

# FALLING INTO TRAPS?

## PATENT THICKETS, PATENT COMMERCIALIZATION, AND STOCK RETURNS

Po-Hsuan Hsu Hsiao-Hui Lee Tong Zhou

University of Hong Kong

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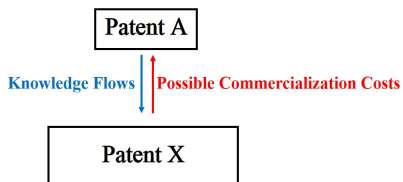
## ► Technological progress

- Isaac Newton: *“If I have seen further it is by standing on the shoulders of giants.”*
- To motivate innovation, governments offer patent rights to inventors in exchange for the disclosure of their inventions.
- Patent system requires disclosure of “prior arts” as knowledge base (i.e., “citations”).



# AN ILLUSTRATIVE EXAMPLE

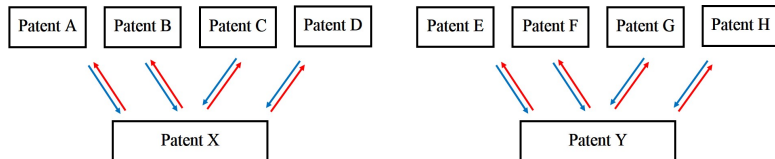
- ▶ Patent X cites Patent A.
- ▶ Patent X is based on Patent A.



- ▶ **Commercialization costs:** If the inventor of Patent X wants to commercialize Patent X, he/she **may** need to negotiate with the owner of Patent A (to be modelled).

# AN ILLUSTRATIVE EXAMPLE

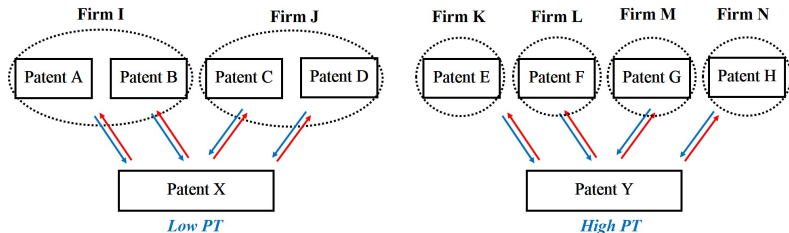
- ▶ Now suppose both Patents X and Y cite four previous **complementary** patents.



- ▶ Blue arrows: knowledge flows.
- ▶ Red arrows: possible commercialization costs.

# AN ILLUSTRATIVE EXAMPLE

- ▶ However, they have different patent thicket (ownership fragmentation).
  - ▶ A and B (C and D) are owned by Firm I (J).
  - ▶ E, F, G, and H are owned by four different firms.



- ▶ Possible commercialization costs of Patent Y are likely higher.
  - ▶ Owner of Patent Y is **compulsory** to negotiate with **all** four firms.
- ▶ Future stochastic cash flows of Patent Y are lower than Patent X.

## ▶ **Completeness in citations**

- ▶ U.S. patent laws require patent applicants to provide a **full list of references (“prior arts”)** that are related to the patentability of the applications (“duty of candor”). Such reference list will be reviewed and supplemented by patent examiners.
- ▶ The incomplete disclosure of prior arts will result in **rejection of application** (Caballero and Jaffe 1993; Roach and Cohen 2013) or **invalidation of patents** in court decisions (Allison and Lemley 1998; Sampat 2010).
- ▶ This legal requirement of completeness allows us to assume that **the reference list reflects the distribution of prior knowledge a patent is based on as well as ownership distribution.**

## ▶ **Relevance in citations**

- ▶ For novelty requirement, applicants cannot cite irrelevant patents.

