Profitability of R&D main explanatory factor of neo-Schumpeterian growth

- Profitability of R&D related to:
- Market power of producers of innovation goods

- Distinguish between:
- *Pre-innovation market power*
- *Post-innovation market power*

Competition and growth

- Higher post-innovation market power may result from:
- Lower competition **between industries**: lower α → lower elasticity of substitution between machines
- Lower competition **within industries**: Higher protection from imitation → higher constrained monopoly price → faster growth

Within industry competition and growth

standard Schumpeterian model assumes:

radical innovations + no tacit knowledge (no explicit role for experience)

→ producer of inovation goods is a **monopolist**

→ R&D is carried out **only by outsiders**, because they earn higher benefits from innovation than the monopolist, and face the same R&D cost

→ problem of pre-innovation competition does not arise because pre-innovation profit is necessarily zero!

evidence **1:** Scherer (1965)

based on Fortune's 500 companies, concludes…

relation between firm size and patenting is:

- **positive**
- **weaker at large firm-size**
- large firms are better equipped to face sunk-costs related to R&D, but the above is no direct evidence that monopoly power promotes R&D.

evidence **2:** Nickell (1996)

Based on London Stock Exchange Firms, concludes:

lower market share → higher TFP level

lower monopoly rents → higher TFP growth

evidence **3:** Blundell, Griffith, Van Renen (1997)

Based on sample of UK firms, conclude:

Larger firms → have larger Knowledge stock

→ innovate to deter entry

This is at variance with standard result:

radical innovations + free entry

⇓

no R&D by incumbent monopolists

evidence 4: Aghion et al. (2005)

“Existing work on [*within-industry*] competition and innovation… points to the existence of two counteracting effects:

on the one hand, more intense product market competition … induces neck-and-neck firms at the technological frontier to innovate in order to escape competition;

on the other hand, more intense competition [*among firms with similar technology level*] tends to discourage firms behind the current technology frontier to innovate and thereby catch-up with frontier firms.

Which of these two effects dominates, in turn depends upon the degree of competition in the economy..”

Jones, Aghion, Jones (2017) *italics added*

Aghion et al (2005): sample 311 UK firms receiving US patent grants 1973-1994

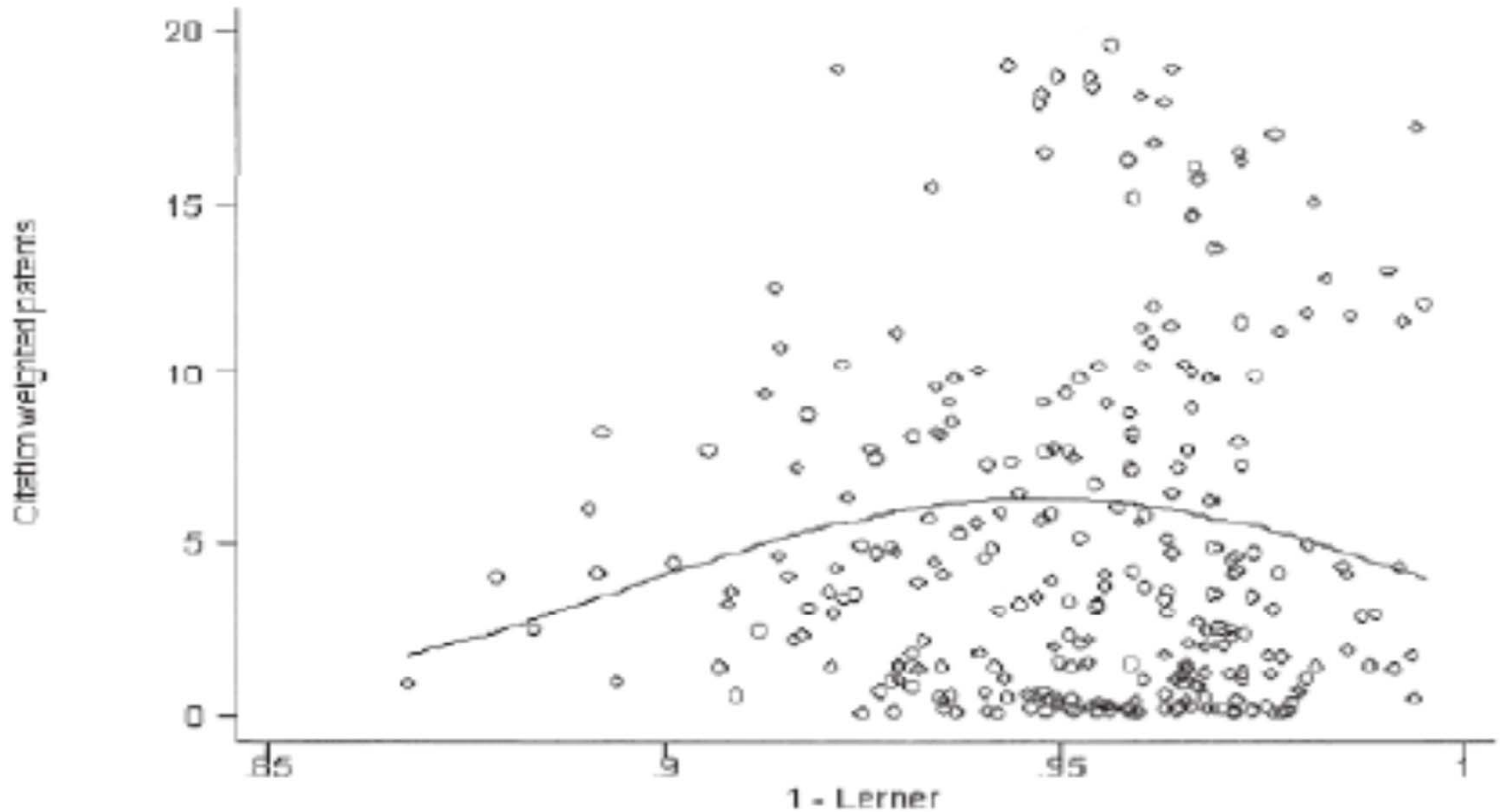


FIGURE I
Scatter Plot of Innovation on Competition

Aghion et al (2005)

