Competitive Pressure and the Adoption of Complementary Innovations

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General Questions

- Innovation is the ultimate determinant of growth possibilities and standard of living.
- Does competition favor innovation more than monopoly?
- Are all innovations alike?
- How do we identify an exogenous increase in market pressure?

Arrow vs. Schumpeter

Which view prevail has very important policy implications:

- Arrow: Competition favors innovation.
  - Double benefits, both static and dynamic.
- Schumpeter: Monopoly favors innovation.
  - Trade off between static loss and dynamic gains.
- Schmookler: Both might be right depending on the type of innovation considered.

Plethora of Theoretical Results

- Gilbert (2006): Competition favors innovation if property rights are non-exclusive.
- Schmutzler (2007): With differentiated products, adoption of a cost reducing innovation by my competitor reduces my incentives to innovate if products are substitutes.
- Vives (2008): Incentives to innovate depend on whether entry is free or restricted.

Common Themes in the Literature

- Cross-industry / cross-country studies with different degree of competition.
- Institutional heterogeneity.
- Non-conclusive results.
- Aggregate measures of innovation.
- Neglect all other decisions variables of the firms.
- Results heavily driven by functional form assumptions.

Vindicating the Chicago Critique...

Gilbert (2008):

"It is not that we dont have a model of market structure and R&D, but rather that we have many models and it is important to know which model is appropriate for each market context."

Distinguishing Features of This Paper

- Focus on a well defined industry.
- Distinguish between product and process innovation.
- Innovation is not an isolated decision.
  $\Rightarrow$ Scale.
- Potentially correlated returns of strategies.
  $\Rightarrow$ Complementarities.
- Need to address unobservable heterogeneity.

Advantages

- Ignoring complementarities would have led us to conclude that an increase in competitive pressure had no effect on innovation at all.
- Treating the scale as exogenous would have wrongly attributed competition a positive role on the adoption of product innovation.
- Results are robust to the existence of unobserved heterogeneity, market definition, their degree of urbanization, and anticipation of the liberalization of the industry.

Main Results

- Increase in competitive pressure does not have direct effect on the returns of innovations.
- Increase in competition induces an increase of the optimal scale of production which in turn shifts the return of product innovation.
- Product and process innovations appear to be substitutes and thus firms specialize in one of the two.

Data Description

French automobile dealerships, 2000-2004:

- Sales of new and used vehicles.
- Sales of parts and accessories.
- It also includes service and maintenance.

Information available:

- Sales. Turnover (*AMADEUS*).
- Profits. Accounting profits (*AMADEUS*).
- Product innovation: HR management software (*HH*).
- Process innovation: Applications Development Soft. (*HH*).
- Socio-economic. variables at *dèpartement* level (*INSEE*).

