Financing Innovation with Innovation

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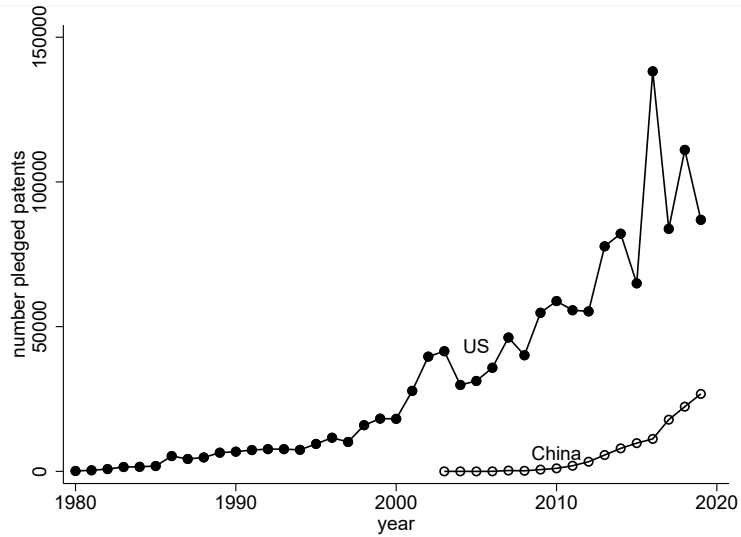
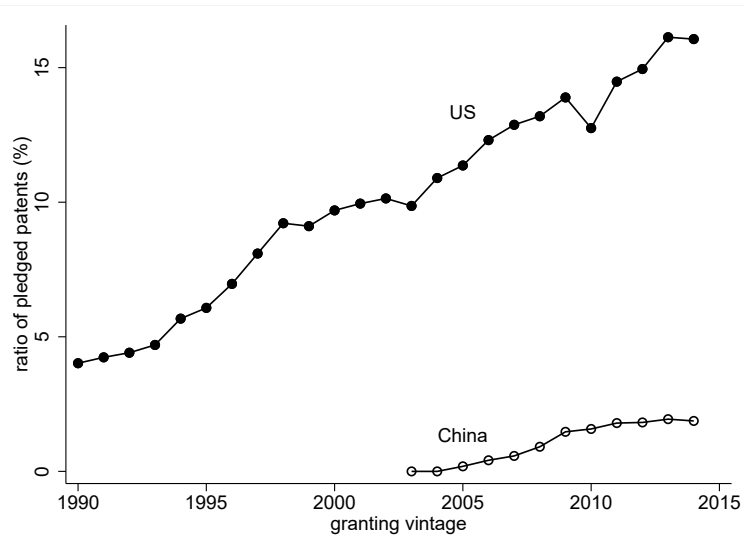
  1. What's the micro foundation of "patent as collateral"?
  2. What's the implication of "patent as collateral" for innovation and macro?
- Takeaway: Firms could finance innovation (R&D) with innovation (patents), and there is positive output and welfare gain from such financial development

Motivation Fact 1: Aggregate Trend

- Both numbers and ratios of pledged patents are raising
- US has a more developed "patent as collateral" market than China



(a) Number of Pledged Patents (Aggregate)



(b) Ratio of Pledged Patents (Aggregate)

Motivation Fact 2: An Interview with a CEO in the Industry

We interviewed a CEO who started a patent valuation company in Beijing, and below is the flow chart of how "patent as collateral" works:

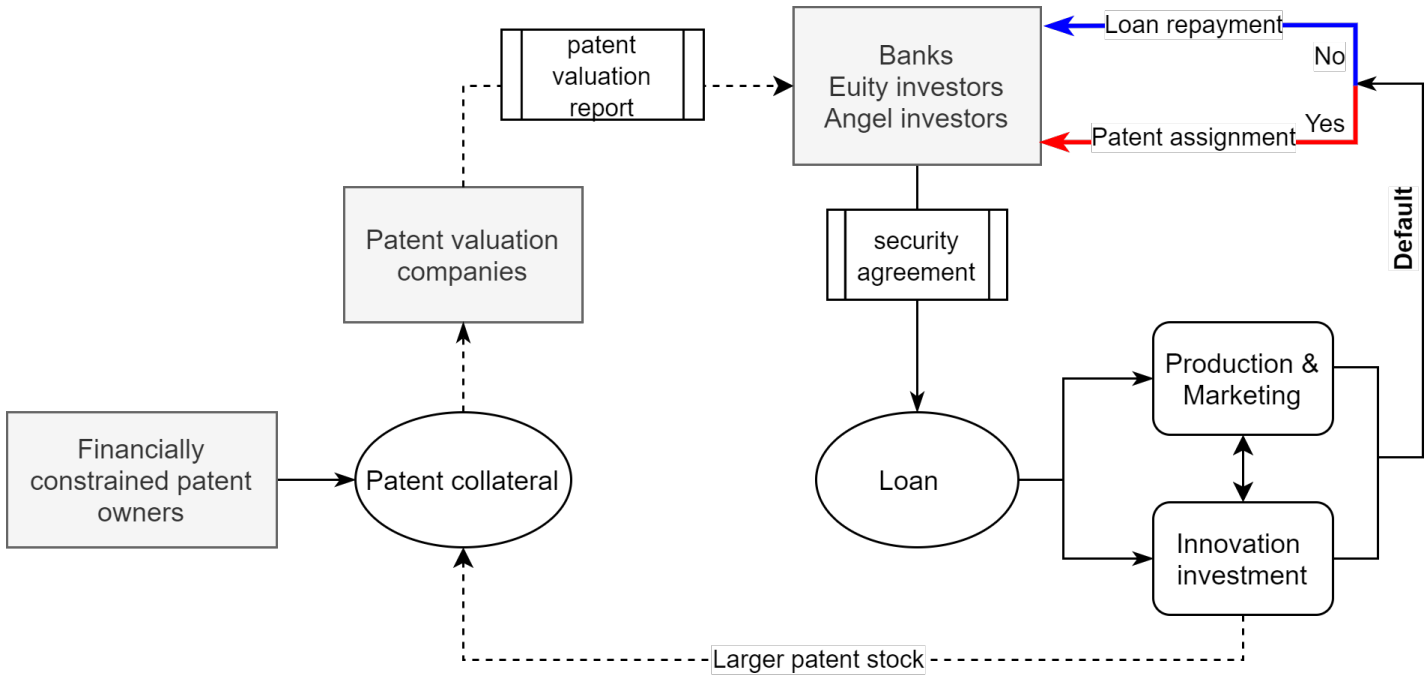


Figure: Flow chart of obtaining patent-backed Loans

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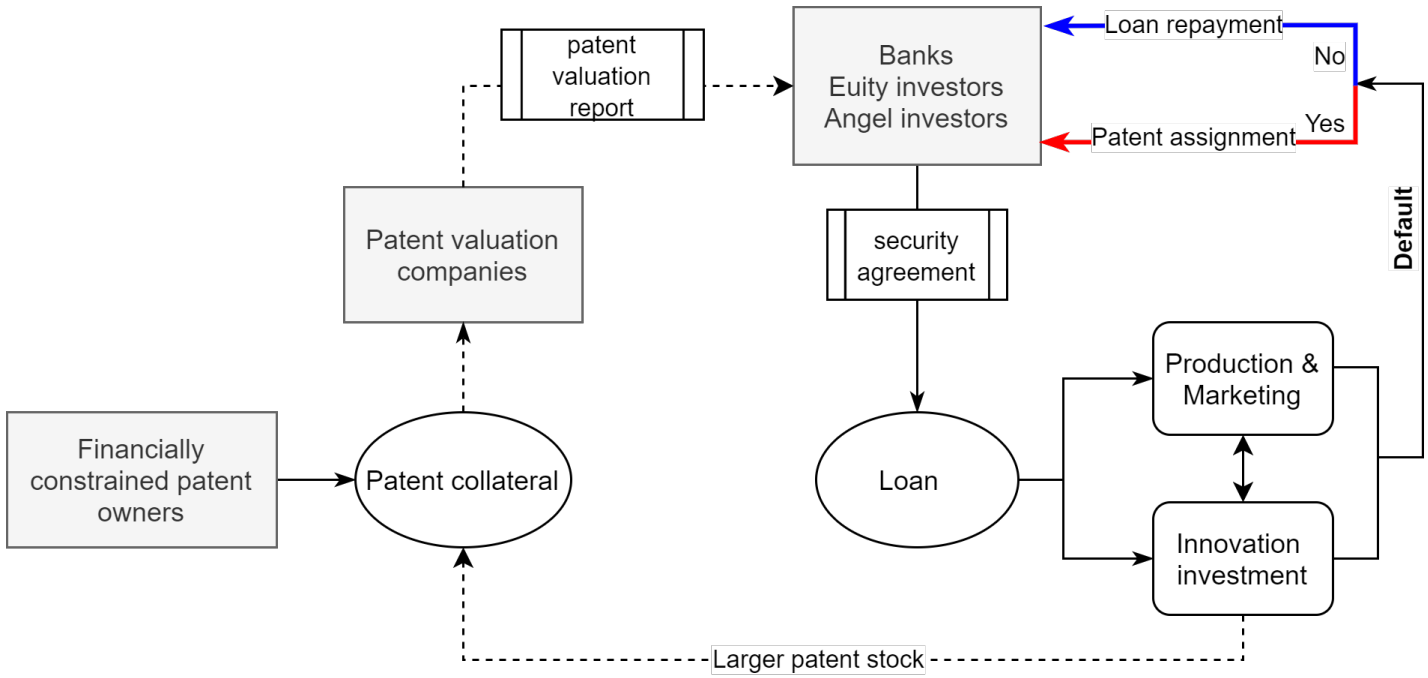
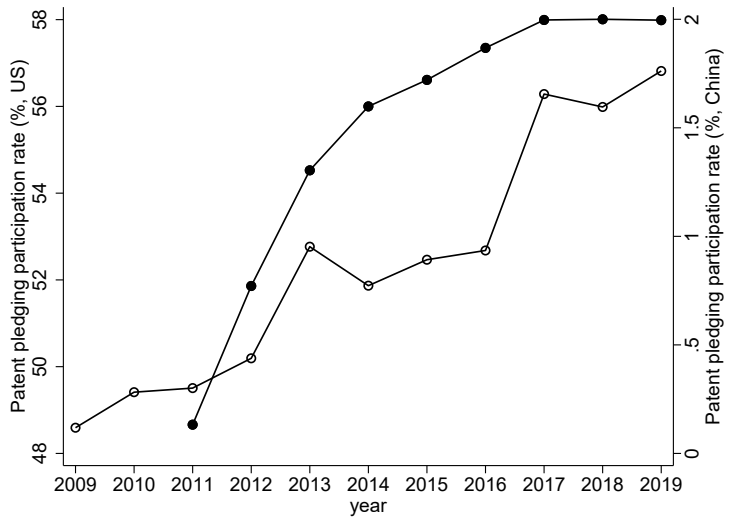


