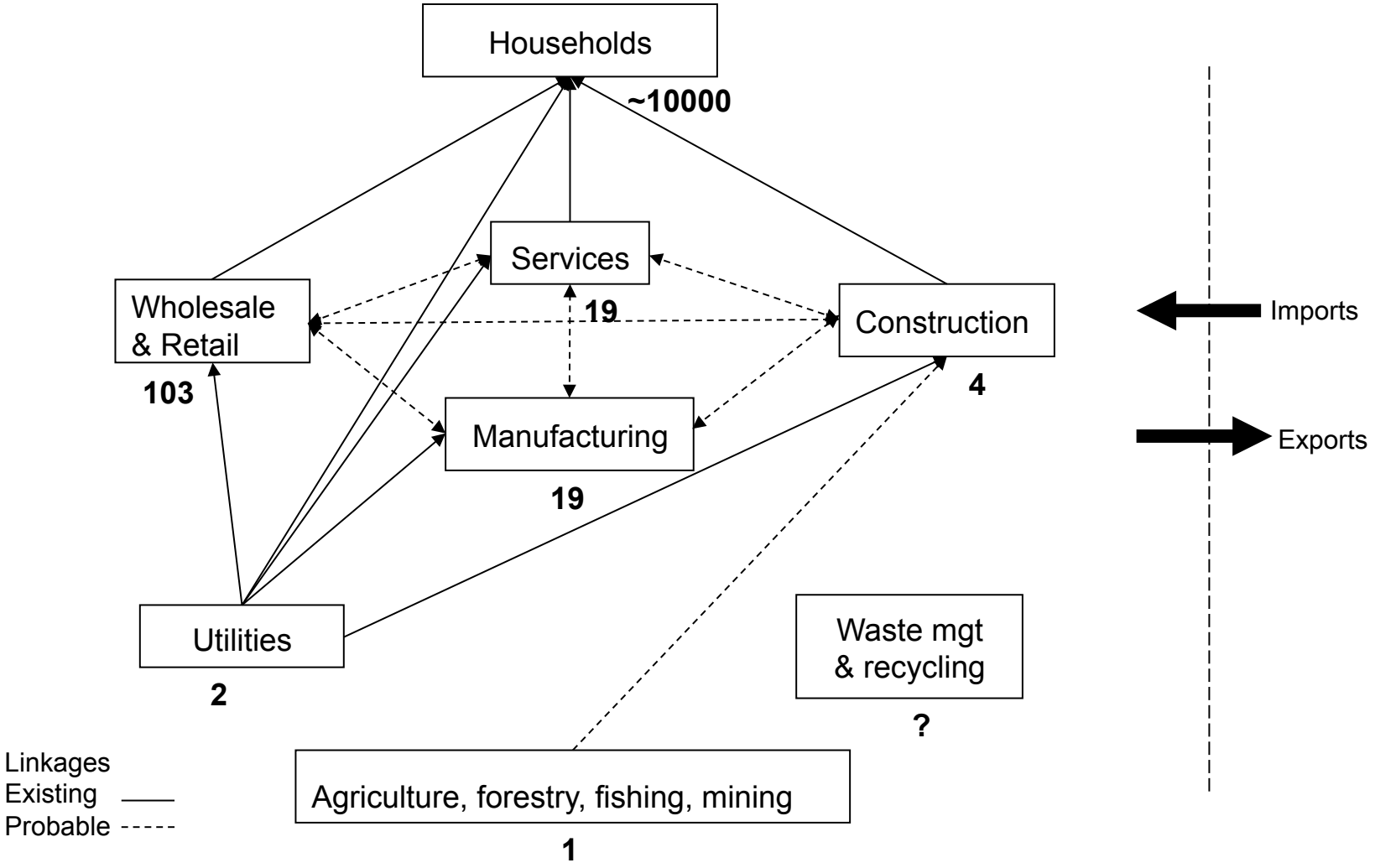
Index	1960	1970	1980	1990	2000
Location Quotient (LQ)	0.304	0.253	0.277	0.208	0.205
Shannon Weiner Diversity Index (H)	2.064	2.117	1.868	1.757	1.710
Species Evenness (E)	0.861	0.852	0.752	0.732	0.743