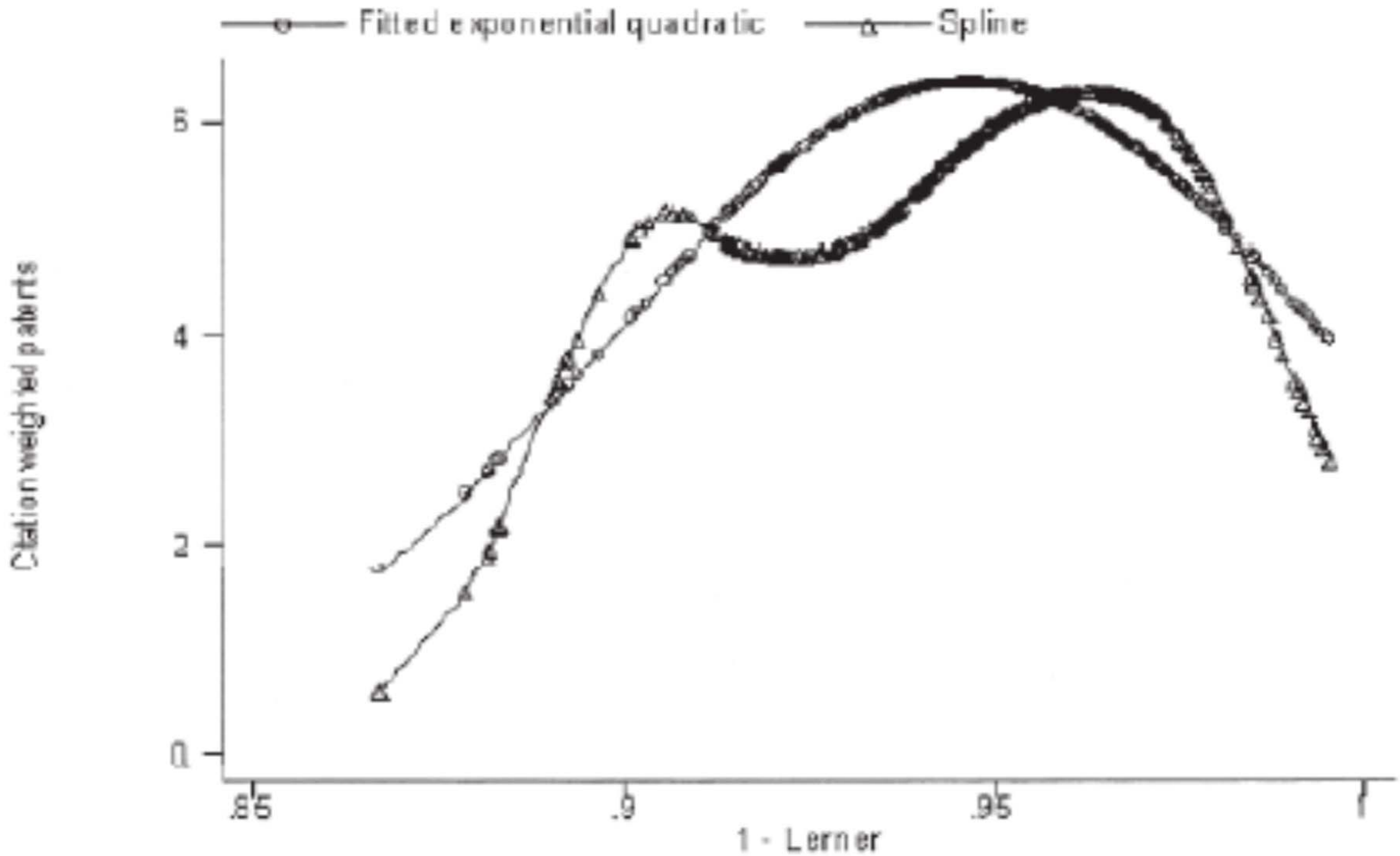
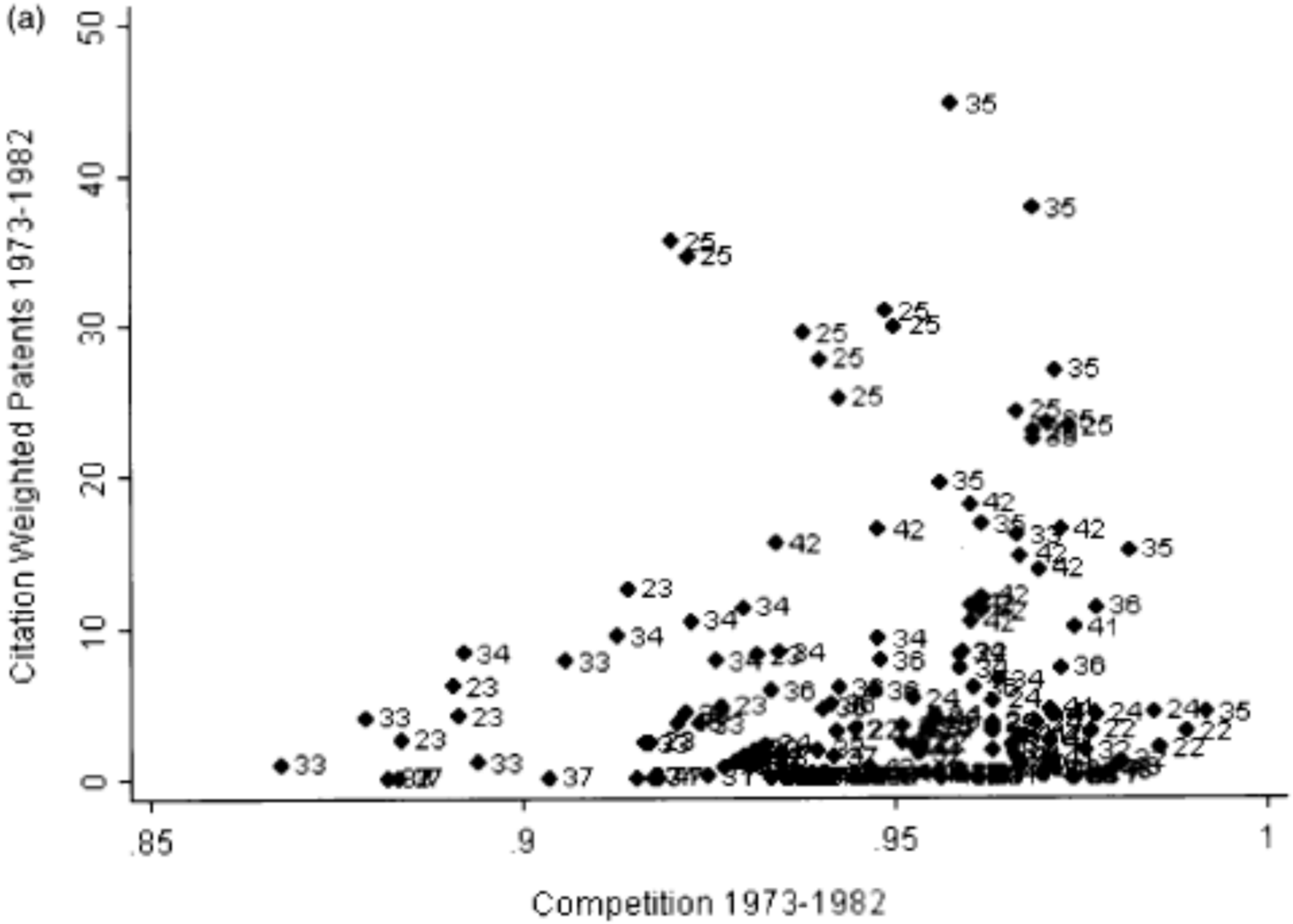