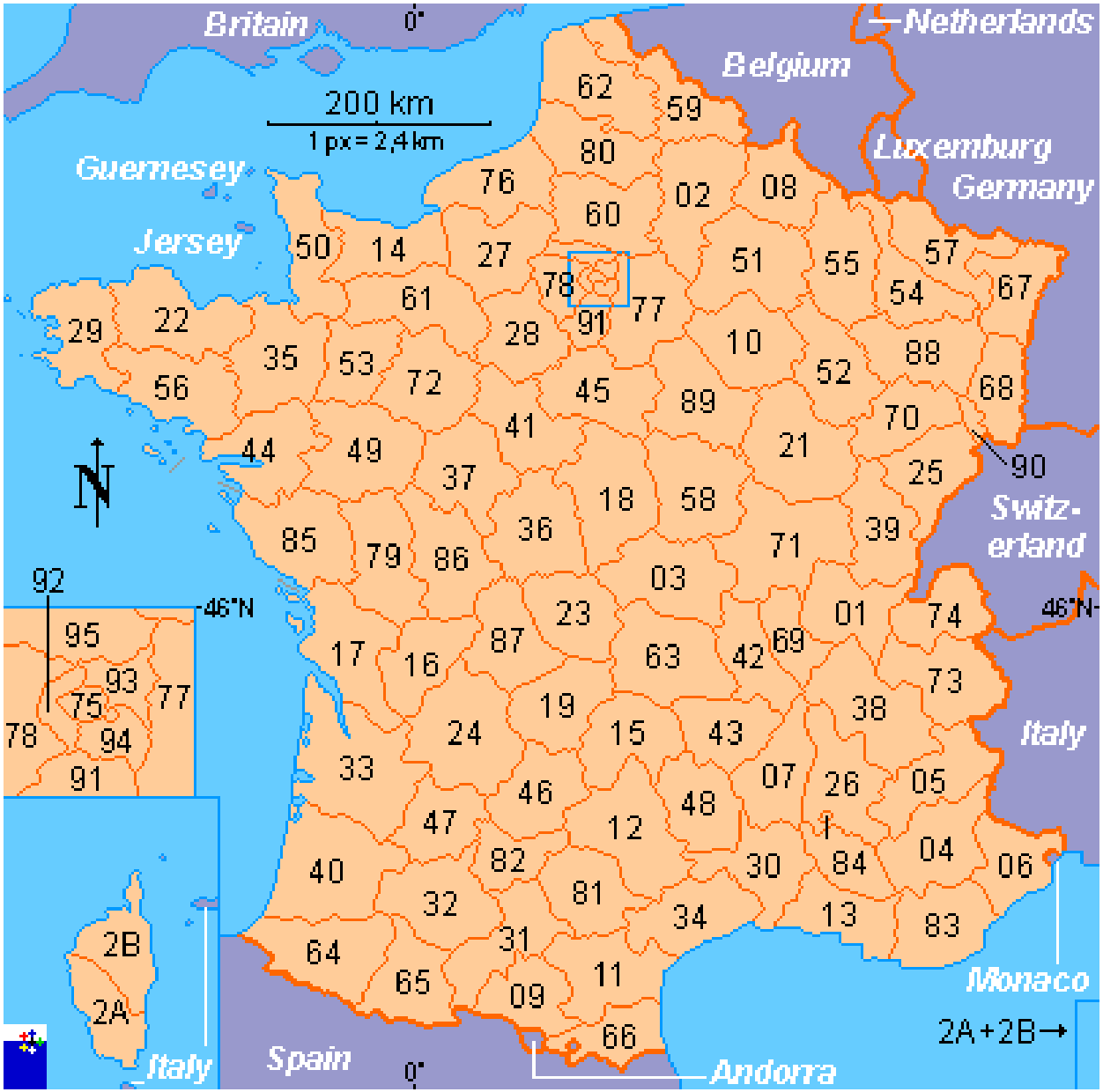
Innovations

HR – Human Resource Management Software:

- Control of personnel data flow such as:
  - Participation in benefit programs.
  - Administering recruiting process.
  - Accounting for salesmen commissions and payments.

APPS – Applications Development Software:

- Dealer specific software applications that need to be programmed using C++ Basic, Fortran, or other languages.
- Optimal management of storage.
- Websites: provision of information to potential customers.


Britain
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1 px = 2,4 km
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Germany
Guernesey
Jersey
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46°N
Italy
Spain
Monaco
Andorra
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Vertical Restraints

Selectivity:

- Imposes staffing, advertising, after sales services.
- Dealers can only sell to end consumers.
- Restricts competition from unauthorized dealers.

Territorial Exclusivity:

- Limits the number of dealers in an area.
- Bans opening branches outside the area.

Liberalization

Restructuring of the automobile distribution system:

- Subdealers either became dealers of left the network: 21% decline in the number of dealers between 2002 and 2003.
- Concentration *vs.* competitive effects:
  - Larger dealers are more likely to comply with quality standards.
  - Larger dealers engage in multi-branding more frequently.
  - Vacant locations in less populated areas allow entry of Asian dealers.
  - Overall, automobile prices decline by 12% between 1996 and 2004, which together with higher income and easier credit helps to explain the increase of sales per dealer (as opposed to only the exit of subdealers).
- Some other restrictions such as exclusive dealing were also phased out after September 2002.

Liberalization Dummy

We will simply identify the change of regulation regime by variable LIB, which takes value 1 for years 2003-2004.

- Is this change in regulation a good proxy for competitive pressure?
  - Expiration of Regulation 1475/95 was predictable.
  - The features of the new regulation regime were not completely anticipated.
  - The new regulation has little to do with the likelihood of dealers adopting innovations or not.
  - The new regulation only affects the conditions of appropriability of the rents of innovation.

