Propensity to patent, R&D and market competition

Szabolcs Blazsek

joint work with Alvaro Escribano,
Universidad Carlos III de Madrid

Universidad Francisco Marroquín
Free lunch + GESG seminar
24 October 2014

- Blazsek, S., Escribano, A., 2009. Knowledge spillovers in U.S. patents: A dynamic patent intensity model with secret common innovation factors. Working Paper 09-89, *Economic Series*, Universidad Carlos III de Madrid.
- Blazsek, S., Escribano, A., 2010. Knowledge spillovers in U.S. patents: A dynamic patent intensity model with secret common innovation factors. *Journal of Econometrics* 159, 14-32.
- Blazsek, S., Escribano, A., 2012. Patents, secret innovations and firm's rate of return: Differential effects of the innovation leader. Working Paper 12-02, *Economic Series, Universidad Carlos III de Madrid*.
- Blazsek, S., Escribano, A., 2014. Propensity to patent, R&D and market competition: Dynamic spillovers of innovation leaders and followers. Working Paper 14-12, *Economic Series, Universidad Carlos III de Madrid*.

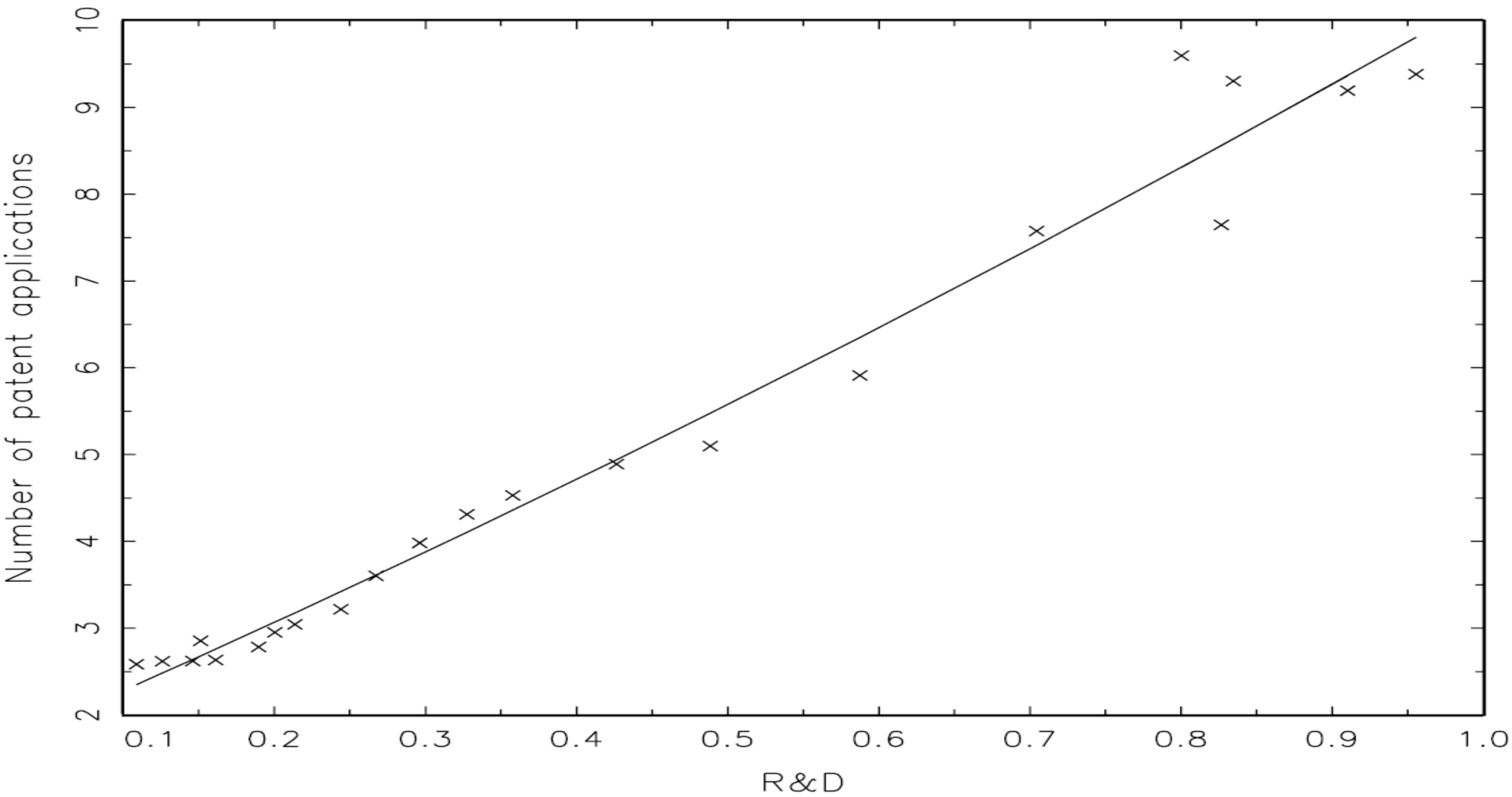
Some questions

- Why do firms invest in R&D?
- Why do firms publish patents?
- In your opinion, what determines the proportion of R&D protected by patents at firms?