## ▶ **Empirical support**

- ▶ Patentees tend to prosecute infringement of a patent when cited by firms active in related technology areas. (Lanjouw and Schankerman 2001)

# INDUSTRY CARES ABOUT PATENT THICKET

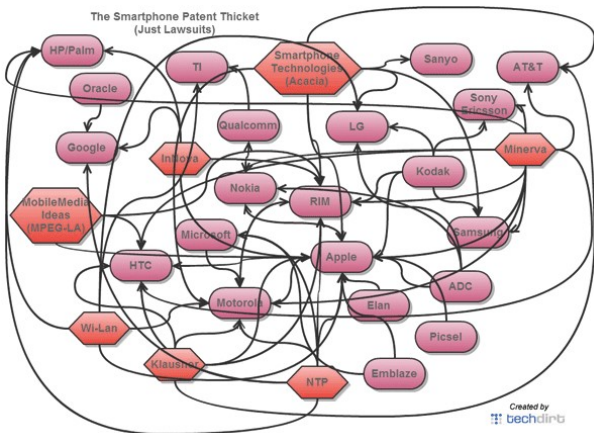
- ▶ Taking smartphone as an example, guess **how many patents are involved in your smartphone?**
- ▶ RPX, a public-listed patent management company, pointed out (2011):

“Based on our research, we believe there are more than **250,000** active patents relevant to today’s smartphones, a significant increase compared to our estimate of approximately **70,000** patents that were active and relevant to mobile phones in 2000...”

  - ▶ “[I]ncluding touchscreens, internet access, streaming video, media playback, application store readiness and other web-based services, and WiFi connectivity options.”

# INDUSTRY CARES ABOUT PATENT THICKET

- ▶ How severe is patent thicket in smartphone industry? Lawsuit map.





# INDUSTRY CARES ABOUT PATENT THICKET

- ▶ A 2013 report by the world intellectual property organization (WIPO):

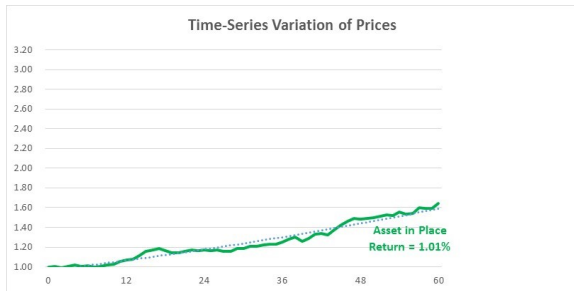
“Each patent holder owns **an exclusive right** to one or many small features of the smart phone, and can therefore try to **prevent others from manufacturing the smart phone as a whole**. As the numbers of players and patented features increase, the transaction costs of assembling a “completely licensed” smart phone become burdensome, because the manufacturer has to **deal separately with the owner of each feature** or patented component.”
- ▶ As there are so many patents involved in the smartphone industry, applying a new technology to manufacture a smartphone will be **difficult**.

# WHAT IS PATENT THICKET?

- ▶ **Patent thicket = patent ownership fragmentation.**
  - ▶ Shapiro (2001): “a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology.”
- ▶ **Patent thickets, patent commercialization, and stock returns.**
  - ▶ **Higher** patent thickets  $\Rightarrow$  **delayed** patent commercialization  $\Rightarrow$  **lower** cash flows  $\Rightarrow$  **lower** risk exposure and **lower** stock returns.

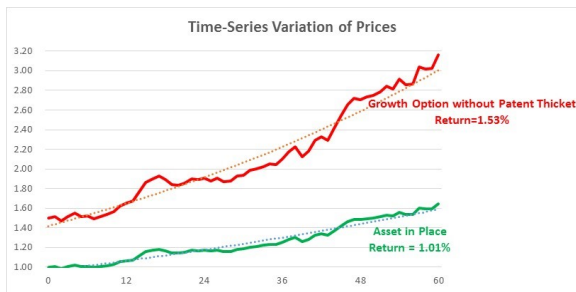
# INTUITION OF A REAL OPTION MODEL

- ▶ Future cash flows are governed by a systematic stochastic process.
- ▶ Asset prices are discounted future cash flows.