FIGURE II
Innovation and Competition: Exponential Quadratic and the Semiparametric Specifications with Year and Industry Effects

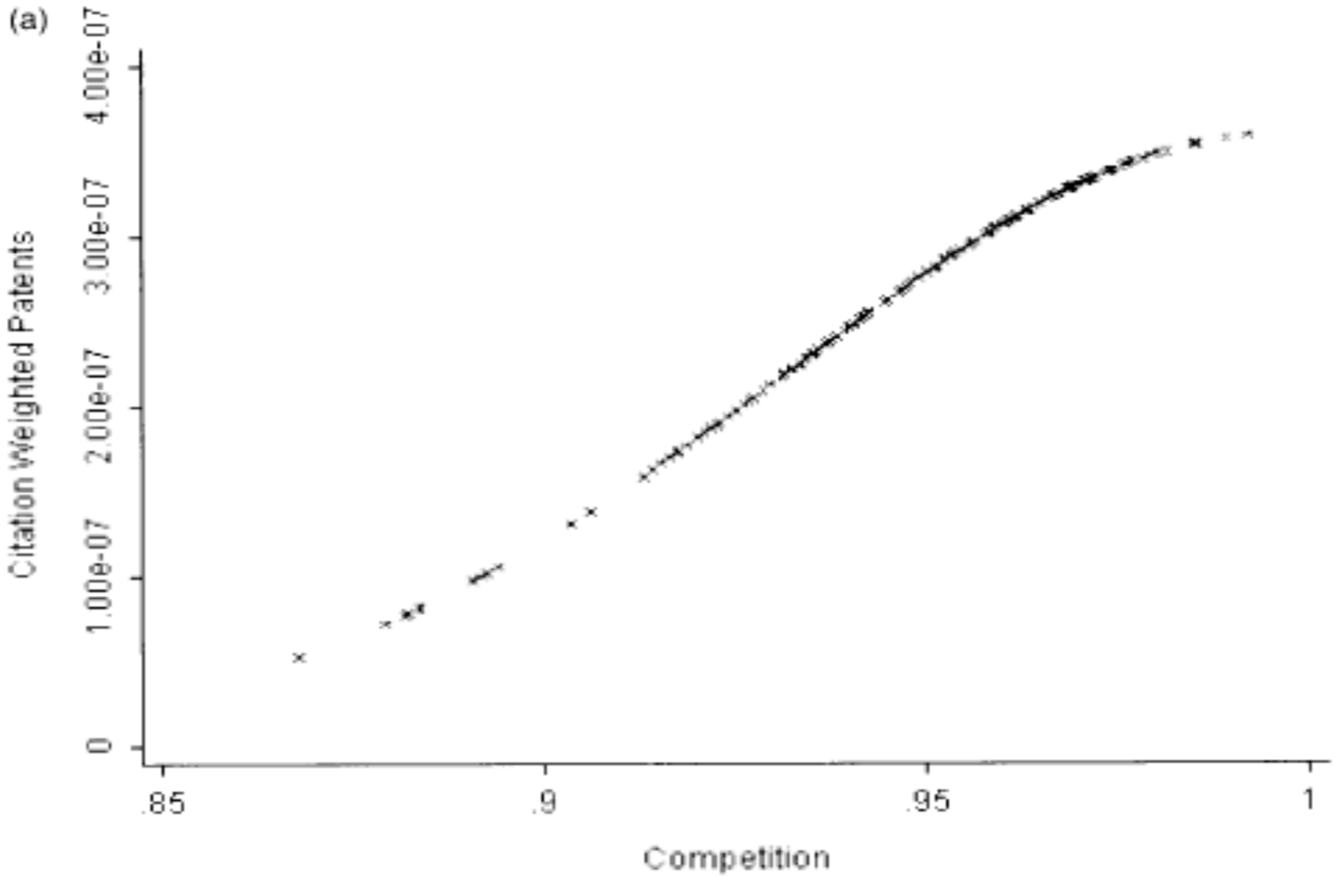
UK evidence reconsidered by Correa (2012):

- Questions empirical results by Aghion *et al*. (2005)
- finds that inverted-U relation 1973-1994 caused by **structural break in 1982** due to change in US patent legislation (higher patent protection)
- positive monotone relationship 1973–1982
- flat (not statist. significant) relation 1983-1994