Sample of firms from the U.S. (1979-2004)

	Industry	Number of firms	Number of patents	Patents/firm
1	Paper, printing	89	16,877	190
2	Chemicals	82	40,449	493
3	Rubber, plastics	82	5,045	62
4	Wood, lumber, furniture	154	10,310	67
5	Primary metals	63	2,874	46
6	Fabricated metals	98	4,869	50
7	Machinery, engines	261	23,720	91
8	Electrical machinery	109	34,006	312
9	Autos	93	20,015	215
10	Transportation equipment	38	20,410	537
11	Textiles, apparel, footwear	79	1,487	19
12	Pharmaceuticals	530	54,681	103
13	Food, tobacco	77	3,314	43
14	Computers, comp. eq.	1232	251,446	204
15	Petroleum refining, prods.	32	27,287	853
16	Non-manufacturing	1457	42,939	29
	Total hi-tech	1991	400,992	201
	Total non-hi-tech	2485	158,737	64
	Total	4476	559,729	125

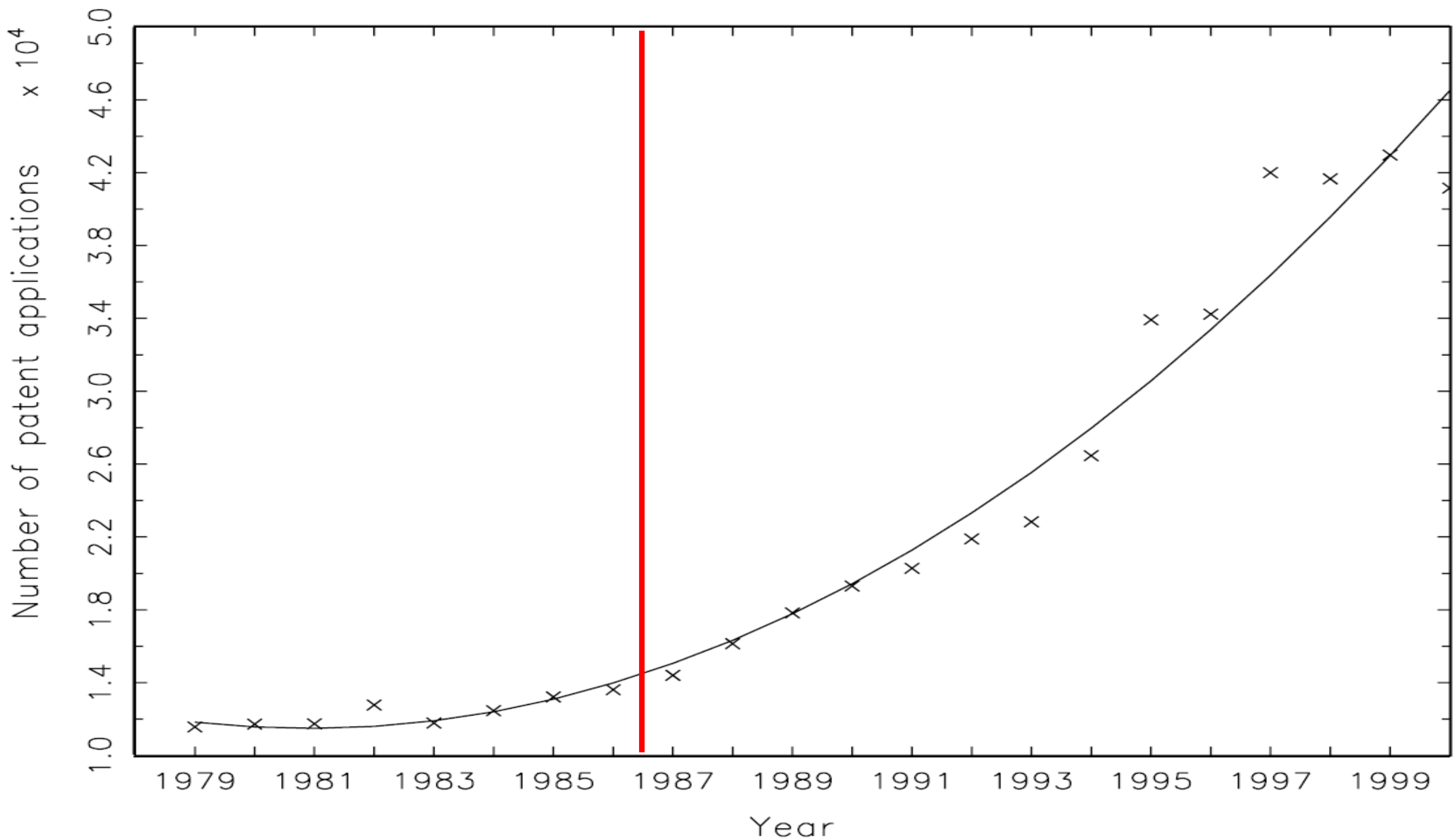
- Patent count per firm and R&D per firm in the U.S.