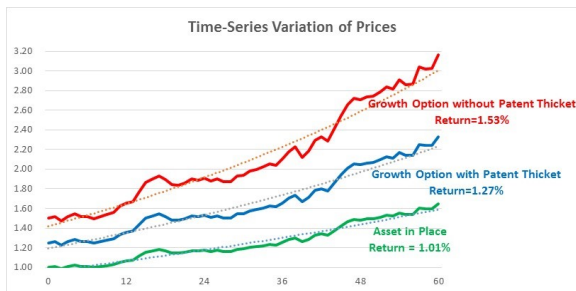
# INTUITION OF A REAL OPTION MODEL

- ▶ Because of implicit leverage, growth option (patent) is of higher price than asset in place.
- ▶ Also, growth option has higher systematic risk exposure and expected return.



# INTUITION OF A REAL OPTION MODEL

- ▶ **Patents with patent thickets are of lower prices.**
  - ▶ Because patent thickets erode future cash flows.
  - ▶ These patents have lower systematic risk exposure and expected return.



- ▶ **A firm facing deeper patent thickets has lower systematic risk exposure and lower expected stock returns.**

- ▶ Higher patent thicket (PT), **more patent litigation.**
- ▶ Higher patent thicket (PT), **slower product inventions.**

### ▶ One firm with one patent

- ▶ Asset in place: an instantaneous dividend  $\theta_t$  forever.
- ▶ One patent: an instantaneous dividend  $\zeta\theta_t$  once applied successfully.
- ▶ Royalty: simultaneous negotiation and  $Q$  is settled down.

### ▶ Commercializing the patent

- ▶ The patent is surrounded by  $n$  owners. (**patent thicket =  $n$** )
- ▶ When a patent is exploited (i.e., exercising the option), royalty is paid to each owner.  $Q \equiv \sum_{i=1}^n q_i$
- ▶ When a patent is exploited, each owner receives  $q_i$  but foregoes private cost  $c_i$ .

### ▶ Market fundamental

- ▶  $d\theta_t = \mu\theta_t dt + \sigma\theta_t dz_t$ .

### ▶ Stochastic discount factor (exogenous)

- ▶  $dM_t = -rM_t dt - \kappa M_t dz_t$ .

# THE MODEL

## — SOLUTION TO THE EQUILIBRIUM

- ▶ Price of asset in place:  $P_t^I = \rho\theta_t$ .
- ▶ Decision of firm to solve  $\tau^*$  (exercising time of growth option):

$$P_t^O = \sup_{\tau} E_t \left[ \int_{\tau}^{\infty} \frac{M_s}{M_t} \zeta \theta_s ds - \frac{M_{\tau}}{M_t} Q \right].$$

$$P_t = P_t^I + P_t^O.$$

- ▶ Decision of patent owners to solve  $q^*$  (royalty):

$$\max_{q_i} E_t \left[ \frac{M_{\tau^*}}{M_t} (q_i - c_i) \right].$$

- ▶ With  $\tau$  and  $q$  determined together, we solve  $P_t$  as a function of  $n$ .



- ▶ Proposition 1: Systematic risk exposure decreases with patent thicket.

$$\beta_t \equiv -\frac{E_t [R_t \cdot dM_t / M_t]}{\text{Var}_t [dM_t / M_t]} \Rightarrow \frac{d\beta_t}{dn} < 0.$$

- ▶ Proposition 2: Expected stock return decreases with patent thicket.

$$R_t \equiv \frac{dP_t + \theta_t dt}{P_t} \Rightarrow \frac{dE_t [R_t]}{dn} < 0.$$

## ▶ Patent portfolio size

- ▶ The assumption that a firm is granted with only one patent is relaxed in an extended model.
- ▶ It delivers new model predictions consistent with empirical results.