Equilibrium Approach

- Firms choose one out of four possible innovation profiles: (0,0), (1,0), (0,1), (1,1).
- Simultaneously, they also choose the scale of production.
- Together with the choice of other strategies, this determines the observable level of profits.
- Returns of each strategy include observable and unobservable components.
- Given a flexible distribution of the unobserved returns, estimates maximize the likelihood that each firm chooses the combination of strategies actually implemented.

Profit Function

- (Finally) implements Athey-Stern (1998).
- Combines "adoption" and "productivity" approaches.
- Flexible functional approach.

The profit function is:

$$\begin{aligned}\pi_i(x_{di}, x_{ci}, x_{yi}) = (\theta_\pi + \epsilon_{\pi i}) + (\theta_d + \epsilon_{di})x_{di} + (\theta_c + \epsilon_{ci})x_{ci} \\ + (\theta_y + \epsilon_{yi})x_{yi} + \delta_{dc}x_{di}x_{ci} + \delta_{dy}x_{di}x_{yi} \\ + \delta_{cy}x_{ci}x_{yi} - (\gamma/2)x_{yi}^2.\end{aligned}$$

Scale Decision

Use the Envelope Theorem to obtain the optimal scale choice contingent on the innovation profile:

$$x^{\star}_{y\,i}(x_{d\,i}, x_{c\,i}) = \gamma^{-1}(\theta_y + \epsilon_{y\,i} + \delta_{dy} x_{d\,i} + \delta_{cy} x_{c\,i}).$$

Rewrite the profit function as:

$$\begin{aligned}\pi^{\star}_{i}(x_{d\,i}, x_{c\,i}) = \kappa_{\pi\,i} + \epsilon_{\pi\,i} + (\kappa_{d\,i} + \epsilon_{d\,i}) x_{d\,i} + (\kappa_{c\,i} + \epsilon_{c\,i}) x_{c\,i} \\ + \delta x_{d\,i} x_{c\,i},\end{aligned}$$

where:

$$\begin{aligned}\kappa_{\pi\,i} &= \theta_\pi + (\theta_y + \epsilon_{y\,i})^2/(2\gamma), \\ \kappa_{d\,i} &= \theta_d + \delta_{dy}\left[\delta_{dy}/2 + (\theta_y + \epsilon_{y\,i})\right]/\gamma, \\ \kappa_{c\,i} &= \theta_c + \delta_{cy}\left[\delta_{cy}/2 + (\theta_y + \epsilon_{y\,i})\right]/\gamma, \\ \delta &= \delta_{dc} + \delta_{dy}\delta_{cy}/\gamma.\end{aligned}$$