Correa (2012): competition and citation-weighted patents 1973-1982



Correa (2012) estimates monotonic non-linear relation for 1973-1982



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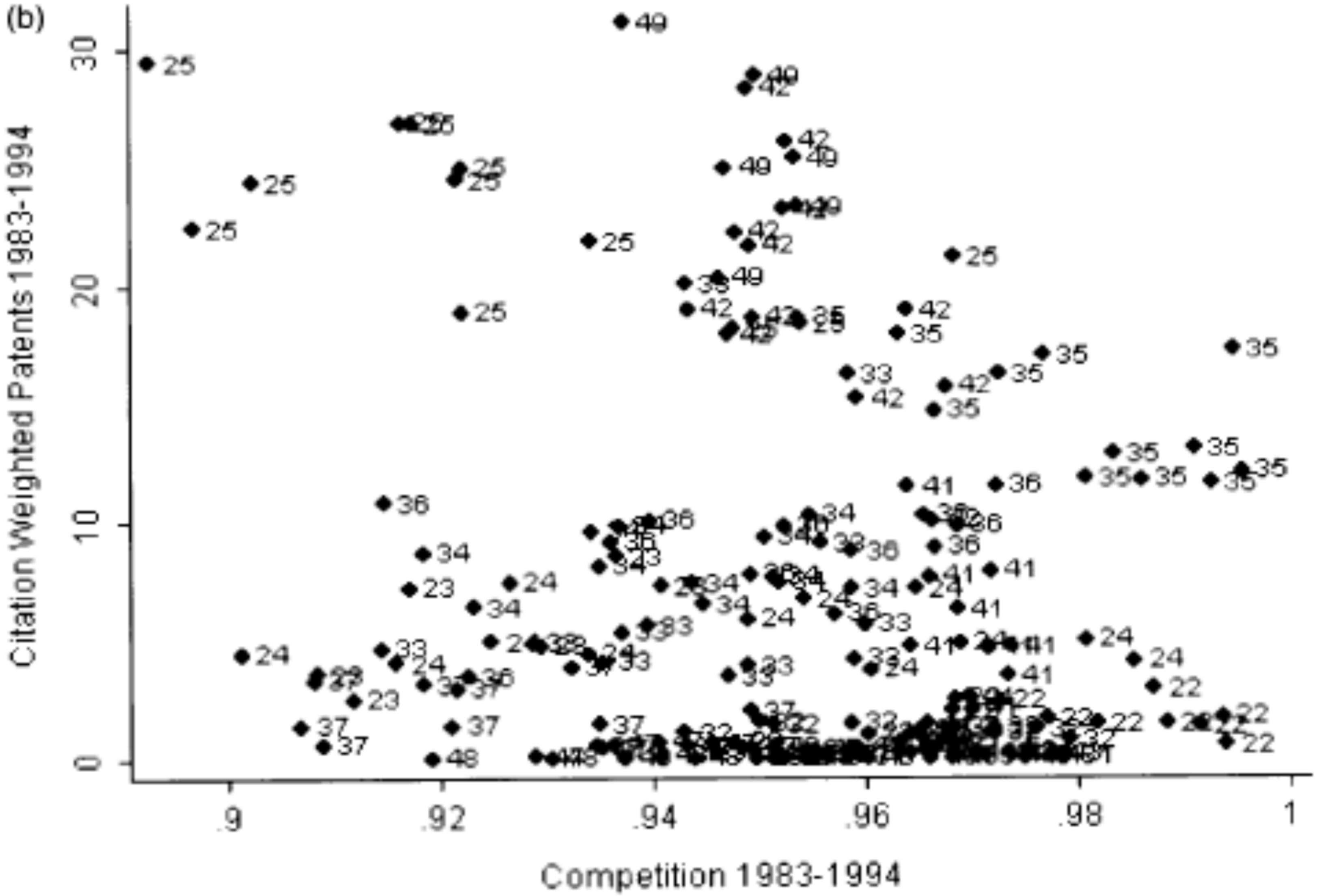

empirical evidence on market-power and innovation

problem 1: how do we measure innovation?

1. **innovation measured by patent counts** or citation-weighted patents counts (weighing relative importance of patents)
2. **innovation measured by TFP growth** (as in Nickell 1996) complication: TFP-growth estimates assume

   output elasticity of a factor = factor share in Y

- but this only holds under perfect competition!

3. **Innovation measured by labour-productivity growth**

problem 2: reverse causality

- high-productivity firms grow faster and therefore… gain higher <u>ex-post market shares</u>
- Inaccurate econometrics may yield:

  Over-estimation of productivity effects of market share

  under-estimation of productivity effects of competition
- Solution: **correcting for endogeneity of competition**
- **After correction, we expect a stronger positive effect of competition on innovation**

How reconciling neo-Schumpeterian growth with empirical evidence on competition and innovation?

- **replace radical innovation + codifiable knowledge with**
- **incremental innovations + tacit knowledge**

outsider's innovation does not displace incumbent from market

→ **possibly, more than 1 firm in the same sector**

Question: what degree of competition among firms in this sector?

In search of different hypotheses…

- if more than 1 firm with similar technology…, profit depends on competition between incumbents

- If only 1 leader, profit constrained by advantage with respect to outsider. Here the market power of the leader, hence the degree of competition with the follower is fixed by technology distance

innovation

- only two firms A and B in each sector (entry barriers)

- Tacit knowledge: before improving upon frontier-knowledge a follower must catch up with the leader
  (no immediate leap-frogging)

- Knowledge spillovers are such that maximum technological distance is 1 step

innovation

- only two firms A and B in each sector (entry barriers)
- → if A's and B's technology level is the same, the sector is **levelled** and both A and B may invest in R&D

innovation

- only two firms A and B in each sector (entry barriers)
- → if A's and B's technology level is the same, the sector is **levelled and** both A and B may invest in R&D
- → if one firm is one step ahead, the sector is **un-levelled**:

  - the **leader** has no incentive to invest in R&D, because the maximum technology distance = 1 step.

  - the **follower** may have an incentive to to invest in R&D

A model of step by step innovations and knowledge spillovers

- PRODUCTION:
- A continuum [0, 1] of consumer-good sectors (m=1)
- Each sector j is a duopoly. firms A and B in j produce

  $x_A = A_A L_A \qquad x_B = A_B L_B$

  sector output = $x = x_A + x_B$
- Two types of sectors:

  level: A , B are 'neck and neck' (same technology level)

  unlevel: A, B have different technology level

A model of step by step innovations and knowledge spillovers

- PRODUCTION:

- Firm i labour productivity = $x_i / L_i = A_i = \gamma^{k(i)}$ $i = A, B$
- $k(i)$ = i's technology level $\gamma > 1$

A model of step by step innovations and knowledge spillovers

- PRODUCTION:

- $\gamma > 1$ technology improvement
- $x_i / L_i = A_i = \gamma^{k(i)}$ $i = A, B$ Firm i labour productivity
- $k(i)$ i's technology level

- $1/ A_i = \gamma^{-k(i)} = L_i / x_i$ labour input per unit of x_i
- $w \gamma^{-k(i)}$ unit cost of firm i = A, B

innovation

- R&D expenditure $\psi(\mu) = \mu^2/2$ by a level firm moves technology 1 step ahead with **probability** **μ**