## ▶ Counterparties' bargaining power

- ▶ In one extended model, we directly allow different counterparties to have different bargaining power in a simultaneous bargaining game.
- ▶ In another extended model, we consider a sequential bargaining game (bigger firms move first).

## ▶ Negotiation process

- ▶ In the basic model, we assume a simultaneous bargaining game and mute coordination among all previous patent owners.
- ▶ In an extended model, we consider a sequential bargaining game to allow some coordination.

- ▶ Patents data: Kogan, Papanikolaou, Seru, and Stoffman (2012)
  - ▶ Sample period: 1976-2010
- ▶ Stocks data: CRSP
  - ▶ Only domestic common shares on NYSE, AMEX, and NASDAQ
  - ▶ Financial and other firms excluded (FF44-48)
- ▶ Accounting data: Compustat
- ▶ Patent litigations data: Lex Machina
  - ▶ Sample period: 2000-2015
- ▶ New product announcements data: Capital IQ
  - ▶ Sample period: 2001-2015

- ▶ **Patent Thicket (PT)**. Ziedonis (2004)

$$PT_{i,t} = Frag_{i,t} \cdot \frac{Numpats_{i,t}}{Numpats_{i,t} - 1}, \text{ when } Numpats_{i,t} > 1;$$

$$PT_{i,t} = Frag_{i,t}, \text{ when } Numpats_{i,t} = 1,$$

where  $Numpats_{i,t}$  denotes the number of patents granted to firm  $i$  from year  $t - 4$  to  $t$ , and

$$Frag_{i,t} = 1 - \sum_{j=1}^J \left( \frac{Numcites_{i,t}^j}{Numcites_{i,t}} \right)^2, \quad i \neq j,$$

where  $Numcites_{i,t}^j$  denotes the number of citations of firm  $j$  by firm  $i$ .

### ▶ **Patent litigation.**

- ▶ The propensity that a firm will be involved in litigation.
- ▶ Number of litigation cases against it over a five-year window.

### ▶ **Patent commercialization.**

- ▶ How effective a firm is able to commercialize its patents.
- ▶ Number of new products launched over number of patents granted over a five-year window.

### ▶ **Market beta.**

- ▶ Loading on the market factor over a five-year window.

- ▶ **We test the cost channel of PT using patent litigations data.**
  - ▶ If a firm jumps up by one PT quintile, it encounters 0.20 more litigation cases as defendants (\$8.7m) over the next five years. [Full-sample average: 0.27.]
  - ▶ Robust to industry fixed effects, patent portfolio size, counterparties' bargaining power...
- ▶ **We test the real option story of PT using new product announcements data.**
  - ▶ If a firm jumps up by one PT quintile, it launches 29% fewer new products out of patent portfolio over the next five years. [Full-sample average: 31%.]
  - ▶ Robust to industry fixed effects, patent portfolio size, counterparties' bargaining power...

- ▶ **Test conditional CAPM argument using panel regressions.**
  - ▶ A firm's **market beta drops by 0.10 or 0.13**, as it moves from the bottom PT quintile to the top quintile.
    - ▶ On average a sample firm has a market beta of 1.24.
    - ▶ Robust to **industry fixed effects, patent portfolio size, counterparties' bargaining power...**
  - ▶ Firms in the top PT quintile **have lower volatilities in ROA, ROE, investment, and sales** compared with those in the bottom quintile.
- ▶ **Examine PT-return relation using portfolio analysis.**
  - ▶ Monthly excess stock returns of firms in the top quintile of PT **underperform** those in the bottom quintile by 0.42% **to** 0.78%.
    - ▶ Robust to **industry fixed effects, patent portfolio size, counterparties' bargaining power...**

# CONCLUDING REMARKS

- ▶ The effect of **fragmented patent ownership (patent thickets)** on asset pricing.
- ▶ A real option model with empirical supports.
  - ▶ Deeper patent thickets  $\Rightarrow$  **higher** commercialization costs (more litigation) and **delayed** patent commercialization (fewer new products).
  - ▶ Proposition 1: Deeper patent thickets  $\Rightarrow$  **lower** risk exposure (lower market beta).
  - ▶ Proposition 2: Deeper patent thickets  $\Rightarrow$  **lower** stock returns.
- ▶ Our results are robust to control for:
  - ▶ Industry heterogeneity.
  - ▶ Patent portfolio size.
  - ▶ Counterparties' bargaining power.