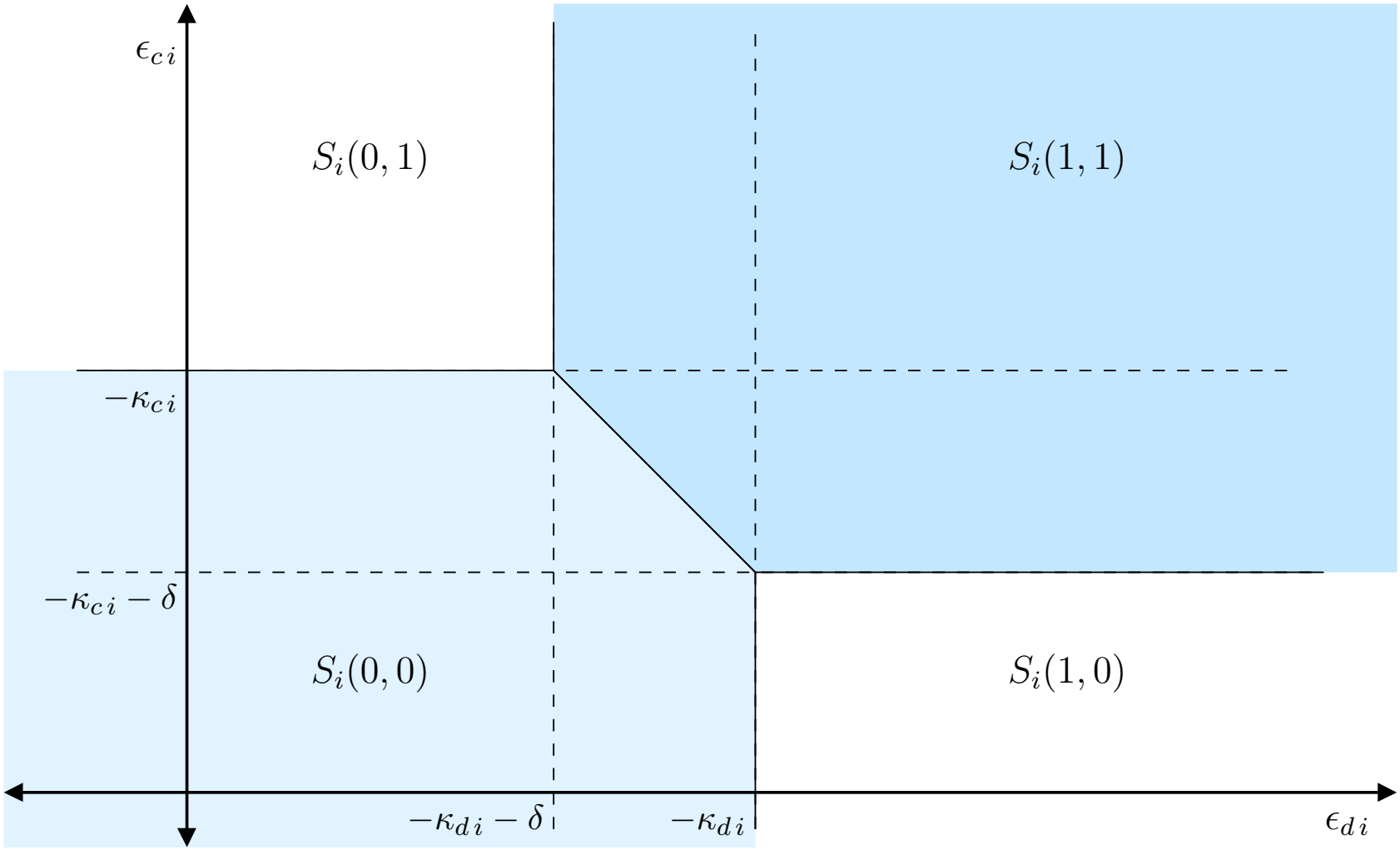
Innovation Decisions

A firm will adopt both innovations if:

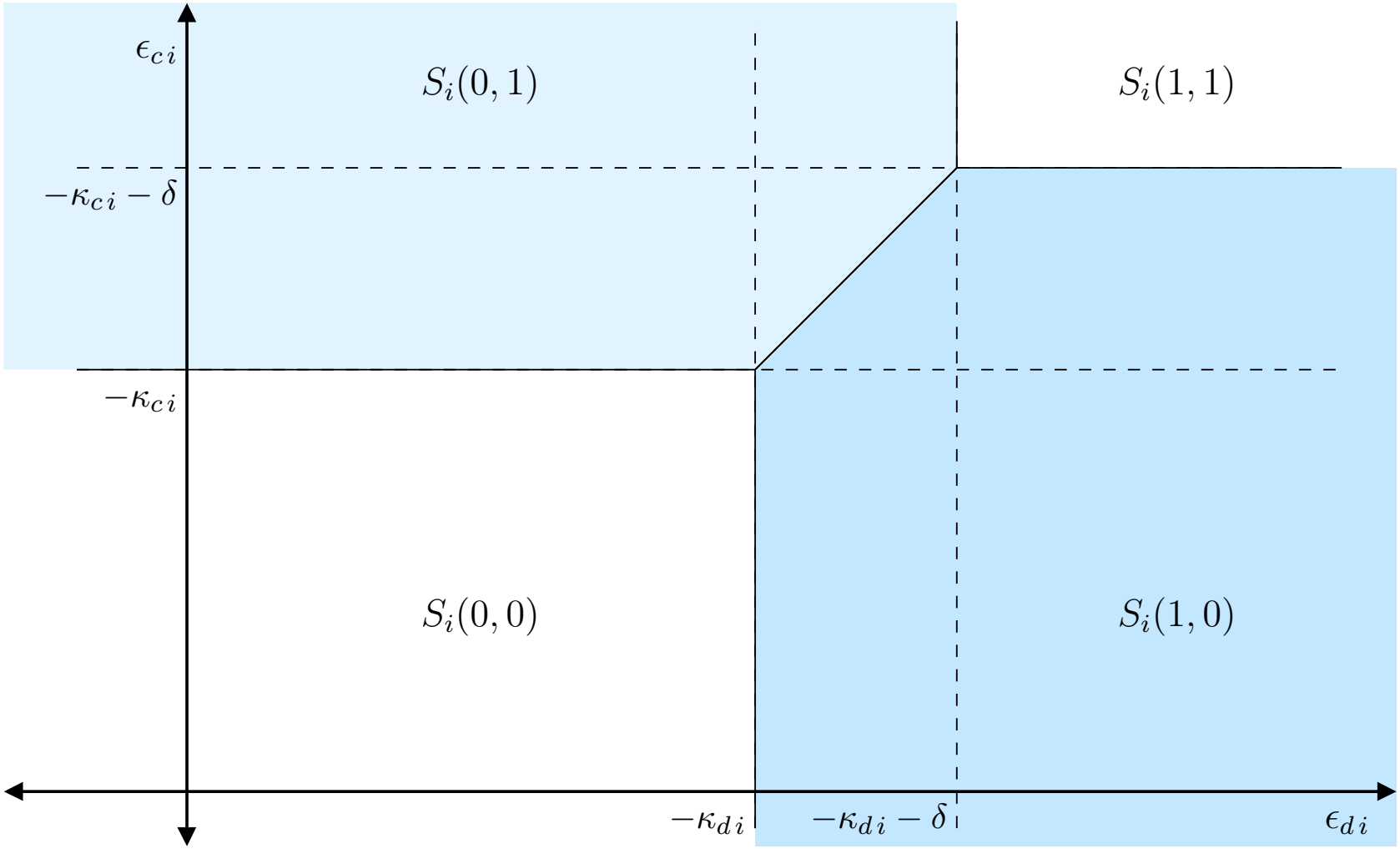
$$\begin{aligned}\pi^\star(1,1) &> \pi^\star(1,0),\\ \pi^\star(1,1) &> \pi^\star(0,1),\\ \pi^\star(1,1) &> \pi^\star(0,0),\end{aligned}$$

or in terms of the unobserved returns:

$$\begin{aligned}\epsilon_{di} &> -\kappa_{di} - \delta,\\ \epsilon_{ci} &> -\kappa_{ci} - \delta,\\ \epsilon_{di} + \epsilon_{ci} &> -\kappa_{di} - \kappa_{ci} - \delta.\end{aligned}$$


ϵ_{ci}
$S_i(0,1)$
$S_i(1,1)$
$-\kappa_{ci}$
$-\kappa_{ci}-\delta$
$S_i(0,0)$
$S_i(1,0)$
$-\kappa_{di}-\delta$
$-\kappa_{di}$
ϵ_{di}

$$\delta > 0$$


ϵ_{ci}
$S_i(0,1)$
$S_i(1,1)$
$-\kappa_{ci}-\delta$
$-\kappa_{ci}$
$S_i(0,0)$
$S_i(1,0)$
$-\kappa_{di}$
$-\kappa_{di}-\delta$
ϵ_{di}

$$\delta < 0$$

Stochastic Assumptions

Non-observable returns are jointly distributed according to an unrestricted multivariate normal distribution.

$$f(\epsilon_{d\,i}, \epsilon_{c\,i}, \epsilon_{y\,i}, \epsilon_{\pi\,i}) = (\sigma_d \sigma_c \sigma_y \sigma_\pi)^{-1} \phi_4 \left(\frac{\epsilon_{d\,i}}{\sigma_d}, \frac{\epsilon_{c\,i}}{\sigma_c}, \frac{\epsilon_{y\,i}}{\sigma_y}, \frac{\epsilon_{\pi\,i}}{\sigma_\pi}; \boldsymbol{R} \right),$$

where:

$$\boldsymbol{R} = \begin{pmatrix} 1 & \rho_{dc} & \rho_{dy} & \rho_{d\pi} \\ \rho_{dc} & 1 & \rho_{cy} & \rho_{c\pi} \\ \rho_{dy} & \rho_{cy} & 1 & \rho_{y\pi} \\ \rho_{d\pi} & \rho_{c\pi} & \rho_{y\pi} & 1 \end{pmatrix}.$$

Maximum Likelihood Estimates - Summary

- No direct effect of liberalization on innovation.
- Positive effect on the scale of production.
- Significant complementarity between scale and product innovation.
- Significant substitutability between product and process innovation.