*Manufacturing sector only

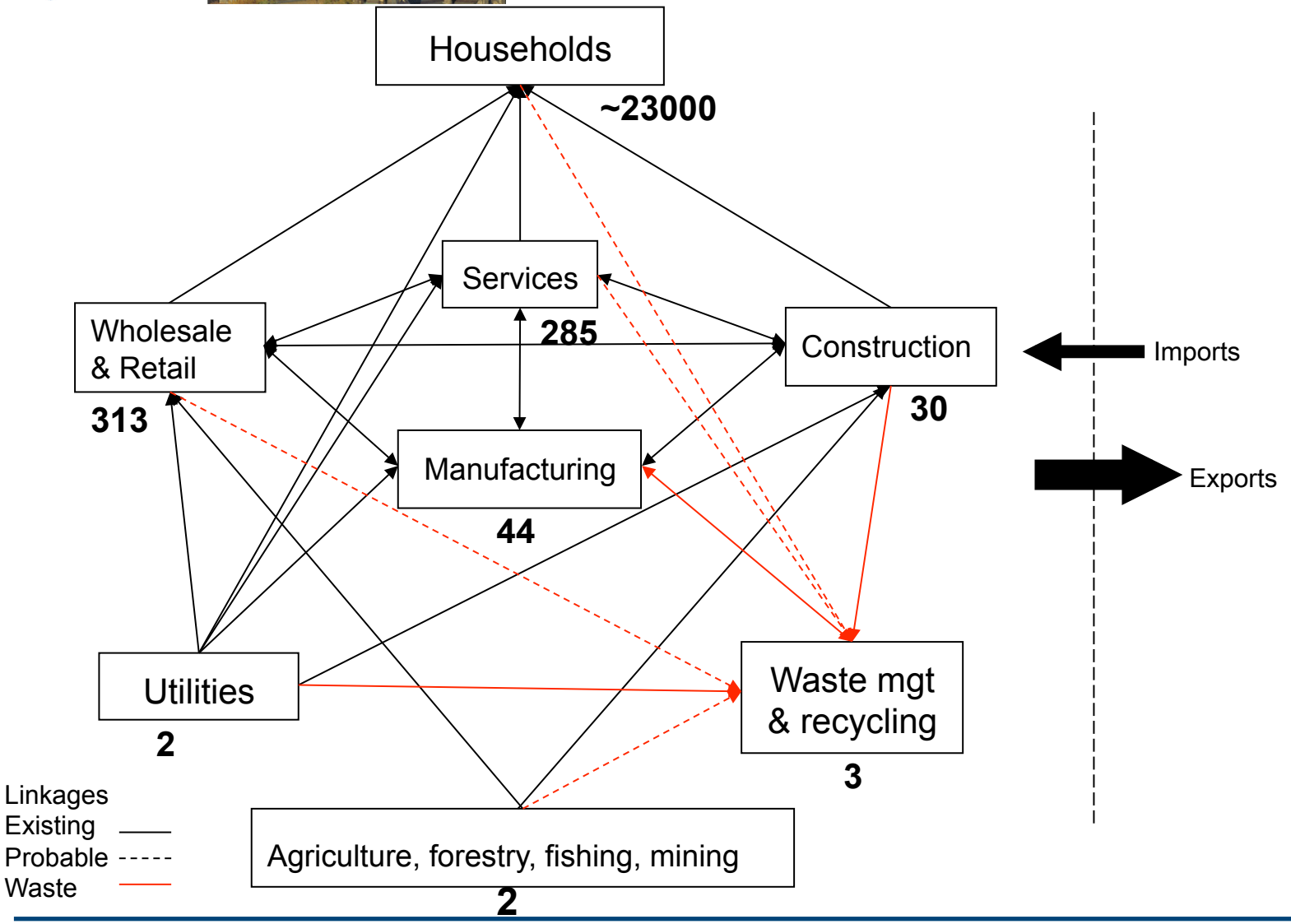
$$LQ_i = re_i/re_t * ne_i/ne_t$$
$$H = \Sigma(n_i/n) * \ln(n_i/n)$$
$$E = H/\ln(s)$$

where
re - regional employment
ne – national employment
i – i^{th} industry
n – number of firms
s – number of industries