Each point is a year from 1979 to 2000

What is your conclusion from the figure?

- Patent application count in the U.S., 1979 to 2000

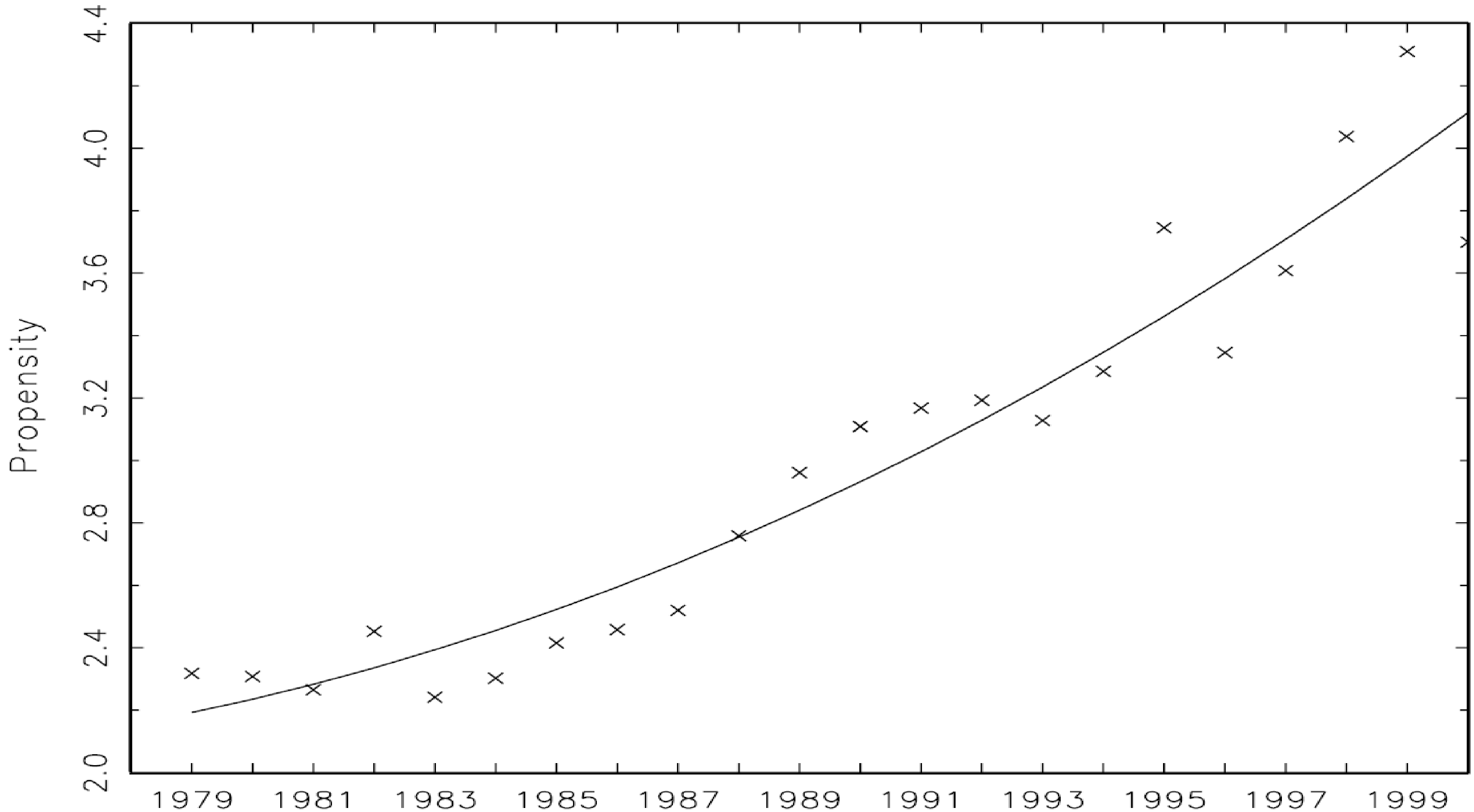


Total U.S. patent applications (1979–2000).

What can you see on this figure from the end of the 1980s?

- From the end of the 1980s, U.S. firms increased significantly patent activity.
- In your opinion, what drove this increase?

- Propensity to patent in the U.S., 1979 to 2000



Propensity to patent = patent application count / R&D expenses.

What can you see on this figure?