		Model I		Model II		Model III		Model IV	
θ_d	*Constant*	19.94	(436.49)	22.88	(573.02)	33.38	(308.19)	217.70	(211.70)
	LIB	−1.24	(26.97)	−1.41	(34.93)	−2.00	(18.78)	−2.84	(13.19)
	ln(*GDPpc*)	3.61	(78.82)	3.24	(83.49)	5.87	(54.41)	−23.22	(33.49)
	ln(*Density*)	−0.19	(4.09)	−0.06	(2.18)	−0.31	(3.20)	12.55	(8.64)
	ln(*Population*)	−0.86	(18.89)	−1.25	(30.35)	−1.45	(13.68)	−31.31	(15.40)**
θ_c	*Constant*	−24.97	(62.64)	−18.47	(545.61)	−240.23	(721.11)	−173.39	(175.20)
	LIB	0.51	(1.35)	0.32	(9.55)	12.75	(16.83)	7.84	(11.00)
	ln(*GDPpc*)	−0.99	(2.73)	−1.04	(30.31)	−76.14	(123.85)	−47.78	(27.25)*
	ln(*Density*)	−0.26	(0.69)	−0.13	(4.09)	13.47	(26.28)	9.05	(6.68)
	ln(*Population*)	1.40	(3.52)	0.94	(27.95)	−11.00	(47.14)	−5.67	(12.21)
θ_y	*Constant*	−15.66	(29.48)	−15.91	(57.56)	−7.26	(26.10)	−15.87	(12.74)
	LIB	2.72	(1.87)	2.73	(2.83)	1.17	(0.93)	1.53	(0.80)*
	ln(*GDPpc*)	16.49	(4.74)***	16.40	(10.59)	7.15	(4.79)	5.73	(2.02)***
	ln(*Density*)	−3.57	(1.15)***	−3.56	(2.94)	−1.56	(0.83)*	−1.47	(0.49)***
	ln(*Population*)	6.87	(2.11)***	6.85	(4.86)	3.02	(1.52)**	3.17	(0.91)***
θ_π	*Constant*	−12.49	(123.67)	−13.55	(433.25)	147.96	(718.30)	49.81	(141.06)
	LIB	−2.32	(7.45)	−2.27	(15.34)	−4.16	(13.12)	−1.55	(8.78)
	ln(*GDPpc*)	56.85	(18.85)***	56.78	(83.74)	45.22	(125.23)	43.89	(21.55)**
	ln(*Density*)	−14.00	(4.38)***	−13.96	(18.95)	−7.93	(25.08)	−9.27	(5.30)*
	ln(*Population*)	22.11	(8.10)***	22.16	(32.00)	4.34	(44.00)	11.18	(9.80)
γ		13.50	(1.07)***	13.49	(1.36)***	5.84	(1.13)***	5.71	(0.46)***
σ_d		4.28	(93.24)	4.46	(110.80)	6.85	(64.58)	143.47	(8.63)***
σ_c		3.57	(8.95)	2.57	(75.49)	130.29	(6.29)***	127.54	(4.64)***
σ_y		21.97	(1.84)***	21.94	(2.44)***	9.51	(1.76)***	9.39	(0.79)***
σ_π		86.10	(2.42)***	86.11	(2.15)***	98.08	(3.70)***	101.98	(3.14)***
δ_{dc}				−0.40	(8.86)			−159.86	(10.80)***
δ_{dy}				0.55	(12.44)			10.15	(1.28)***
δ_{cy}				0.23	(6.31)			0.10	(0.68)
ρ_{dc}						0.107	(0.49)	0.954	(0.01)***
ρ_{dy}						0.217	(0.28)	−0.461	(0.04)***
ρ_{cy}						−0.236	(0.07)***	−0.272	(0.04)***
$\rho_{d\pi}$						−0.042	(0.72)	−0.989	(0.01)***
$\rho_{c\pi}$						−0.969	(0.01)***	−0.964	(0.01)***
$\rho_{y\pi}$						0.468	(0.07)***	0.506	(0.03)***
$-\ln \mathcal{L}$		994.0		987.7		622.7		570.0	

More Results

- Returns of product innovation is higher in smaller markets.
- Returns of process innovation is higher in less affluent markets (where there might not be enough room for profitable product differentiation).
- Larger scales in wealthier and less dense markets.
  - Storage costs dominate Syverson's pro-competitive effect of population density.