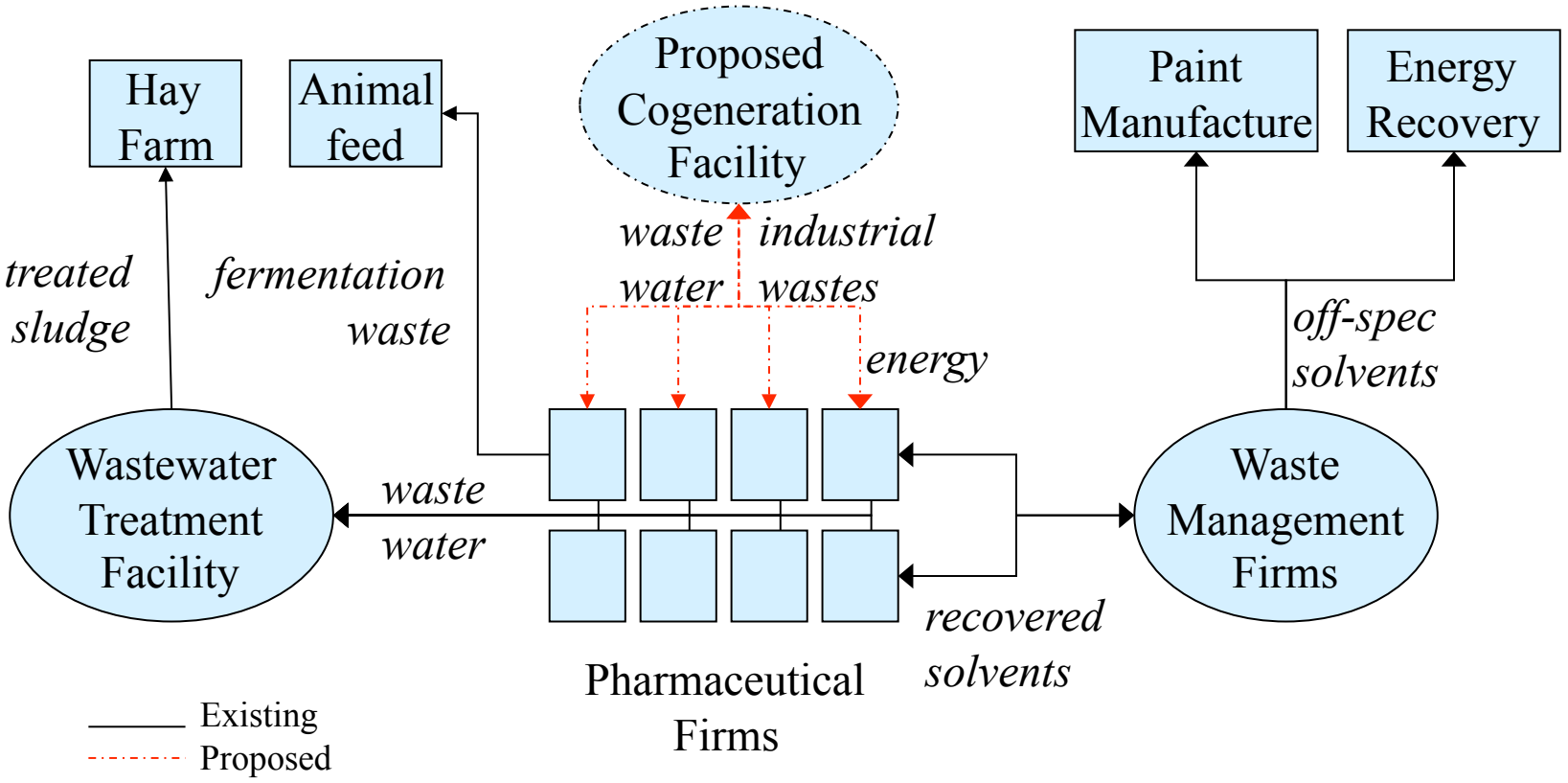
Hypothesized economic structure: 1956



Economic structure: 2002



Industrial symbiosis energy & material conservation



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