- It seems that firms' propensity to patent increased significantly from the end of the 1980s.
- This means that significantly larger proportion of R&D was protected by patents.

- In your opinion, what drove this increase?

- According to *Shapiro (2007)*, the observed increase in R&D efficiency through the 1990s could be due to *increases in R&D differentiation, the increase in the number of research fields and technologies, and the use of more sophisticated patent strategies due to increases in competitive pressure through time*.
- *Shapiro, C., 2007. The design and use of patents. Paper presented at the Economics for Management Lecture Series, IESE-BBVA Prize Lecture, Madrid, Spain.*

- Blazsek, S., Escribano, A., 2014. Propensity to patent, R&D and market competition: Dynamic spillovers of innovation leaders and followers. Working Paper 14-12, *Economic Series, Universidad Carlos III de Madrid*.

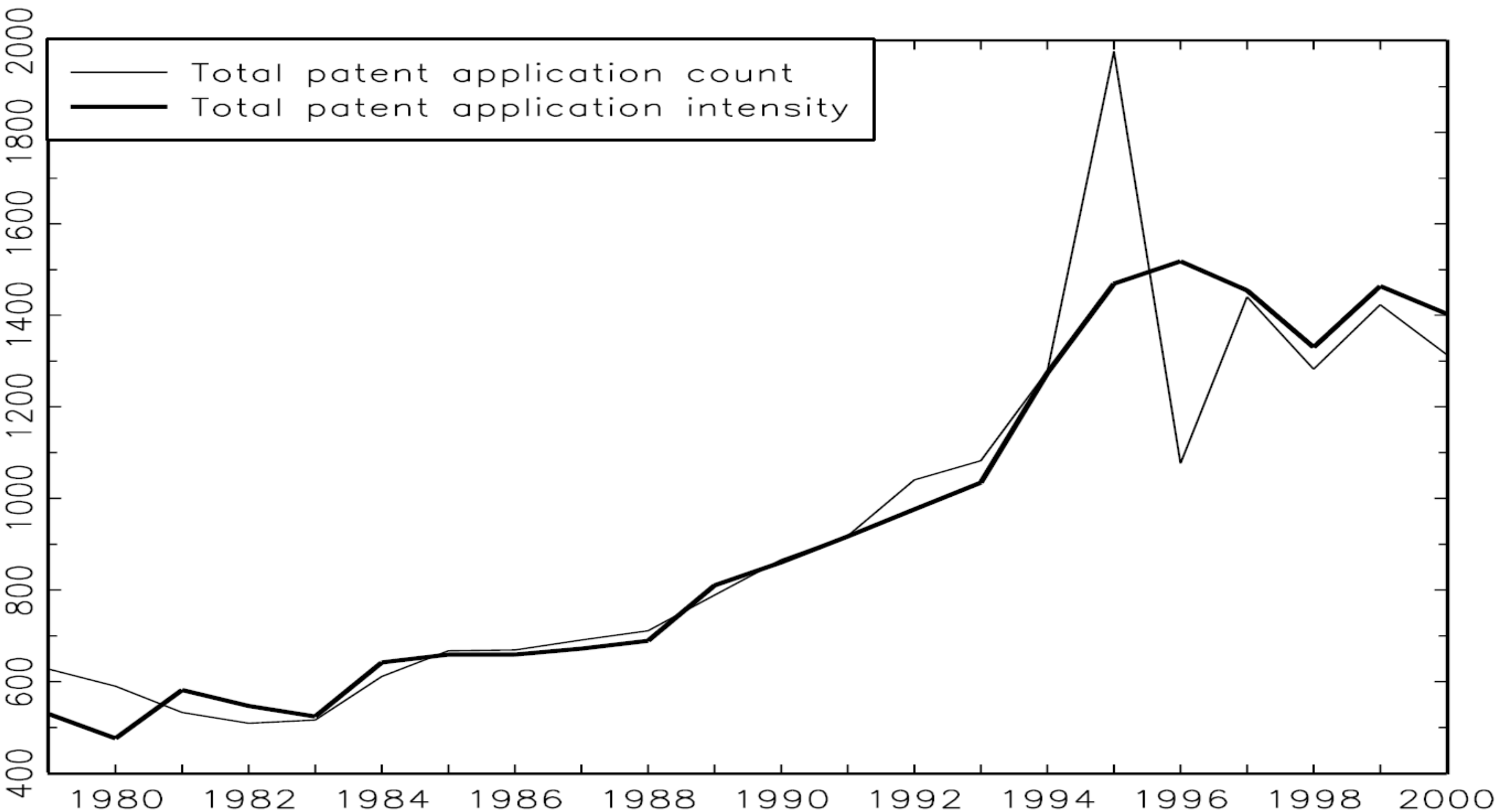
Some literature

- Pakes, A., 1985. On patents, R&D, and the stock market rate of return. *Journal of Political Economy* 93, 390–409.
- Jaffe, A.B., 1986. Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits, and market value. *American Economic Review* 76, 984–1001.
- Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and innovation: An inverted-U relationship. *The Quarterly Journal of Economics* 120, 701–728.