# LEMMA 1

## — THE FIRM'S DECISION

### LEMMA (FIRM'S DECISION)

The optimal stopping time  $\tau^*$  is reached when the market condition reaches  $\theta^*$  (i.e.,  $\theta_{\tau^*} = \theta^*$ ), in which,

$$\theta^* = \frac{\phi^+}{\phi^+ - 1} \frac{Q}{\rho \bar{\zeta}},$$

where  $\phi^+ = \frac{-(\mu - \kappa\sigma - \frac{1}{2}\sigma^2) + \sqrt{(\mu - \kappa\sigma - \frac{1}{2}\sigma^2)^2 + 2\sigma^2 r}}{\sigma^2} > 1$ . The price of the patent is:

$$P_t^O = \left( \frac{\rho \bar{\zeta}}{\phi^+} \right)^{\phi^+} \left( \frac{\phi^+ - 1}{Q} \right)^{\phi^+ - 1} \theta_t^{\phi^+}.$$

# LEMMA 2

## — THE PATENT OWNERS' DECISION

### LEMMA (PATENT OWNERS' DECISION)

*The optimal royalty payment,  $q_i^*$ , can be expressed as:*

$$q_i^* = \frac{1}{\phi^+ - n} \left[ (\phi^+ - n) c_i + \sum_{j=1}^n c_j \right].$$

*When we assume all patent owners' private costs are the same ( $c_i = c_j = c$ ), the optimum can be simplified to  $q_i^* = q_j^* = q^*$  for  $i, j = 1 \dots n$ , and*

$$q^* = \frac{\phi^+}{\phi^+ - n} c > c.$$

- ▶ **Highlight the role of patent thickets in asset prices.**
  - ▶ Firm-level technological development: Lin (2012), Kogan, Papanikolaou, Seru, and Stoffman (2012), Cohen, Diether, and Malloy (2013), and Hirshleifer, Hsu, and Li (2013)...
  - ▶ Aggregate-level technological development: Greenwood, Hercowitz, and Krusell (1997), Hobijn and Jovanovic (2001), Laitner and Stolyarov (2003), Pastor and Veronesi (2009), Hsu (2009), Papanikolaou (2011), and Garleanu, Panageas, and Yu (2012)...
  - ▶ Dynamics of patent ownership is value-relevant but overlooked.
- ▶ **Show general impact of patent thickets on stock returns.**
  - ▶ IO literature examining patent thicket: Shapiro (2001), Ziedonis (2004), Bessen (2004), Clark and Konrad (2008), Cockburn and MacGarvie (2009), Cockburn, MacGarvie, and Mueller (2010)...
  - ▶ Attention is limited to specific industries. Financial markets neglected.

# EMPIRICAL TESTS

## — FUTURE PATENT LITIGATION AND PT

**Commercialization costs of PT.** Deeper patent thickets, MORE future patent litigations.

Future Patent Litigation	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	3.8596*** (0.1344)	4.9262*** (0.1520)	3.6490*** (0.1471)	3.4783*** (0.1446)	0.1954*** (0.0060)	0.2737*** (0.0067)	0.1959*** (0.0064)	0.1831*** (0.0072)
Constant	-4.3276*** (0.1263)	-6.0047*** (0.1495)	-4.5143*** (0.1400)	-5.3289*** (0.1442)	-1.4364*** (0.0292)	-2.3955*** (0.0569)	-1.8276*** (0.0350)	-2.7567*** (0.0605)
Observations	11,490	11,490	11,490	11,490	11,490	11,490	11,490	11,490
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES

*Economic magnitude: if jump up by one PT quintile, encounter 0.20 more litigation cases (\$8.7m) over the next five years. [Full-sample average: 0.27.]*

# EMPIRICAL TESTS

## — FUTURE PATENT COMMERCIALIZATION AND PT

**Commercialization behavior under PT.** *Deeper patent thickets, LOWER future patent commercialization.*

Future Patent Commercialization	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	<b>-5.3040***</b> (0.5225)	<b>-4.9035***</b> (0.5290)	<b>-5.8315***</b> (0.5232)	<b>-4.9173***</b> (0.5310)	<b>-0.2864***</b> (0.0596)	<b>-0.1342**</b> (0.0616)	<b>-0.2912***</b> (0.0595)	<b>-0.1104*</b> (0.0620)
Constant	6.9437*** (0.5279)	3.5911 (4.9705)	7.0691*** (0.5323)	11.0754* (5.7150)	3.1913*** (0.3236)	-0.3886 (4.9694)	2.9300*** (0.3374)	6.5289 (5.7151)
Observations	10,859	10,859	10,859	10,859	10,859	10,859	10,859	10,859
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES

*Economic magnitude: if jump up by one PT quintile, launch 29% fewer new products out of patent portfolio over the next five years. [Full-sample average: 31%.]*

**Proposition 1.** *Deeper patent thickets, LOWER risk (exposure).*

Future Market Beta	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	<b>-0.1729***</b> (0.0415)	<b>-0.1739***</b> (0.0397)	<b>-0.2035***</b> (0.0429)	<b>-0.1942***</b> (0.0419)	<b>-0.0326***</b> (0.0045)	<b>-0.0321***</b> (0.0044)	<b>-0.0262***</b> (0.0044)	<b>-0.0280***</b> (0.0044)
Constant	1.2578*** (0.0502)	0.7688*** (0.1605)	1.3309*** (0.0526)	0.8232*** (0.1612)	1.1999*** (0.0353)	0.7068*** (0.1578)	1.2238*** (0.0373)	0.7407*** (0.1583)
Observations	15,095	15,095	14,558	14,558	15,095	15,095	14,558	14,558
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES

*Economic magnitude: if jump from lowest quintile to highest, market beta over the next five years will drop by 0.13. [Full-sample average: 1.24.]*

# EMPIRICAL TESTS

## — FUTURE OPERATION VOLATILITY (ROA) AND PT

**Proposition 1.** *Deeper patent thickets, LOWER risk (exposure).*

Panel A. Volatility in ROA								
Future Volatility in Operation	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	<b>-0.0332***</b>	<b>-0.0297***</b>	<b>-0.0351***</b>	<b>-0.0321***</b>	<b>-0.0069***</b>	<b>-0.0055***</b>	<b>-0.0064***</b>	<b>-0.0053***</b>
	<b>(0.0031)</b>	<b>(0.0031)</b>	<b>(0.0030)</b>	<b>(0.0029)</b>	<b>(0.0005)</b>	<b>(0.0005)</b>	<b>(0.0004)</b>	<b>(0.0004)</b>
Constant	0.0249	0.0542	0.0554***	0.0486***	0.0142	0.0446	0.0434***	0.0386**
	(0.0621)	(0.0630)	(0.0101)	(0.0180)	(0.0620)	(0.0629)	(0.0098)	(0.0178)
Observations	26,462	26,462	25,051	25,051	26,462	26,462	25,051	25,051
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES

# EMPIRICAL TESTS

## — FUTURE OPERATION VOLATILITY (ROE) AND PT

**Proposition 1.** *Deeper patent thickets, LOWER risk (exposure).*

Panel B. Volatility in ROE								
Future Volatility in Operation	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	<b>-0.1194*</b> <b>(0.0667)</b>	<b>-0.1214*</b> <b>(0.0675)</b>	<b>-0.1207*</b> <b>(0.0685)</b>	<b>-0.1343*</b> <b>(0.0694)</b>	<b>-0.0327***</b> <b>(0.0101)</b>	<b>-0.0288***</b> <b>(0.0103)</b>	<b>-0.0290***</b> <b>(0.0101)</b>	<b>-0.0284***</b> <b>(0.0103)</b>
Constant	0.0912 (1.3302)	0.1600 (1.3823)	0.1525 (1.5674)	0.2055 (1.6083)	0.0662 (1.3294)	0.1310 (1.3817)	0.1066 (1.5662)	0.1525 (1.6073)
Observations	26,451	26,451	25,041	25,041	26,451	26,451	25,041	25,041
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES



# EMPIRICAL TESTS

## — FUTURE OPERATION VOLATILITY (IA) AND PT

**Proposition 1.** *Deeper patent thicket, LOWER risk (exposure).*

Panel C. Volatility in IA								
Future Volatility in Operation	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	<b>-0.0081***</b> (0.0011)	<b>-0.0086***</b> (0.0011)	<b>-0.0088***</b> (0.0010)	<b>-0.0091***</b> (0.0010)	<b>-0.0016***</b> (0.0002)	<b>-0.0015***</b> (0.0002)	<b>-0.0016***</b> (0.0002)	<b>-0.0016***</b> (0.0002)
Constant	0.0436*** (0.0028)	0.0471*** (0.0064)	0.0466*** (0.0027)	0.0520*** (0.0059)	0.0415*** (0.0027)	0.0448*** (0.0064)	0.0438*** (0.0026)	0.0494*** (0.0058)
Observations	26,219	26,219	24,822	24,822	26,219	26,219	24,822	24,822
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES

# EMPIRICAL TESTS

## — FUTURE OPERATION VOLATILITY (SA) AND PT

**Proposition 1.** *Deeper patent thickets, LOWER risk (exposure).*

Panel D. Volatility in SA								
Future Volatility in Operation	Specification 1: Raw Patent Thicket				Specification 2: Ranked Patent Thicket			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Thicket (PT)	<b>-0.0511***</b>	<b>-0.0527***</b>	<b>-0.0563***</b>	<b>-0.0570***</b>	<b>-0.0047***</b>	<b>-0.0047***</b>	<b>-0.0051***</b>	<b>-0.0053***</b>
	<b>(0.0070)</b>	<b>(0.0070)</b>	<b>(0.0064)</b>	<b>(0.0064)</b>	<b>(0.0011)</b>	<b>(0.0011)</b>	<b>(0.0009)</b>	<b>(0.0010)</b>
Constant	0.0437 (0.1404)	0.2398* (0.1442)	0.2829*** (0.0219)	0.3778*** (0.0393)	0.0175 (0.1405)	0.2146 (0.1442)	0.2489*** (0.0214)	0.3480*** (0.0391)
Observations	26,462	26,462	25,051	25,051	26,462	26,462	25,051	25,051
Other Controls	NO	NO	YES	YES	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES

# EMPIRICAL TESTS

## — FUTURE STOCK RETURN AND PT

**Proposition 2.** *Deeper patent thickets, LOWER future stock return.*

PT	Excess Return	CAPM
	Time-series Mean	MKT
No	0.63** (0.25)	0.99*** (0.01)
Low	0.95*** (0.27)	0.98*** (0.03)
2	0.90*** (0.31)	1.10*** (0.04)
3	0.77*** (0.27)	1.03*** (0.02)
4	0.71*** (0.25)	0.95*** (0.02)
High	0.49** (0.24)	0.91*** (0.02)
High-Low	<b>-0.46***</b> <b>(0.16)</b>	<b>-0.07**</b> <b>(0.03)</b>