Figure: Flow chart of obtaining patent-backed Loans

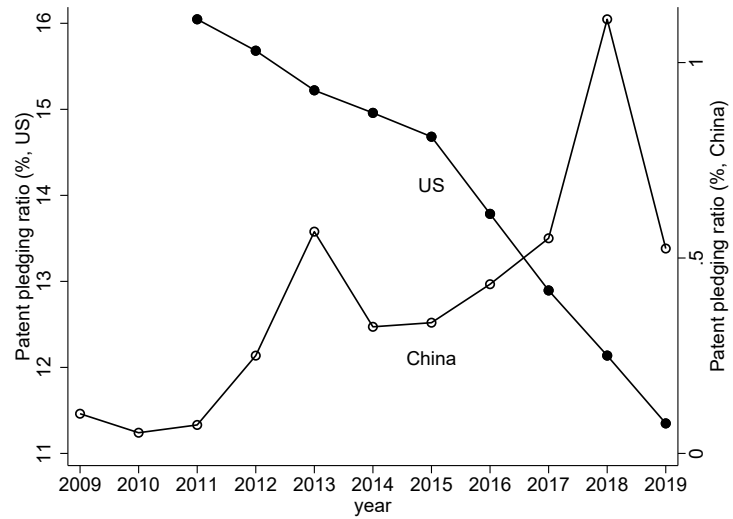
- Patent valuation agents (PVA) are the key
- Two things matter: fixed inspection cost + liquidation value in the report

