PUBLIC POLICIES AND CHANGING BOUNDARIES OF FIRMS IN A "HISTORY FRIENDLY" MODEL OF THE CO-EVOLUTION OF THE COMPUTER AND SEMICONDUCTOR INDUSTRIES

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Workshop: Policy implications from recent advances in the economics of innovation and industrial dynamics

Different types of public policies
in changing and uncertain technological and market environments

Focus on the evolution of two vertically related industries
Computer and semiconductor industries

Use of a history friendly model

Previous work:
Antitrust – timing IJIO 2001
Public procurement as experimental customer -
We do not address the desirability of the policies

We address the effects of alternative forms of public intervention in dynamic, evolving interacting markets

Previous work:
Antitrust – timing IJIO 2001
Public procurement as experimental customers -
Growing literature on industrial dynamics and evolution in which explicit dynamics, heterogeneous agents, increasing returns of various types and path dependency play a major role.

Still, in most models that are part of this literature, policy discussions or implications have been neglected.

Some exceptions:
- Antitrust and the static vs dynamic Schumpeterian efficiency trade off between innovation and monopoly power
- IPR
- Appropriate market design, i.e., electricity markets
Policy measures to promote industrial growth and technological change in dynamically, related co-evolving industries

In these industries you may have Increasing returns on the supply side and network externalities on the demand side

Some aspects of policies
- Timing of policies become relevant

- Side and indirect effects on horizontally and vertically related sectors
  
  ex. heterogeneous customers and a horizontally related market allows for the survival of a new potentially superior technology

- Unintended consequences
  
  ex. The destruction of a downstream monopolist may make an upstream monopolist emerge
We have addressed this issue with a history friendly model (HFM) of the computer and semiconductor industries.

History friendly models (HFM): goal of matching overall patterns in qualitative features.

HFM focus on some particular causal mechanisms.

HFM do not attempt to detailed calibration of parameters.

HFM are in the family of evolutionary models.
HISTORY FRIENDLY MODELS (HFM)

We have addressed this issue with a history friendly model (HFM) of the computer and semiconductor industries.

HFM are simulation models that intend to enhance the understanding of particularly interesting and important phenomena.

HFM are models which aim to capture in stylised form qualitative theories about mechanisms and factors affecting industry evolution and technological advance.

They do not aim to match the quantitative values observed.

They do not specify the model parameters as close as possible to actual empirical values.
HFM aim to explore whether particular mechanisms and forces built into the model can generate (explain) the patterns examined.

HFM are guided by verbal explanations and appreciative theorizing.

HFM are “evolutionary”: boundedly rational agents; behavior guided by routines; learning and capabilities as key variables; historical processes; competition and selection.
HFM have runs that match the qualitative features of the historical patterns and runs that do not match the historical patterns.

We will use a HFM to do some exercises on the effects of different types of policies on the evolution of two related industries.

Good for discussion of policy effects.
Three main periods examined:

a. Mainframes - and transistors as their main SC components

Emergence of IBM as the monopolist in mainframes

b. Introduction of the integrated circuit (IC)

c. Introduction of microprocessors (MP) and birth of the personal computer (PC) industry
Vertical integration and specialization patterns

Early in the history of the computer industry, most computer producers were not vertically integrated. Then some became vertically integrated.

With the introduction of the integrated circuit, IBM was fully integrated into IC, because of coordination advantages (IC embedded system elements), fears of leakages of strategic information and security of supply reasons.

With the introduction of microprocessors (MP), IBM and other vertically integrated producers dis-integrated from the large scale production of standard semiconductors and moved to specialization, because they faced a major technological discontinuity and quite large and competent MP firms.
POLICIES

American policies
Various types of public policies in the computer and semiconductor industries
Government funding of R&D projects aiming at development of computers in the late 1940s and early 1950s
Public procurements of computers and semiconductors
Antitrust against IBM

In Europe: protection of national champions
THE MODEL

Rapid presentation of the model - see Jena Max Plank Institute WP 2006

Focus on results and discussion of results
Computers have a mix of characteristics: cheapness and performance.

Computers use semiconductor (SC) components.

SC components are sold to computer firms and to an external market.

At the beginning of the evolution of the computer industry: SC component technology—transistors—makes possible to have mainframes which are sold to big users (which are more interested in performance than in cheapness).

