Technology entry in the presence of patent thickets

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Our research questions

- Many industries today produce products that read on thousands of patents, potentially held by many firms
- Does this discourage the entry of new firms or firms not previously in that area with better technology?
- Does this vary by firm size?

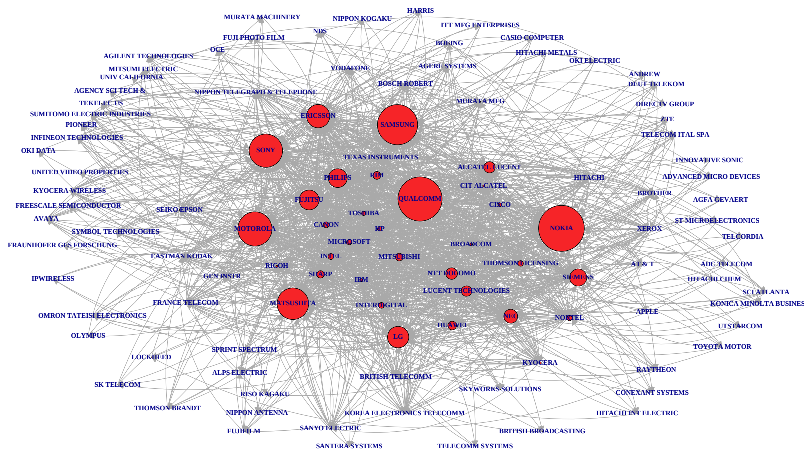
Why this topic?

- Combination of increased patenting worldwide and a perception of low quality, poorly delineated, and therefore overlapping patents being issued in some cases
- The possibility that all this is particularly costly in the case of cumulative innovation
  - Raises the cost of search so high that it inhibits new entry
  - Creates opportunities for monetizing such patents without creating an incentive for innovation
- Is this a new problem? – No
- Is this more important today? - probably

On patent thickets in the 19^{th} C

- "In the manufacture with which I am connected – the sugar trade – there are somewhere like 300 or 400 patents. Now, how are we to know all these 400 patents? How are we to manage continually, in the natural process of making improvements in manufacture, to know which of these patents we are at any time conflicting with? So far as I know, we are not violating any patent; but really, if we are to be exceedingly earnest in the question, probably we would require to have a highly paid clerk in London continually analysing the various patents; and every year, by the multiplication of patents, this difficulty is becoming more formidable."
  - [Macfie, R.A., quoted in *Is the Granting of Patents for Inventions Conducive to the Interests of Trade*?, *Transactions of the National Association for the Promotion of Social Science* 661, 665 (1865) (George W. Hastings, ed.)]

Definition: “A dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology” (Shapiro, 2000)



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The research challenge

- Patents always to some extent a barrier to entry – we ask if thickets increase this barrier
  - Not able to assess welfare impact
- Measuring entry – difficult without a pool of potential entrants
  - We focus on existing firm not yet active in a technology area
- Measuring thickets
  - We use a previously developed measure of potential holdup based on patent citations
- Our study uses data on UK firms that patent at the EPO or UKIPO

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Some prior work

- Heterogeneous effects of thickets on R&D and innovation: firms in better bargaining positions tend to benefit at the expense of others.
  - Fragmentation of technology increases R&D & patenting, but lowers market value; rivals' patenting reduces all 3; however, firms are not in a prisoners' dilemma (Schankerman & Noel, 2006, US)
  - Firms that do not need licenses benefit from fragmentation in technologies they draw on, while those that must license-in are at a disadvantage (Cockburn et al., 2010, Germany)
  - 1% increase in software patents associated with 0.8% drop in product market entry for 27 detailed software categories (Cockburn and MacGarvie, 2011, US)
- Prior work does not use our measure of thickets – relies mainly on patent numbers or Ziedonis fragmentation measure (based on the ownership of cited patents)

Model

Based on work by Graevenitz et al. (2011, 2013), generalized to allow entry and decreasing returns in patent portfolio value

- Characterize technology areas as having multiple "opportunities"; each opportunity has 1 or more "facets" which indicate degree of complexity
- Value of owning patents increasing in share owned
- R&D costs rise if more firms compete in an opportunity
- Coordination costs if firm enters multiple opportunities
- Legal costs in each opportunity depend on number of patents, share owned, and potential hold-up costs
- Firms choose number of opportunities and number of facets to (try to) patent in order to maximize profits
- Zero profit equilibrium