- R&D expenditure 0 by the laggard moves technology 1 step ahead with spillover-probability h (h = probability of costless imitation)

- R&D expenditure $\psi(\mu) = \mu^2/2$ by the laggard moves technology 1 step ahead with probability $\mu + h$
- No R&D by the leader

Consumers have a preference for variety

- representative household has a uniform expenditure E on every type of good
- Normalize and set E = 1

consumption

- A unit mass of identical consumers
- consumer spends income on a unit mass of goods

$\mathrm{u} = \int_{z=0}^{z=1} log x_z \partial z$ consumer current utility

- $\partial u / \partial x_j = 1 / x_j$
- $|MRS_{j,f}| = \dfrac{x_f}{x_j} = \dfrac{p_j}{p_f}$ interior optimum
- $p_j x_j = p_f x_f = E$ uniform expenditure at t

$E = 1$ numeraire

consumption

- having thus fixed the amount of expenditure addressed to each good x_j
- the household chooses between the outputs x_j^A, x_j^B supplied by firms A, B
- Intuitively, because industry output is homogeneous, the consumer chooses the least expensive between x_j^A, x_j^B

$$p_j = \min(p_{Aj}, p_{Bj})$$

Firm profit π_1 in un-level sector 1

- technology distance = 1 step
- if leader's unit cost is c,
- laggard's unit cost is $\gamma c > c$
- ***leader's profit*** $= \pi_1 = p_1 x_1 - c x_1 = 1 - c x_1$

recall:

$p_1 x_1 = 1$ *a unit mass of consumers, each spending E = 1 on each good*

Firm profit π_1 in un-level sector 1

Leader chooses maximum price p_1

consistent with preservation of leadership:

follower is left outside of the market

$\rightarrow$ $p_1 = \gamma c =$ follower's unit cost

Firm profit π_1 in un-level sector 1

- $p_1 = \gamma c$ $\qquad\qquad p_1 x_1 = 1$

  a unit mass of consumers, each spending E = 1 on each good

$\rightarrow \quad x_1 = 1 / p_1 = 1/\gamma c \qquad cx_1 = 1/\gamma$

$\rightarrow \quad \boldsymbol{\pi_1} = p_1 x_1 - cx_1 = 1 - cx_1 = \mathbf{1 - 1/\gamma}$

the leader's profit in unlevel sector is fixed

firm profit π_0 in <u>level</u> sector

- If Bertrand price competition $\rightarrow \pi_0 = 0$
- If perfect collusion $\rightarrow$ firms A and B maximize total profit π and then share π between them

$$\rightarrow \quad \pi_0 = (1/2)\,\pi$$

for simplicity $\pi = \pi_1$

joint monopoly profit of A and B in level sector equals monopoly profit π_1 in un-level sector

notice that pre-innovation competition can vary only as a result of a varying degree of competition between firms in level sector

Δ = degree of competition in a level sector defined

- $\Delta = (\pi_1 - \pi_0) / \pi_1$ $\qquad$ $\frac{1}{2} \leq \Delta \leq 1$

Perfect collusion $\quad \Delta = \frac{1}{2} \quad \pi_{0A} = \pi_{0B} = \pi_1 / 2$

Bertrand competition $\quad \Delta = 1 \quad \pi_{0A} = \pi_{0B} = 0$

- notice that $\quad \pi_0 = (1 - \Delta)\, \pi_1$

$$(\pi_1 - \pi_0) = \Delta\, \pi_1$$

Innovation intensity μ_0 in a leveled sector increases with intensity of competition in this sector

- Planning horizon: 1 period
- Only 1 R&D investor in 1 period
- At most 1 innovation per period
- Innovator's gross profit:
- π_1 *with probability* μ_0
- π_0 *with probability* $1 - \mu_0$

Innovation intensity n_0 in a leveled sector increases with intensity of competition in this sector

- Planning horizon: 1 period
- Only 1 R&D investor in 1 period
- At most 1 innovation per period
- Innovator's gross profit:
- π_1 *with probability* μ_0
- π_0 *with probability* $1 - \mu_0$
- Max: $[\pi_1 \mu_0 + \pi_0 (1 - \mu_0)] - (\mu_0)^2 / 2$
  with respect to μ_0
- $\rightarrow \quad \mu_0 = \pi_1 - \pi_0 = \Delta\pi_1$
- ***Escape competition effect:*** $d\mu_0 / d\Delta > 0$

Escape competition effect in nek-and-neck sectors

- The higher the degree of competition in a sector in which firms are technologically similar ('neck and neck')

- the lower their profit

- **the higher the profit gain from innovation**, because the innovating firm becomes a monopolistic leader and monoply profit of the leader untouched by competition in leveled sector

Innovation intensity by outsider in un-leveled sector

- The laggard -1 is an outsider:

with R&D expenditure $R = \psi(\mu_{-1}) = \frac{1}{2} (\mu_{-1})^2$

innovation probability is $\mu_{-1} + h$

Innovation intensity by outsider in un-leveled sector

- laggard -1 chooses μ_{-1} to maximize:
- $\pi_{-1} = (\mu_{-1} + h)\, \pi_0 - (\mu_{-1})^2 / 2$

$$\rightarrow \quad \mu_{-1} = \pi_0$$

Innovation intensity by the outsider in un-leveled sector lowered by higher Δ

- $$\mu_{-1} = \pi_0 = (1 - \Delta)\,\pi_1$$

higher competition Δ in a leveled sector…

→ lower π_0

→ lower profit gain from innovation for the outsider

→ lower innovation intensity in un-leveled sector

Schumpeter's effect in leader-follower sectors

- After innovating, the new entrant competes with previous leader and faces a degree of competition Δ

- Post-innovation profit is now inversely related to competition in leveled sector

Δ and the steady-state composition of sectors

(assume that spillover frequency *h* is low enough)

- Intuition:
- Δ low favours outsider's innovation and hinders innovation in level sectors
- Δ low causes high frequency of transition **unlevel** $\longrightarrow$ **level**
- Δ high hinders outsider's innovation and promotes innovation in level sectors
- Δ high causes high frequency of transition **level** $\longrightarrow$ **unlevel**
- **in steady-state, most sectors are neck-and-neck if Δ low, and most sectors are leader-follower if Δ is high enough**