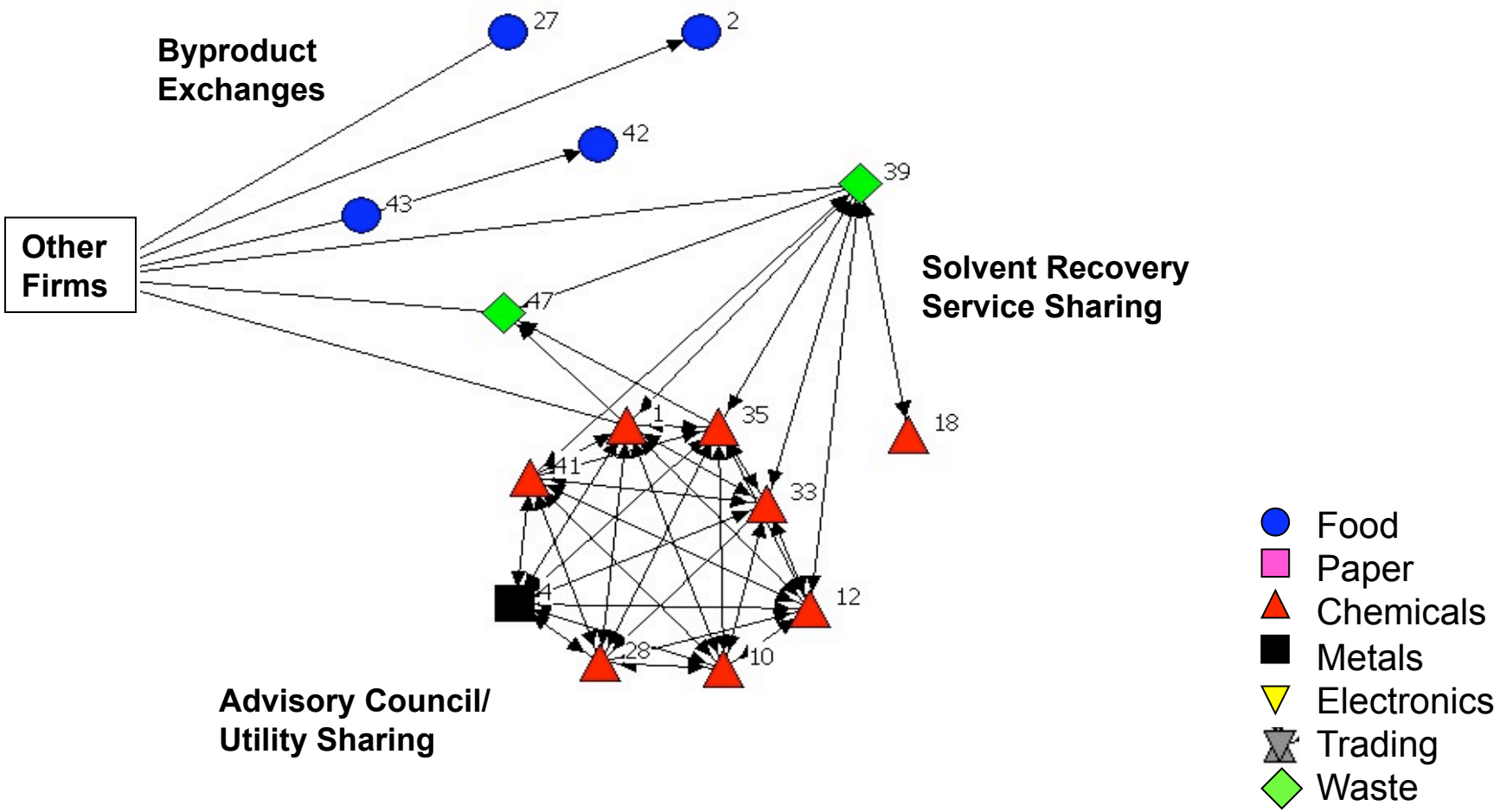
Industrial Symbiosis network relationships



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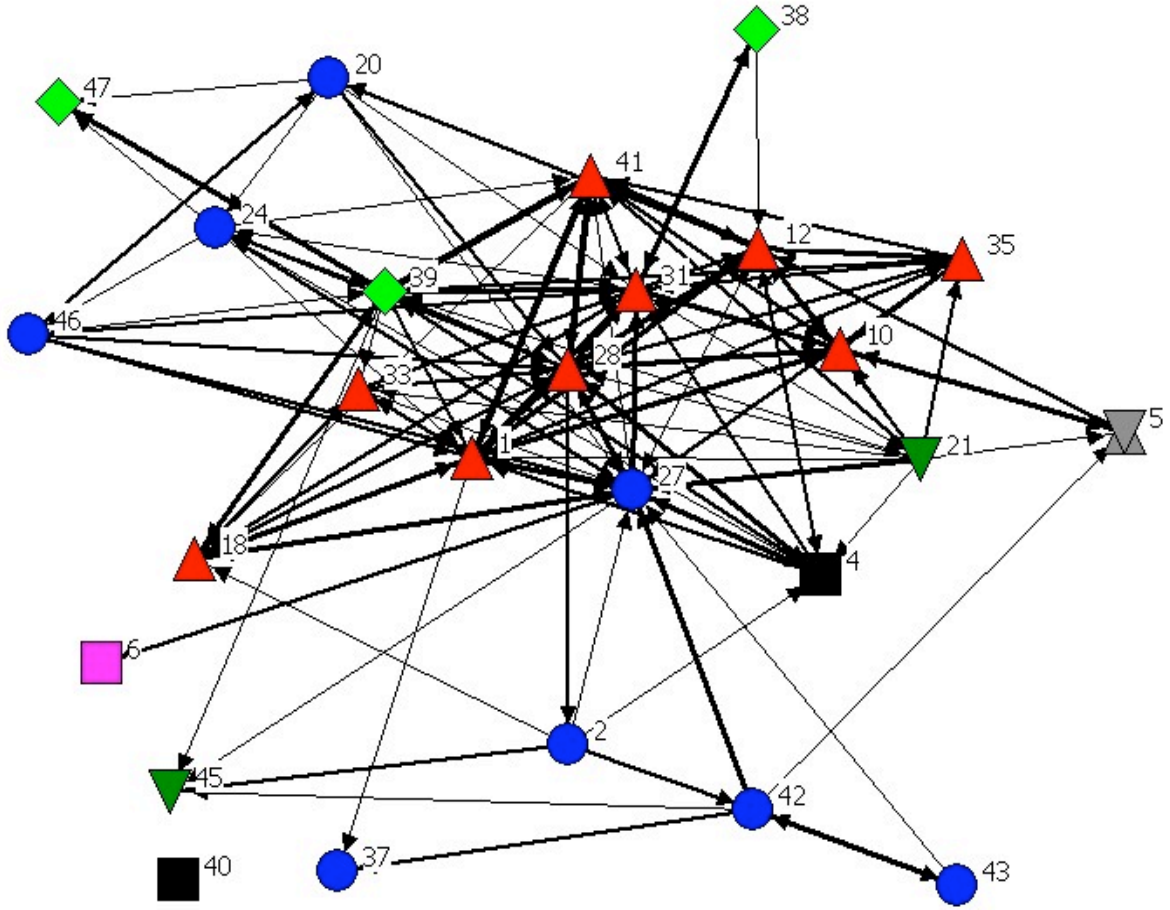
Social structure in 2004