Data

- We start with a U.S. panel data set of 4476 firms for period 1979 to 2000.
- We focus on a specific cluster of technologically similar U.S. firms (technological cluster).
- The cluster includes 111 U.S. firms that are mostly from the pharmaceutical product-market sector.

- Pharmaceutical technological cluster, 1979 to 2000



- We identify patent innovation leaders and innovation followers in the technological cluster.

1. Merck (2834)	IL	GL
2. Eli Lilly (2834)	IF	GL
3. Abbott Lab. (2834)	IF	GL
4. Warner-Lambert (2834)	IF	GL
5. Pfizer (2834)	IF	GL
6. Bristol-Myers (2834)	IF	GL
7. Am. Home Prod. (2834)	IF	GL
8. Alza (2834)	IF	GL
9. Mallinckrodt (2835)	IF	GF
10. Pharmacia & U. (2834)	IF	GF

Patent count model

- We use a Poisson-type patent count data model to separate patented and non-patented R&D activity.

- $E(\tilde{P}_{it}|\mathcal{F}_t) = \lambda_{it} = \tilde{P}^o_{it}\tilde{P}^*_{it}$

- $\ln \tilde{P}^o_{it} = \quad \mu_0 + \gamma_1 t + \gamma_2 t\tilde{r}_{it} + \gamma_3 \tilde{r}^2_{it} + \gamma_4 \tilde{\mathrm{BV}}_{it} + \gamma_5 \tilde{P}_{i1} + \sum_{k=0}^{q} \beta_k \tilde{r}_{it-k} +$

  $\sum_{k=0}^{q} \omega_k \mathrm{BC}_{\mathrm{intra},it-k}\tilde{r}_{it} + \sum_{k=0}^{q} \phi_k \mathrm{BC}_{\mathrm{inter},it-k}\tilde{r}_{it} + \sum_{k=1}^{p} \kappa_k \ln \tilde{P}^o_{it-k}$

- $\ln \tilde{P}^*_{it} = \ln \Phi(\mu_i + \sigma_i l^*_t)$

- $l^*_t = \mu^* l^*_{t-1} + u_t$ with $u_t \sim N(0,1)$ i.i.d.

- Patented R&D = total R&D ($\tilde{P}^o$) x propensity to patent ($\tilde{P}^*$)
- Non-patented R&D ($\tilde{P}^\times$) = $\tilde{P}^o$ x (1−$\tilde{P}^*$)

- Propensity to patent of firms is driven by a common latent factor, l^*.
- A-priory, we do not know what this common latent factor is.

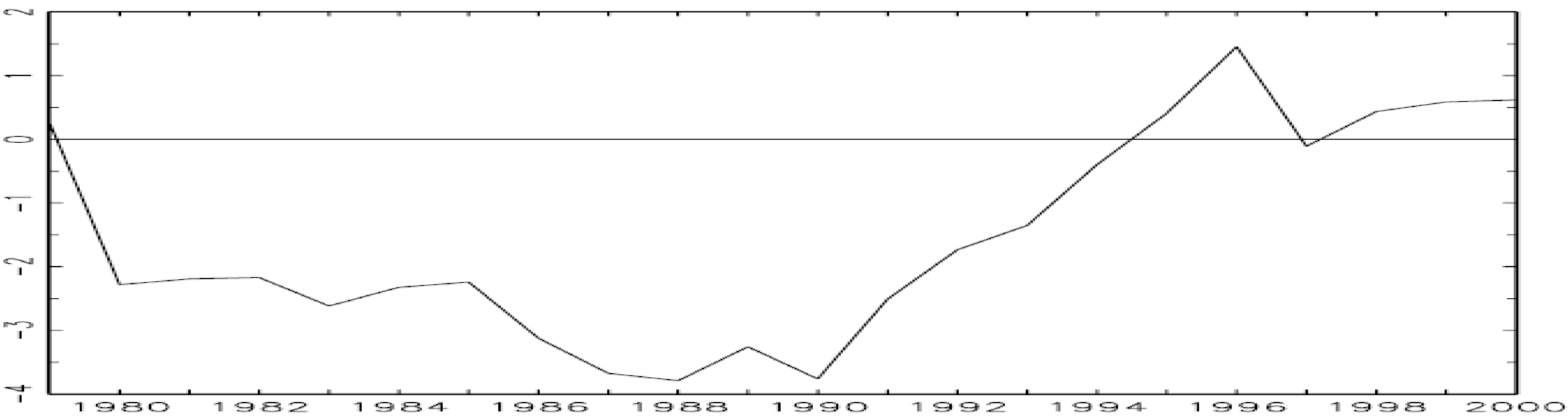
- We use the maximum likelihood method.
- The likelihood of $(\tilde{P}_{it}, l_t^* : t = 1, \ldots, T; i = 1, \ldots, N)$
- is $$\prod_{i=1}^{N} \prod_{t=1}^{T} f(\tilde{P}_{it} | \mathcal{F}_t) f^*(l_t^* | l_{t-1}^*)$$
- However, l^* are not observed. We maximize