Motivation Fact 3: Firm-level Evidence

- Ratios of participation are increasing in both countries at firm-level
- Ratios of pledged patents are at different trends at firm-level



(a) Ratio of Participation (Firm-level)



(b) Ratio of Pledged Patents (Firm-level)

Motivation Fact 4: Financing Innovation with Innovation

- How firms borrow and R&D since the first time using patents as collateral?

$$Y_{it} = \alpha + \beta PC_{it} + \boldsymbol{\gamma} \mathbf{Z}'_{it} + \lambda_i + \lambda_t + \xi_{it}, \tag{1}$$

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Panel (a) US Data								
	leverage				*log(R&D)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PC	0.008***	0.006***	0.003**	0.003**	0.068***	0.028***	0.025***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)	(0.007)	(0.008)	(0.008)
L.log(asset)		0.033***	0.046***	0.046***		0.575***	0.589***	0.602***
		(0.001)	(0.001)	(0.001)		(0.005)	(0.007)	(0.008)
L.Tobin's Q			0.526***	0.521***			0.028	-0.013
			(0.003)	(0.003)			(0.021)	(0.021)
L.ROE			-0.052***				-0.211***	
			(0.003)				(0.025)	
L.ROA				-0.105***				-0.843***
				(0.010)				(0.070)
N	102093	92128	48821	48822	46953	41648	20678	20679
adj. R^2	0.754	0.778	0.890	0.889	0.944	0.960	0.970	0.970

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$$Y_{it} = \alpha + \beta PC_{it} + \boldsymbol{\gamma} \mathbf{Z}'_{it} + \lambda_i + \lambda_t + \xi_{it}, \tag{2}$$

- PC_{it} is a dummy = 1 after the firm started using patents as collateral

Panel (b) Chinese Data								
	leverage				*log(R&D)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PC	0.031***	0.022**	0.021**	0.020**	0.168***	0.105**	0.100*	0.098*
	(0.010)	(0.009)	(0.009)	(0.009)	(0.056)	(0.053)	(0.053)	(0.053)
L.log(asset)		0.052***	0.072***	0.072***		0.610***	0.633***	0.634***
		(0.003)	(0.003)	(0.003)		(0.022)	(0.023)	(0.023)
L.Tobin's Q			0.016***	0.018***			0.044***	0.042***
			(0.001)	(0.001)			(0.009)	(0.009)
L.ROE			-0.237***				1.017***	
			(0.017)				(0.129)	
L.ROA				-0.777***				2.605***
				(0.030)				(0.222)
N	24000	20971	20325	20327	21901	19204	18651	18653
adj. R^2	0.725	0.752	0.763	0.774	0.808	0.840	0.844	0.845

Takeaways from the Motivation Facts

- "Patent as collateral" is getting more and more popular in the aggregation
- The valuation agents are key: inspection cost + liquidation value
- Ratios of participation are raising at firm-level
- Firms' leverage and innovation increase upon starting using "patent as collateral"

A Minimum Het-Firm GE Model

Innovative Firms

- Production:

$$y_{it} = (z_{it} a_{it}^{\gamma}) k_{it}^{\alpha} l_{it}^{\nu}, \gamma + \alpha + \nu < 1; \log(z_{it}) = \rho_z \log(z_{it-1}) + \sigma_z \varepsilon_{it}$$

- Optimal labor/capital choices:

$$l_{it}^{*} = \left[\left(\frac{\nu}{w_t} \right)^{1-\alpha} \left(\frac{\alpha}{r_t^k} \right)^{\alpha} z_{it} a_{it}^{\gamma} \right]^{\frac{1}{1-\alpha-\nu}} \text{ and } \quad k_{it}^{*} = \left[\left(\frac{\nu}{w_{it}} \right)^{\nu} \left(\frac{\alpha}{r_t^k} \right)^{1-\nu} z_{it} a_{it}^{\gamma} \right]^{\frac{1}{1-\alpha-\nu}}$$