Steady-state composition between lev/unlev sectors

- ρ_1 = steady state fraction of unlevel sectors
- $\rho_0 = 1 - \rho_1$ = steady state fraction of level sectors

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- $(\mu_{-1} + h)$ = probability of transition:

  unleveled $\rightarrow$ leveled

Steady-state composition between lev/unlev sectors

- ρ_1 = steady state fraction of unlevel sectors
- $\rho_0 = 1 - \rho_1$ = steady state fraction of level sectors
- $(\mu_{-1} + h)$ = probability of transition:

  unleveled $\longrightarrow$ leveled

- $(\mu_{-1} + h)\,\rho_1$ = expected steady state transitions

  unleveled $\longrightarrow$ leveled

Steady-state composition between lev/unlev sectors

- μ_0 = probability that a level sector becomes unlevel
- $\mu_0 (1 - \rho_1)$ = expected steady state transitions

  leveled $\rightarrow$ unleveled

Δ and the steady state composition

- steady state number of level/unlevel sectors is stationary

→ transitions in one direction = transitions in the other

$$(\mu_{-1} + h)\, \rho_1 = \mu_0\, (1 - \rho_1)$$

Δ and the steady state composition

$$(\mu_{-1} + h)\, \rho_1 = \mu_0\, (1 - \rho_1)$$

$$\rho_1 = \mu_0 \,/\, (\mu_{-1} + h + \mu_0)$$

Remark:

the higher the probability μ_0 of innovation in level sectors,

the higher the steady state fraction ρ_1 of <u>un-level sectors</u>!

μ_0 is high when competition Δ in level sector is high,

high Δ causes high steady-state proportion of unlevel sectors

low Δ causes high steady-state proportion of level sectors

intuition

- If Δ low, prevalence of level sectors
- If Δ low: higher Δ → more innovation

- If Δ high, prevalence of un-level sectors, if h not too large!
- If Δ high and *h* is not too large:

  higher Δ → less innovation

- If *h* large, higher Δ → more innovation always

Aggregate innovation flow

- $I = (\mu_{-1} + h)\,\rho_1 + \mu_0\,(1 - \rho_1) = 2\,(\mu_{-1} + h)\,\rho_1$

Aggregate innovation flow

- $I = (\mu_{-1} + h)\, \rho_1 + \mu_0\, (1 - \rho_1) = 2\, (\mu_{-1} + h)\, \rho_1$
- $\rho_1 = \mu_0 / (\mu_{-1} + h + \mu_0)$
- $I = 2\, (\mu_{-1} + h)\, \mu_0 \;/\; (\mu_{-1} + h + \mu_0)$

Aggregate innovation flow

- $I = 2\ (\mu_{-1} + h)\ \mu_0\ /\ (\mu_{-1} + h + \mu_0)$
- Using the first orfder conditions for optimum R&D:
- $\mu_{-1} = \pi_0 = (1 - \Delta)\ \pi_1$
- $\mu_0 = \pi_1 - \pi_0 = \Delta\pi_1$

Obtain I as a function of Δ and leader's profit π_1

- $I = 2\,(\mu_{-1} + h)\,\mu_0 \;/\; (\mu_{-1} + h + \mu_0)$

- $\mu_{-1} = \pi_0 = (1 - \Delta)\,\pi_1$
- $\mu_0 = \pi_1 - \pi_0 = \Delta\pi_1$
- $\mu_{-1} + \mu_0 = \pi_1$

- $I = \{2[(1 - \Delta)\,\pi_1 + h]\,\Delta\,\pi_1\} \;/\; (\pi_1 + h)$

competition and innovation

- $I = \{2[(1 - \Delta)\ \pi_1 + h]\ \Delta\ \pi_1\} / (\pi_1 + h)$
- $dI / d\Delta = \{2\ \pi_1[(1 - 2\Delta)\ \pi_1 + h]\} / (\pi_1 + h)$

- Study sign of $dI / d\Delta$ at sufficiently low and high values of Δ

Relation between Δ and aggregate innovation

- $dI / d\Delta = \{2\,\pi_1[(1 - 2\Delta)\,\pi_1 + h]\} / (\pi_1 + h)$

$$d^2I / (d\Delta)^2 < 0$$

Relation between Δ and aggregate innovation

- $dI / d\Delta = \{2 \pi_1[(1 - 2\Delta) \pi_1 + h]\} / (\pi_1 + h)$

  $d^2I / (d\Delta)^2 < 0$

- Low competition:
- At $\Delta = ½$ $\qquad dI / d\Delta = (2\pi_1 h) / (\pi_1 + h) > 0$

Relation between Δ and aggregate innovation

$$dI / d\Delta = \{2\,\pi_1[(1 - 2\Delta)\,\pi_1 + h]\} / (\pi_1 + h)$$

- High competition:
- at $\Delta = 1$: $dI / d\Delta = (-\pi_1 + h)\,2\,\pi_1 / (\pi_1 + h)$
- $dI / d\Delta < 0$ *if and only if* $\pi_1 > h$

- Intuition:

  higher h increases:

  1. frequency of transitions unlevel $\longrightarrow$ level
  2. the steady-state number of level sectors

  If h $\geq \pi_1$ the relation between Δ and innovation is that prevailing in level sectors.

  the escape-competition effect prevails..

conclusions

- If leader's post-innovation rents are 'large'

$$\rightarrow \quad \pi_1 > h$$

$$\rightarrow \quad dI / d\Delta > 0 \text{ at low } \Delta$$

$$dI / d\Delta < 0 \text{ at high } \Delta$$

Predictions:

- If leader's post innovation rents are 'large'

$$\rightarrow \quad \pi_1 > h$$

$$\rightarrow \quad dI / d\Delta > 0 \text{ at low } \Delta$$

$$dI / d\Delta < 0 \text{ at high } \Delta$$

∩ shaped relation between competition and growth

- If leader's post innovation rents are not 'large'

$$\rightarrow \pi_1 < h$$

$$\rightarrow dI / d\Delta > 0 \text{ at any } \Delta$$

competition always good for growth

Qualification 1
Max technology distance > 1 step

→ Optimal technology distance is endogenous

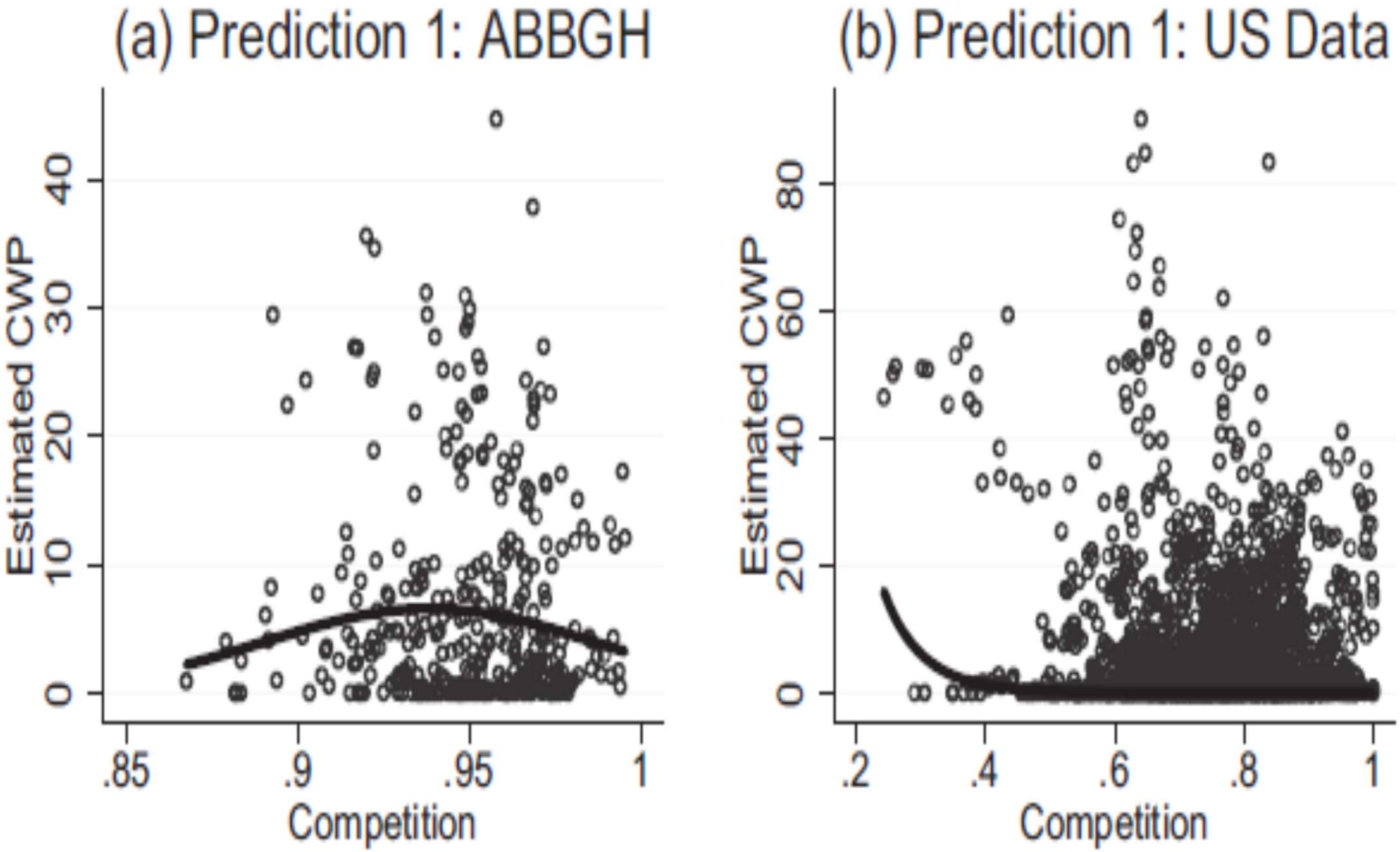
- R&D investment by the leader targets optimal technology distance

Qualification 1
Max technology distance > 1 step

→ Optimal technology distance is endogenous

- R&D investment by the leader targets optimal technology distance
- Relation between optimal technology distance and ease of entry (size of knowledge spillovers, indivisibility of R&D…) needs investigation
- Plausibly, more R&D by the leader, with greater ease of entry (less market protection)

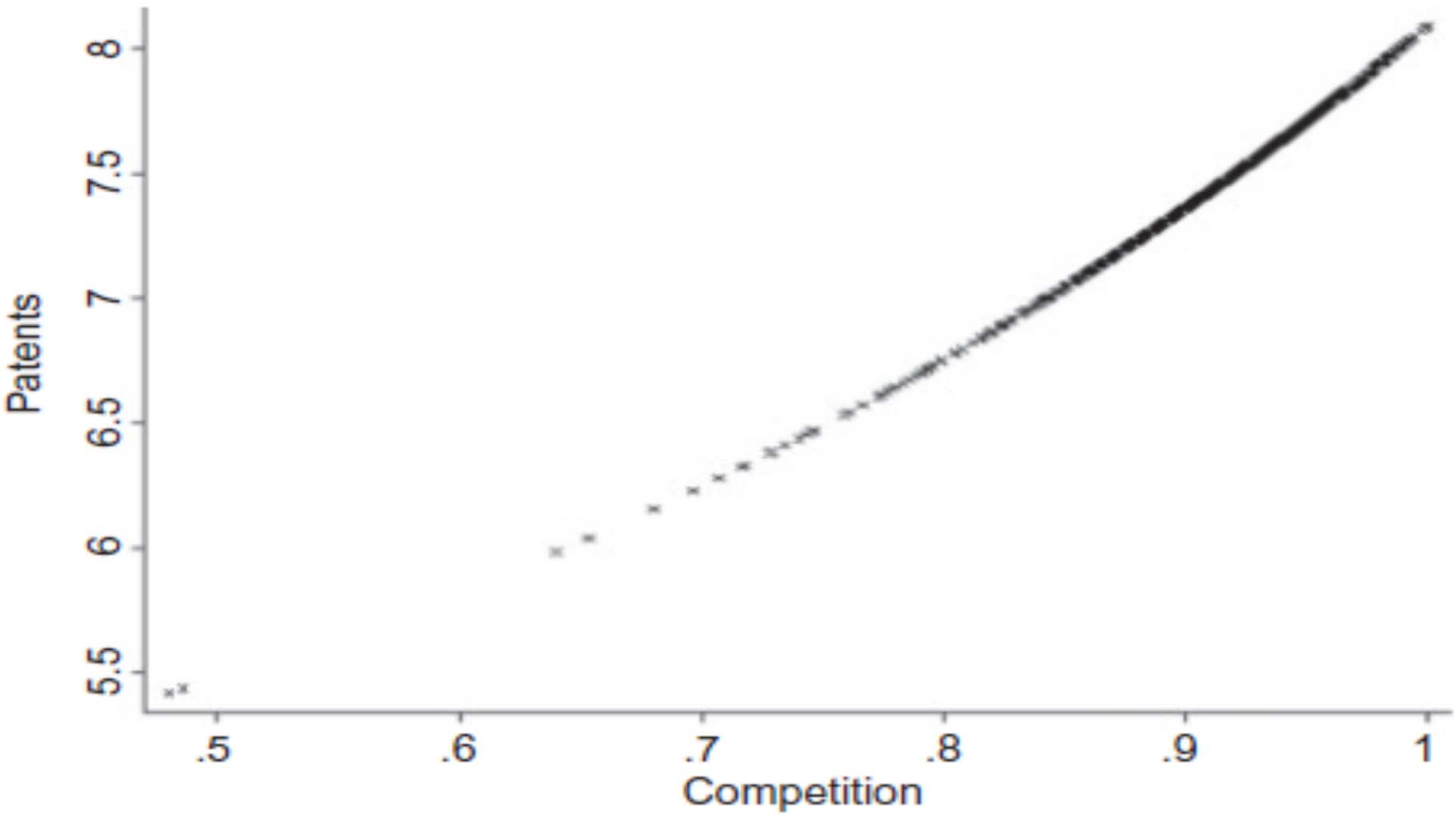
Qualification 2: Hashmi (2013) variant of Aghion et al (2005) model yields differences between USA and UK