$$\mathcal{L}(\tilde{P} | \mathcal{F}_e; \theta) = \int_{\mathbb{R}^T} \prod_{i=1}^{N} \prod_{t=1}^{T} \frac{\exp(-\lambda_{it}) \lambda_{it}^{\tilde{P}_{it}}}{\tilde{P}_{it}!} \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{(l_t^* - \mu^* l_{t-1}^*)^2}{2} \right] dL^*$$

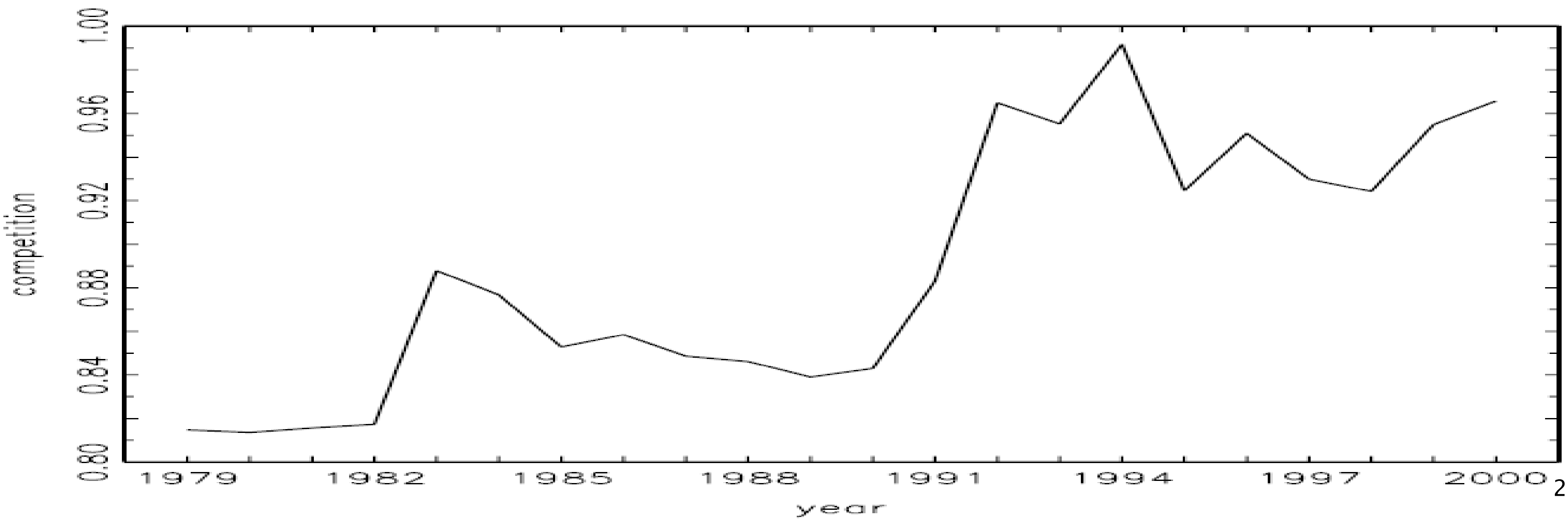
Efficient importance sampling technique (Richard and Zhang, 2007, JoE)

Propensity to patent and market competition

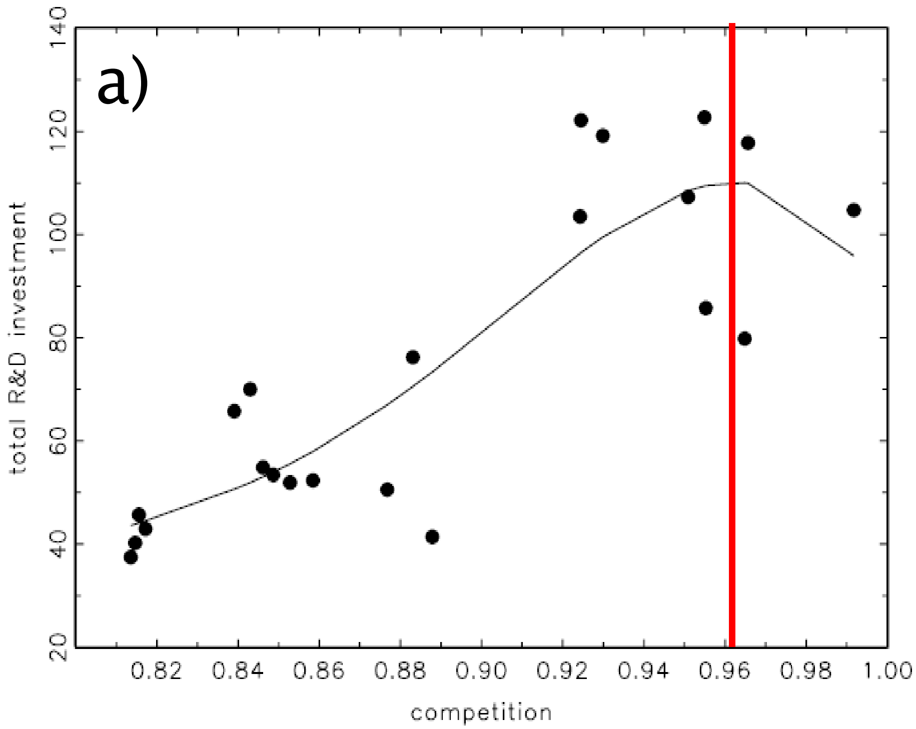
- Common latent factor, l^*, 1979–2000:

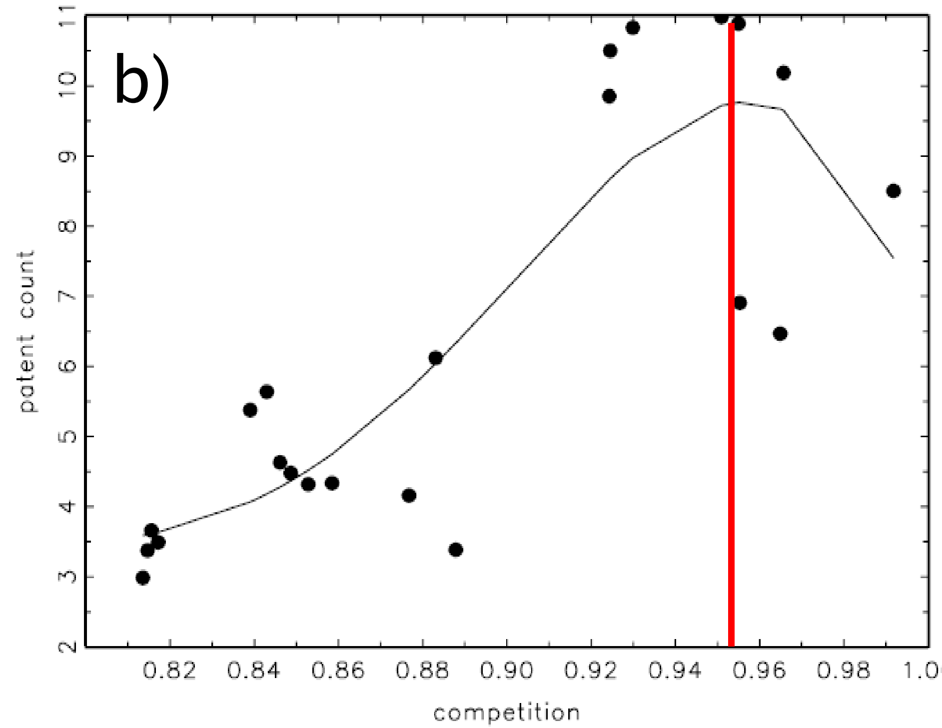


- $\text{Competition}_t = 1 - \frac{1}{N}\sum_{i=1}^{N} \frac{\text{operating profit}_{it} - \text{financial costs}_{it}}{\text{sales}_{it}}$



- Propensity to patent and market competition seem to move together in the technological cluster.
- *This may suggest that pharmaceutical firms reacted to the increasing level of market competition by patenting a significantly higher proportion of their innovation output after 1990.*