Firm profit function

$$\pi_{ik}(o_i, f_i) = o_i\left(V(\tilde{F}_k)\Delta(s_{ik}) - L(\gamma_{ik}, s_{ik}, h_k) - C_0(\sum_j^{N_O} o_j) - f_i p_k C_a\right) - C_c(o_i)$$

i = firm, *k* = opportunity (within a technology class), *j* = other firms
o, f number of opportunities and number of facets of that opportunity applied for by firm (not all are granted)
$V(F_k)$ value of holding all patents on an opportunity
$\Delta(s_{ik})$ proportion of value extracted by firm *i* as function of its patented share of facets
$L(\gamma_{ik}, s_{ik}, h_k)$ legal costs as a function of granted patents, share of patents, hold-up potential
$C_0()$ R&D costs; C_a patenting costs; $C_c()$ R&D coordination cost

Stage 1: Firms enter until profits are zero
Stage 2: Firms simultaneously choose the number of opportunities o_i to invest in and the number of facets per opportunity f_i to patent in order to maximize profits π_{ik}.

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Model propositions for "testing"

[Game is supermodular and has a free entry equilibrium]

1. Greater technological opportunity (more opportunities per technology increases entry
2. Greater complexity of a technology (more facets per opportunity) increases entry
3. Higher legal costs due to hold-up reduces entry

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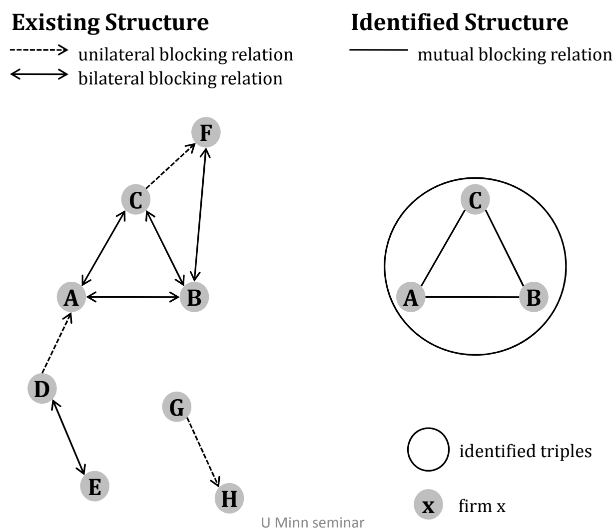
Measurement

- Entry – first time firm applies for a patent in that technology area
- Technological opportunity – overall EPO patenting in that technology or past growth in scientific references in patents in that technology
- Complexity – citation network density in that technology (number of USPTO citations between 1975 and current year divided by number possible)
- Possible hold-up (ownership thickets) – mutual X-Y citation triples at EPO (Graevenitz et al., 2011)

Measuring thickets

- We proxy for thickets using a measure based on citations between firms
  - Define a measure of thickets in terms of critical references between firms' patent applications
- X and Y citations in the EPO search report
  - indicate that the cited patent *application* contains prior art which limits one or more claims in the citing patent application.
  - X: cited patent alone
  - Y: cited patent in combination with another reference

Defining triples – X or Y cites between firms define a blocking relationship (3 year moving average)

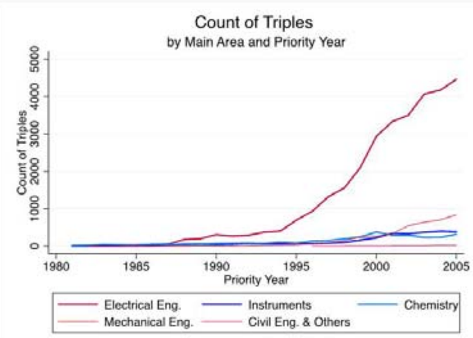


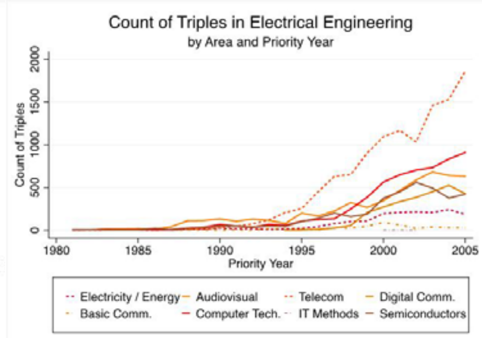
Citation triples

- Based on the "objective" research of patent examiners.
- Captures the network aspect of patent thickets using an established measure of local network structure.
- Captures firm and time specific variation in intensity of thickets.
- A *proxy* measure of potential hold-up or thickets.
- Applications versus grants:

	Share with		
	Any X cite	Any Y cite	X or Y cite
Granted	30.7%	15.9%	37.3%
Not granted	43.0%	20.0%	49.7%

Triples by technology sector





NB: largest possible triples count = n!/(3!(n-3)!) = n(n-1)(n-2)/6, so the minimum number of firms involved ≈ cube root of 6*triples count
→ ~30 for electrical; ~10 for the others

Data sources

- PATSTAT 2011 yielding data on UK and EPO patents until 2009.
- FAME 2005, 2009 - covering the population of registered UK firms until 2009.
- PATSTAT and FAME are matched at firm level.
- Sample
  - all UK firms with at least one patent application between 2001 and 2009.
  - Sample of all non-patenting UK firms, matched by size class, age class, and 2-digit industry
- 20,384 firms that might enter 34 technology areas, yielding 666,576 observations at risk with 10,228 actual entries.

Probability of Entry

- We estimate the probability a firm enters a particular technology class for the first time, as a function of
  - firm sector
  - firm size
  - past firm patent applications
  - EPO patent apps in that class and year
  - Past 5-year growth of non-patent (scientific) references in that class
  - citation network density in that class and year
  - the density of triples in that class (3-year MA)
  - year
  - .....possibly other controls and interactions
- NB: raw correlations of our key measures are approximately zero

Results

Coefficients for the hazard of entry into patenting in a TF34 Class 538,452 firm-TF34 observations with 10,665 entries (20,384 firms) Cox proportional hazards model, weighted by sampling probability			
Log (network density)	0.115*** (0.024)		0.107*** (0.023)
Log (triples density)		-0.138***(0.011)	-0.101*** (0.010)
Log (patents in class)	0.317*** (0.025)	0.506*** (0.031)	0.514*** (0.027)
Log (non-pat ref. gr.)	0.060*** (0.022)	0.084*** (0.022)	-0.009 (0.021)
Log (firm assets)	0.270*** (0.011)	0.270*** (0.011)	0.142*** (0.013)
Log (firm patent stock)			0.836*** (0.021)
Log likelihood	-66.0	-65.9	-58.7
D of F	12	12	14
Chi-squared	1270.6	1429.1	3465.1

Stratified by industry (baseline hazard varies by industry)
2002-2009, year dummies included; Standard errors clustered on firm

Results summary

- Interpretation:
  - Tech opportunity: larger classes more likely to be entered – one s.d. change increases the hazard by ~26%
  - Complexity: areas with denser citation networks more likely to be entered – one s.d. change increases the hazard by ~28%
  - Thickets: areas with triples less likely to be entered – one s.d. change reduces hazard by ~15%

    →All three consistent with the model
- Also
  - Larger firms more likely to enter – one s.d. in size increases hazard by ~45-75%
  - Firms that have previously patented elsewhere more likely to enter – one s.d. change increases hazard by ~100%

Impact by firm size

- Interact the key variables with firm size:
  - Network density effect increases with size
  - Tech opportunity effect declines with size
  - Thickets impact does not vary with size
- Conclusion:
  - UK SMEs are not more affected by thickets than larger firms
  - However, they do respond more to technology opportunity and less to complexity

Robustness

- Coefficients unchanged if:
  - Drop large firms (assets>1 billion GBP)
  - Drop telecomm sector
  - Use a minimum founding year of 1990 instead of 1978
- Coefficients weaker but still significant if
  - For each firm, drop tech classes that firms in that firm's industry ever enter
- No effect from industry concentration at the 2-digit or 4-digit level, but poorly measured
- Duples have an even stronger impact

Conclusions

- Evidence that patent thickets or hold-up potential reduces patented technology entry by UK firms, regardless of their size
- Caveats:
  - no welfare implications measured
  - study is technology and patenting based, does not measure product market entry
  - however, many product markets will require patents for entry