- Net revenue:

$$f(z_{it}, a_{it}) = \max_{k,l} \left\{ y_{it} - w_t l_{it} - r_t^k k_{it} \right\} = \left(\frac{\nu}{w_t} \right)^{\frac{\nu}{1-\alpha-\nu}} \left(\frac{\alpha}{r_t^k} \right)^{\frac{\alpha}{1-\alpha-\nu}} \left(z_{it} a_{it}^{\gamma} \right)^{\frac{1}{1-\alpha-\nu}}$$

- Financing:
inspection cost is uniformly distributed $\xi \in [0, \bar{\xi}]$ paid in labor units.

$$b_{it}(1 + r_t) \leqslant \begin{cases} \chi(1 - \delta_a) a_{it} & \text{if } F_{it} = A \\ 0 & \text{if } F_{it} = N \end{cases}$$

Recursive Problem for Innovation Firm

- First stage: optimal choices of pledge, innovation, and debt:

$$\pi^*(z_{it}, n_{it-1}, F_{it}) = \max_{a_{it}, b_{it}} \{f(z_{it}, a_{it}) + (1-\delta^a) q_t^a a_{it} - (1+r_t) b_{it}\}, \tag{3}$$

$$\xi^*(z_{it}, n_{it-1}) = \frac{\pi^*(z_{it}, n_{it-1}, A) - \pi^*(z_{it}, n_{it-1}, N)}{w_t}. \tag{4}$$

subject to both constraints

$$q_t^a a_{it} = n_{it-1} + b_{it}, \tag{5}$$

$$b_{it}(1+r_t) \leqslant F_{it} \cdot \chi(1-\delta_a) a_{it}. \tag{6}$$

- Second stage: optimal dividend policy

$$v(z_{it}, n_{it-1}, F_{it}) = \max_{d_{it}} \left\{ d_{it}(z_{it}, n_{it-1}, F_{it}) + E[\Lambda_{t+1} v(z_{i,t+1}, n_{it})] \right\} \tag{7}$$

subject to net worth accumulation

$$n_{it}(z_{it}, n_{it-1}, F_{it}) = \pi^*(z_{it}, n_{it-1}, F_{it}) - d_{it}(z_{it}, n_{it-1}, F_{it}) - \xi_{it} \tag{8}$$

Other Firms, Household, and GE

- Physical Capital Producer: $\Phi\left(I_t^k/K_t\right) = I_t^k + \frac{1}{2}\phi_k(I_t^k/K_t - \delta_k)^2 K_t$
- Innovation Capital Producer: $\Phi\left(I_t^a/A_t\right) = \left(\frac{I_t^a/A_t}{\delta_a}\right)^{1/\phi_a}$
- Households: $E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\eta}}{1-\eta} - \psi L_t\right)$ s.t. $C_t + \frac{1}{1+r_t} B_t \leqslant B_{t-1} + W_t L_t$
- Households FOCs:

  $$W_t = -\frac{U_l(C_t,L_t)}{U_c(C_t,L_t)} = \psi C_t^{\eta};\ \Lambda_{t+1} = \frac{1}{1+r_t} = \beta \frac{U_c(C_{t+1},L_{t+1})}{U_c(C_t,L_t)} = \beta\left(\frac{C_t}{C_{t+1}}\right)^{\eta}$$

- We solve both steady states and transaction paths for both US and China

Parameterization of Steady States

Table: Fixed Parameters

Parameter	Description	Value
β	Discount factor	0.96
η	Log utility	1
ψ	Leisure preference	2
α	Physical capital share	0.20
γ	Innovation capital share	0.15
ν	Labor share	0.50
δ_k	Physical capital depreciation rate	0.10
δ_a	Innovation capital depreciation rate	0.20