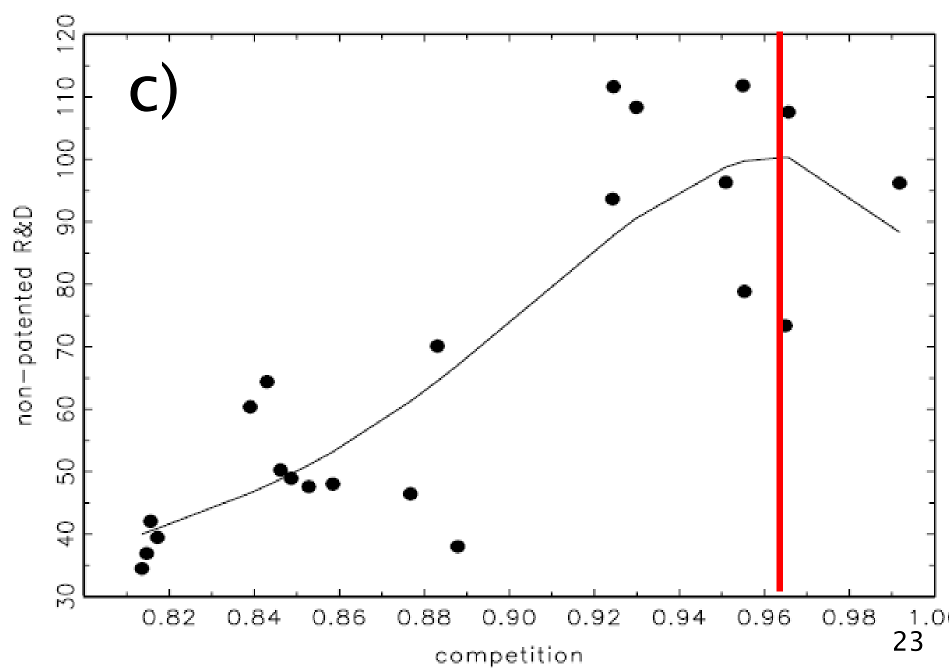




For every year (1979-2000):

a) Total R&D investment
b) Patent application count
c) Non-patented R&D

and competition



- We find an inverted-U relationship between competition and three measures of innovation:
  a) Total R&D investment ($\tilde{P}^{o}$)
  b) Patent application count ($\tilde{P}$)
  c) Non-patented R&D ($\tilde{P}^{\times}$)
- The maximum level of innovation is achieved at the 95%-97% level of competition, which is equivalent to an average 3%-5% price cost margin in the drug industry.

Within–firm effects; PVAR(1) model

We study the dynamic relations among stock return (q), log R&D (r), log patented R&D ($\ln P$), and log non–patented R&D ($\ln P^{\times}$) within firms.

$$\begin{bmatrix} q_{it} \\ r_{it} \\ \ln P_{it} \\ \ln P_{it}^{\times} \end{bmatrix} = \begin{bmatrix} a_{q,i} \\ a_{r,i} \\ a_{P,i} \\ a_{\times,i} \end{bmatrix} + \underbrace{\begin{bmatrix} \zeta_{11}^{*} & \zeta_{12}^{*} & \zeta_{13}^{*} & \zeta_{14}^{*} \\ \zeta_{21}^{*} & \zeta_{22}^{*} & \zeta_{23}^{*} & \zeta_{24}^{*} \\ \zeta_{31}^{*} & \zeta_{32}^{*} & \zeta_{33}^{*} & \zeta_{34}^{*} \\ \zeta_{41}^{*} & \zeta_{42}^{*} & \zeta_{43}^{*} & \zeta_{44}^{*} \end{bmatrix}}_{\zeta^{*}} \begin{bmatrix} q_{it-1} \\ r_{it-1} \\ \ln P_{it-1} \\ \ln P_{it-1}^{\times} \end{bmatrix}$$

$$+ \underbrace{\begin{bmatrix} \sigma_{1}^{*} & 0 & 0 & 0 \\ \sigma_{12}^{*} & \sigma_{2}^{*} & 0 & 0 \\ \sigma_{13}^{*} & \sigma_{23}^{*} & \sigma_{3}^{*} & 0 \\ \sigma_{14}^{*} & \sigma_{24}^{*} & \sigma_{34}^{*} & \sigma_{4}^{*} \end{bmatrix}}_{\Omega^{*}} \begin{bmatrix} e_{1it} \\ e_{2it} \\ e_{3it} \\ e_{4it} \end{bmatrix}$$

PVAR(1) with fixed effects
See Fig. 4.

Effects between innovation leader and followers; PVAR(1) model

We study the dynamic relations among stock return (q), log R&D (r), log patented R&D ($\ln P$), and log non-patented R&D ($\ln P^{\times}$) between the innovation leader and its followers.

Extended PVAR(1) with fixed effects

$$Y_{it} = a_i + \zeta^* Y_{it-1} + \zeta^*_{\mathrm{IL}} Y_{\mathrm{IL},t-1} D_{it}(i \in \mathrm{IF})$$
$$+ \zeta^*_{\mathrm{IF}} \left(\sum_{k \in \mathrm{IF}} Y_{kt-1} \right) D_{it}(i = \mathrm{IL}) + \Omega^* e_{it}$$

$Y_{it} = (q_{it}, r_{it}, \ln P_{it}, \ln P_{it}{}^{\times})'$

PVAR(1) with fixed effects See Figs 5 to 7.

Discussion

- *Aghion, Bloom, Blundell and Griffith* (2005, QJE) conclude that increasing market competition discourages laggard firms to innovate while encourages neck-to-neck firms to innovate.
- In the cluster analyzed, we find positive spillover effect between innovation leaders and followers in both directions. These indicate that in the cluster studied *firms are neck-to-neck in innovation activity*.
- The results show that the innovations leader has a contemporaneous impact on followers and for followers it takes about three years to influence the leader.

Thank you for your attention!

sblazsek@ufm.edu