# EMPIRICAL TESTS

## — FUTURE STOCK RETURN AND PT (SORTED WITHIN INDUSTRY)

**Proposition 2.** *Deeper patent thickets, LOWER future stock returns.*

PT	Excess Return	
	Time-series Mean	CAPM MKT
Low	0.99*** (0.26)	0.98*** (0.02)
	0.90*** (0.30)	1.10*** (0.03)
2	0.67** (0.28)	1.06*** (0.03)
3	0.75*** (0.24)	0.92*** (0.02)
4	0.52** (0.24)	0.90*** (0.02)
High		
High-Low	<b>-0.48*** (0.14)</b>	<b>-0.08*** (0.03)</b>

## ▶ One firm

- ▶ Asset in place: an instantaneous dividend  $\theta_t$  forever.
- ▶  $A$  homogeneous, independent patents: an instantaneous dividend  $\xi\theta_t$  once applied successfully. (**patent portfolio size =  $A$** )
- ▶ Royalty negotiation:  $Q$  is settled down once the patent is granted.

## ▶ Patent exploitation

- ▶ Each patent is surrounded by  $n$  owners. (**patent thicket =  $n$** )
- ▶ When a patent is exploited, royalty is paid to each owner.  $Q \equiv \sum_{i=1}^n q_i$
- ▶ When a patent is exploited, each owner receives  $q_i$  but forego  $c_i$ .

## ▶ Market fundamental

- ▶  $d\theta_t = \mu\theta_t dt + \sigma\theta_t dz_t$ .

## ▶ Stochastic discount factor

- ▶  $dM_t = -rM_t dt - \kappa M_t dz_t$ .

# AN EXTENDED MODEL

## — SOLUTION TO THE EQUILIBRIUM

- ▶ Decision of firm to solve  $\tau^*$  (exercising time):

$$P_t^O = \sup_{\tau} E_t \left[ \int_{\tau}^{\infty} \frac{M_s}{M_t} \zeta \theta_s ds - \frac{M_{\tau}}{M_t} Q \right].$$

$$P_t = P_t^I + AP_t^O.$$

- ▶ Decision of patent owners to solve  $q^*$  (royalty):

$$\max_{q_i} E_t \left[ \frac{M_{\tau^*}}{M_t} (q_i - c_i) \right].$$

- ▶ With  $\tau$  and  $q$  determined together, we solve  $P_t$  as a function of  $n$  and  $A$ .

# AN EXTENDED MODEL

## — COMPARATIVE STATICS

- ▶ Proposition 1: Systematic risk exposure decreases with patent thicket and increases with patent portfolio size.

$$\frac{d\beta_t}{dn} < 0 \text{ and } \frac{d\beta_t}{dA} > 0.$$

- ▶ Proposition 2: Expected stock return decreases with patent thicket and increases with patent portfolio size.

$$\frac{dE_t[R_t]}{dn} < 0 \text{ and } \frac{dE_t[R_t]}{dA} > 0.$$

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# AN EXTENDED MODEL

## — EMPIRICAL RESULTS

PT \ CTBE	Low	2	3	4	High	High-Low	Average across Five Quintiles	
Low	0.67	1.34	1.60	1.32	2.74	2.07*** (0.54)		
2	0.82	0.82	1.33	0.64	1.61	0.78** (0.38)	<b>Excess Return</b>	<b>Market Beta</b>
3	0.63	0.69	0.83	1.26	1.32	0.69** (0.35)	<b>0.86*** (0.25)</b>	<b>0.39*** (0.05)</b>
4	0.49	0.74	0.62	0.80	1.19	0.69* (0.38)		
High	0.56	0.14	0.57	0.74	0.62	0.06 (0.28)		
<b>High-Low</b>	-0.10 (0.21)	-1.20*** (0.31)	-1.03*** (0.32)	-0.58** (0.27)	-2.11*** (0.57)			
<b>Average across Five Quintiles</b>	<b>Excess Return</b>		<b>-1.00*** (0.19)</b>					
	<b>Market Beta</b>		<b>-0.16*** (0.04)</b>					