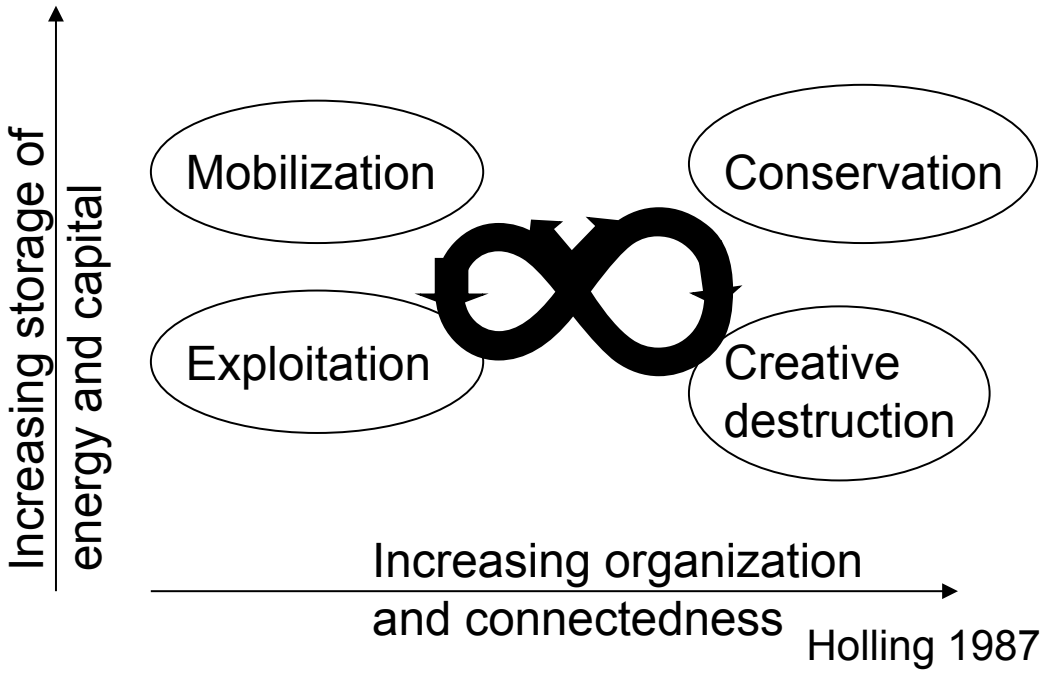


- Food
- Paper
- Chemicals
- Metals
- Electronics
- Trading
- Waste

Barceloneta system evolution

Complex system cycle

- Collapse of agriculture led to release of resources and subsequent exploitation by manufacturing firms
- Increasing no. and types of structural linkages among firms
- Increasing amount of local resource conservation and recycling
- Shifting industrial composition, but system maintains high level of diversity
- Pharmaceutical industry entering transition period



Summary

- Industrial ecosystem described
  - Economic, material, and social structures
  - System evolution followed complex system cycle

- Further work
  - Complete natural history of the system by aligning changes in external events and local resource availability to observed patterns in industry structure and evolution
  - Examine lessons of this case for theory building