Hashmi (2013)

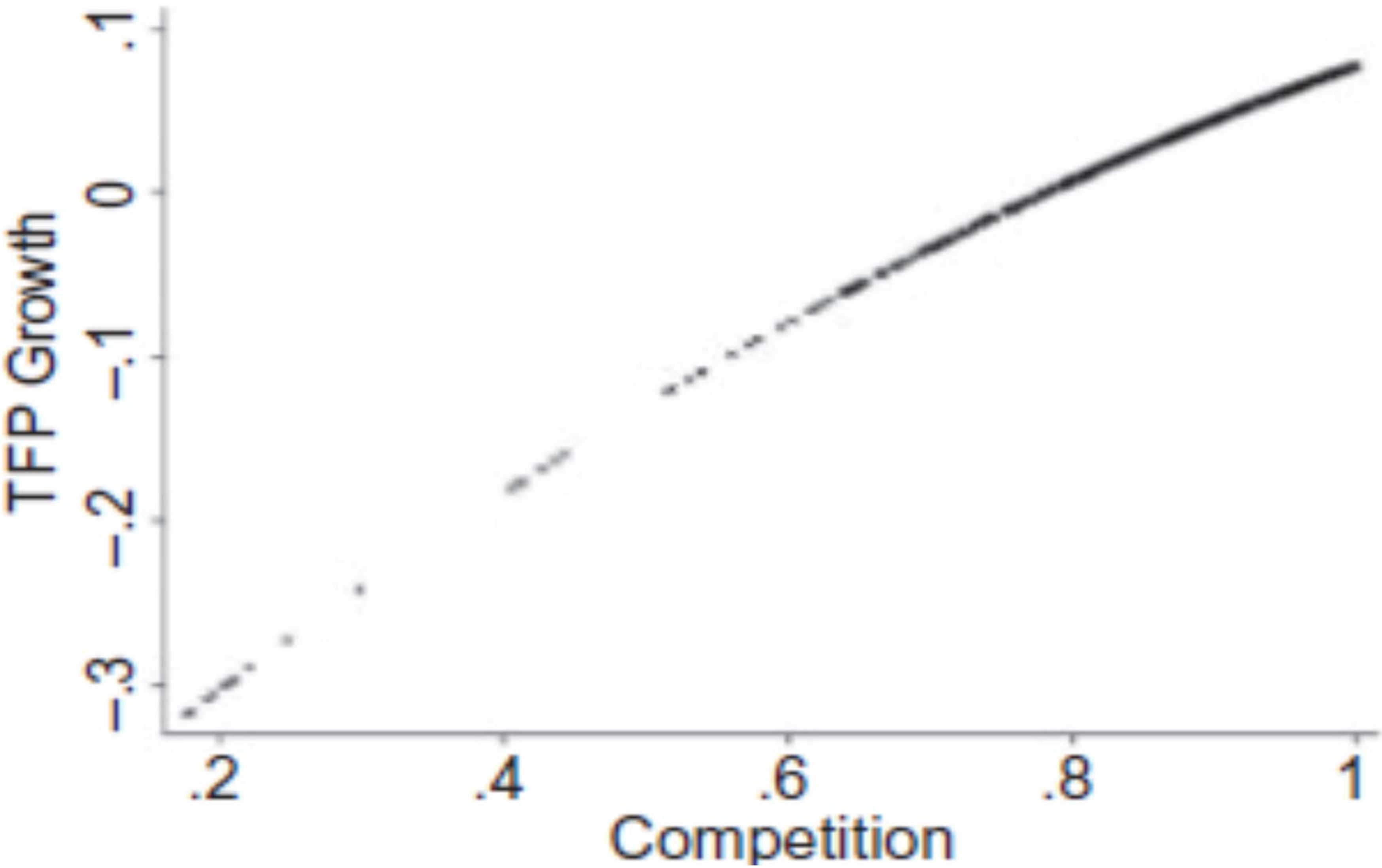
- Difference between UK and US results possibly due to:
- Higher frequency of neck-neck sectors in UK than in US
- Caused by institutional and structural features other than the degree of competition in neck-neck sectors

Correa and Ornaghi (2014): new evidence on US industry competition and patents:



(a) Specification 1A

Correa and Ornaghi (2014): new evidence on US industry competition and TFP growth:



Qualification 3
Foreing entry in a sector far from technology frontier

- If sector technology is far from technology frontier, grater ease of entry / less market protection may imply loss of the market to the advantage of technologically superior foreign firms

Qualification 2
Foreing entry in a sector far from technology frontier

- If sector technology is far from technology frontier, grater ease of entry / less market protection may imply loss of the market to the advantage of technologically superior foreign firms
- Argument reminiscent of ‘infant industry protection’
- Effects of competition and anti-regulation polices may be different in sectors/country close to or far from the world wide technology frontier