First technological discontinuity in SC components: integrated circuits (IC)
Entry of new SC firms producing IC.

Second technological discontinuity in SC components: microprocessors (MP)
Entry of new SC firms producing MP.

MP are used in mainframes and in the same time they open a new market: personal computers (PC). The new PC market appeals to a new set of consumers—individuals—who are more interested in cheapness than in performance.
COMPUTERS

Merit of design M of computers

\[ M_{i,t} = A \cdot \left[ \tau (M_{i,t}^C)^{-\rho} + (1 - \tau) \cdot (M_{i,t}^S)^{-\rho} \right]^{\frac{-1}{\rho}} \]

C= components
S= systems
DEMAND FOR COMPUTERS

Two customers groups: big firms and small users

Completely separated markets

Each group is composed by a large number of heterogeneous subgroups

Markets are characterized by different levels of bandwagon effects
DEMAND FOR COMPUTERS

\[ M_{i,t} = \alpha \cdot w_{i,t}^\delta \cdot z_{i,t}^{(1-\delta)} \]

\[ L_{i,t} = M^\alpha (1 + s_{i,t-1})^\beta \]

\[ Pr_{i,t} = \frac{L_{i,t}}{\sum L_{i,t}} \]

w = cheapness  \quad z = performance  \quad i \quad s = market share
DEMAND FOR COMPONENTS

Demand comes from two sources

a. Computer firms

b. Users different from computer firms: external markets

When computer producer selects a particular supplier on the basis of a ranking of the mod, the computer firm is contractually tied to that supplier for a certain number of periods
DEMAND FOR COMPONENTS

\[ L_{i,t}^C = M_c^\alpha (1 + s_{i,t-1})^{\beta 2} \]

\[ \text{Pr}_{i,t}^C = \frac{L_{i,t}^C}{\sum L_{i,t}^C} \]
Profits, prices and technological progress

Prices are determined by adding a mark-up on production costs.

Technical progress is modelled through the double draw scheme (Nelson and Winter 1982).

The mean of the distribution from which firms draw is a linear combination of the level of publicly available knowledge and the value of Mod achieved by the firm in the previous period.
FIRMS’ BEHAVIOUR AND TECHNICAL PROGRESS

PROFITS: \[ \pi_{i,t} = M_{i,t} \cdot p_{i,t} - M_{i,t} \cdot o_{i,t} \]

PRICE: \[ p_{i,t} = o_{i,t} \cdot (1 + m) \]

R&D OF INTEGRATED FIRMS: \[ R_{i,t}^C = m \cdot c_{i,t}^C + f \cdot R_{i,t} \]

FIRM DRAWS: \[ d_{i,t} = \frac{R_{i,t}}{v} \]

MEAN OF NORMAL DISTRIBUTION: \[ \mu_{i,t} = h \cdot M_{i,t-1} + (1-h) \cdot K^K_t \]

PUBLIC KNOWLEDGE: \[ K^K_t = \lim_K \cdot \left[ e^{\varphi_k \cdot t} \cdot \left( 1 - \frac{1}{n \cdot (t - tc_k)} \right) \right] \]
TECHNOLOGICAL AND MARKET DISCONTINUITIES

Technological discontinuities

Transistors

Integrated circuits

Microprocessors

Initial level of public knowledge associated to a new basic component technology is lower than that reached by current technology

Market discontinuities

Microprocessors are not just used in mainframes

They also allow the development of personal computers
SPECIALIZATION AND INTEGRATION DECISIONS

Not symmetrical decisions

VERTICAL INTEGRATION decision is affected by:

- the relative size of the computer firm compared to the largest SC component producer
- the age of the SC component technology

Integrated producers enjoy some coordination advantages. The productivity of their R&D efforts on components is enhanced.