Robustness of Results

- The model with complementarities dominates any other specification.
- Regressors are informative. LIB dummy could be omitted altogether although it is still significant in the scale equation.
- The inclusion of a large city in the *dèpartement*, the definition of the relevant market, and the possibility of anticipation of liberalization can all be rejected.

	χ^2	d.f.	p-value
LR tests for model comparisons			
Model I vs. Model II	12.64	3	0.005
Model I vs. Model III	742.58	6	0.000
Model I vs. Model IV	848.06	9	0.000
Model II vs. Model III	729.94	3	0.000
Model II vs. Model IV	835.43	6	0.000
Model III vs. Model IV	105.48	3	0.000
Wald test for joint significance			
All covariates	37.12	16	0.002
LIB	6.20	4	0.184
ln(*GDPpc*)	13.76	4	0.008
ln(*Density*)	9.60	4	0.048
ln(*Population*)	16.13	4	0.003
LR tests for additional regressors			
Y2001	0.88	4	0.928
Y2002	2.89	4	0.576
Urban	4.22	4	0.377
Near	1.54	4	0.819

Overall Direct and Indirect Effects

- The total effect of regressors on returns include indirect effects through complementarities, as each one of them also has an effect on the rest of endogenous variables.
    - Furthermore, unobserved returns are correlated.
- Simulations decompose the total effects into direct and effects induced by complementarity.
    - Liberalization triggers a median increase of 23% of the scale (27% direct, -4% complementarity).
    - This is the only unambiguous result.

	5%	25%	50%	75%	95%
Total Effects					
$x_{yi}(\%)$	0.03	13.73	22.87	32.06	44.91
x_{ci}	−1.72	1.88	4.38	6.89	10.49
x_{di}	−7.51	−4.38	−2.35	−0.31	2.82
π(1000€)	−5.09	−1.56	0.91	3.42	7.22
None	−7.67	−4.07	−1.72	0.63	3.91
Only product	−6.89	−4.23	−2.50	−0.94	1.41
Only process	−1.25	1.88	4.07	6.26	9.55
Both	−1.56	−0.47	0.16	0.94	2.19
Direct Effects					
$x_{yi}(\%)$	3.02	17.23	26.94	36.45	50.43
x_{ci}	−3.44	0.00	2.35	4.85	8.45
x_{di}	−6.42	−2.97	−0.63	1.41	4.85
π(1000€)	−3.72	−1.11	0.60	2.40	5.03
None	−7.51	−3.91	−1.56	0.78	4.23
Only product	−2.03	−1.25	−0.78	−0.31	0.31
Only process	−0.31	1.25	2.35	3.44	5.16
Both	−5.32	−2.19	0.00	2.19	5.63
Complementarities Effects					
$x_{yi}(\%)$	−13.49	−7.69	−3.96	−0.49	4.86
x_{ci}	−1.72	0.47	1.88	3.44	5.79
x_{di}	−5.16	−2.97	−1.56	−0.16	2.03
π(1000€)	−5.88	−2.14	0.37	2.81	6.27
None	−1.72	−0.78	−0.16	0.31	1.41
Only product	−5.48	−3.13	−1.72	−0.31	1.72
Only process	−1.88	0.16	1.72	3.29	5.63
Both	−3.76	−1.25	0.16	1.72	4.07

Summary

- Arrow was right for product innovation.
- Schumpeter was right for process innovation.
- Schmookler just got it right.

- Possible Extensions:
  - Estimate a "Random System Model," *i.e.*, allow $(\delta_{dc}, \delta_{dy}, \delta_{cy})$ to include stochastic components. There must be convincing reasons to believe that we can identify common unobserved returns for each combination of strategies (difficult).
  - Panel data: Dynamic complementarities.