SPECIALIZATION decision is affected by:

- comparison between the quality of SC components produced in-house and the quality of SC components available on the market
VERTICAL INTEGRATION

\[ V_{i,t} = \min \left( \frac{A_{\gamma}}{g}, 1 \right)^{\gamma_1} \cdot \left( \frac{q_{i,t}}{q_t^C} \right)^{\gamma_2} \]

\[ \text{Prob(Integrate)}_{i,t} = \frac{b \cdot V_{i,t}}{1 + V_{i,t}} \]

A = time from each discontinuity  \quad q = \text{size}
SPECIALIZATION

\[ Z_{i,t} = \max \left( \frac{\max M_t^C - M_{i,t}^C}{M_{i,t}^C}, 0 \right) \]

\[ \text{Prob}(\text{Specialize})_{i,t} = \frac{A \cdot Z_{i,t}}{1 + Z_{i,t}} \]
ENTRY AND EXIT

Entry occurs when a new component technology or a new computer type is available

Initially the quality of their products is lower than the one of incumbents. But the growth of their public knowledge and the size of the external markey make their design improve

Exit when the market share falls under a certain threshold
EXIT

\[ E_{i,t} = (1 - e) \cdot l + e \cdot s_{i,t} \]

Exit if \( E_{i,t} < E \)

\( L \) = inverse of the number of firms active in the market at the beginning of the simulation

\( E \) = constant
THE HISTORY-FRIENDLY SIMULATION

- Mainframes and the emergence of IBM
  IBM vertically integrates in SC components

- Integrated circuits (IC):
  Entry of new SC firms
  IBM remains vertically integrated

- Microprocessors MP:
  Entry of new MP firms and a large external market for MP

- A new computer market (PC) emerges for different users (individuals)
  PC producers remain specialized and buy MP

- A dominant microprocessor firm emerges in SC industry
IBM dis-integrate
History Friendly Simulation

Figure 1a: Herfindahl index

Figure 1b: integration ratio
POLICIES

OBJECTIVES: competition and technological change

Interventions on the SUPPLY SIDE

  Support for basic research
  Foster diffusion of knowledge
  Break monopoly
  Support entry

Interventions at the DEMAND SIDE

  Open standards
  Selective public procurement
  Procurement as an additional market
SUPPORT FOR BASIC RESEARCH

Increase the rate of growth of public knowledge

Increase technological performance of the best technology and the average technology

No effect on concentration (given the increasing returns in the supply and the demand sides)
Increase the diffusion of knowledge

Technical change is less cumulative at the firm level

Herfindhal

Reduces concentration in semiconductors and PCs, but not in mainframes

Reduces the rate of growth of Mod
ANTITRUST

It intervenes only once

No effect on concentration
Support for entry in microprocessors. 

Herfindahl

a. Increase in the initial number of firms: no change in concentration

b. Periodic entry in microprocessor: reduction in concentration
Support for entry in microprocessors: av Mod e best Mod.
Support for open standards: Herfindahl

Reduction in concentration
Support for open standards:  Integration ratio

Reduction in vertical integration
Selective public procurement in TR and IC  Herfindahl

Increase in Concentration
Selective public procurement in TR and IC      Best mod

Increase in Mod

![Graph showing selective public procurement and HF over time.]
Selective and permanent public procurement. Integration ratio

Reduction in vertical integration
Permanent public procurement as additional market: Herfindahl

TR: it increase the number of TR firms surviving

IC: on a somewhat concentrated IC industry, it increases concentration
Permanent public procurement as additional market: avMod TR and IC
Unintended consequences(1) : open standards  Herfindahl

The creation of OPEN STANDARDS in computers leads to the growth of concentration in components because bandwagon in components demand may emerge.
Unintended consequences (1): open standards

Reduction of vertical integration

Integration ratio

Graph showing the integration ratio over time, with two lines representing MF and PC.
*Unintended consequences (2): ANTITRUST policy provokes diversification, the emergence of a monopolist in a related system market and the disappearance of component industry (no ext.market)*  

Herfindahl
Unintended consequences (2): antitrust, diversification and disappearance of the component industry

The PC leader becomes vertically integrated as the mainframe leader is
Unintended consequences (3): open standards lead to the emergence of a component industry

Herfindahl

Initial conditions: no external markets and no merchant producer of semiconductors
Unintended consequences (3): open standards lead to the emergence of a component industry

Integration ratio

Graph showing the integration ratio over time for MF and PC.
Conclusions

We have examined public policy in dynamic interdependent markets with heterogeneous agents, cumulative technical advance and major technological and market discontinuities.

Supply side policies have different effects on the various policy targets.

Demand side policies affect concentration more than supply side policies.

Side effects of policies are relevant.

Unintended consequences across horizontal and vertical markets have to be taken into full account.