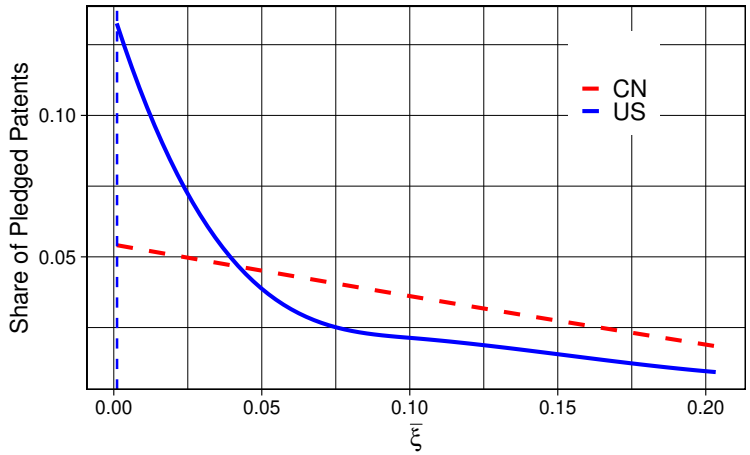
Table: Fitted Parameters

Parameter	Description	U.S.	China
$\bar{\xi}$	Inspection cost of innovation collateral	**0.0011**	**1.21**
χ	Innovation capital liquidation value	**0.32**	**0.117**
ρ_z	Productivity persistence (fixed)	0.90	0.90
σ_z	Productivity volatility	0.032	0.10

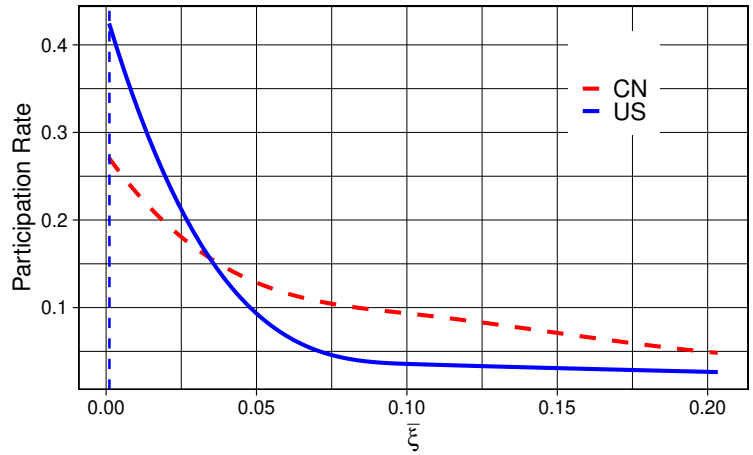
Table: Targeted Average Firm-level Moments

	US		China	
	Data	Model	Data	Model
Ratio of pledged patents (%)	13.91	14.20	0.47	0.47
Ratio of participation firms (%)	55.84	54.75	1.06	1.09
Patent assets std/mean (%)	56.60	55.03	121.70	121.20

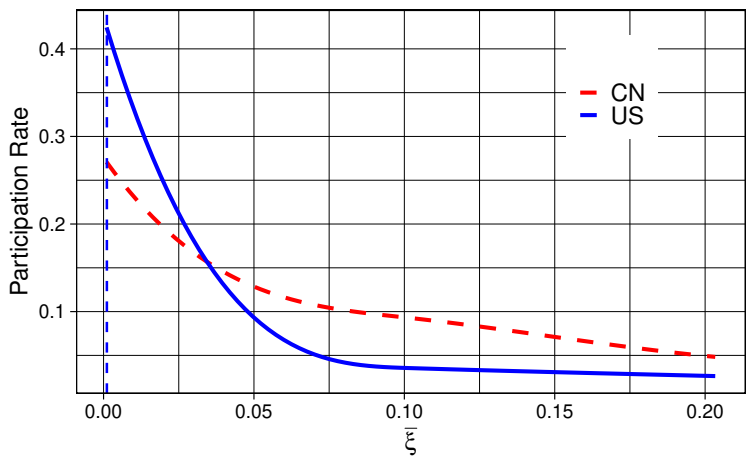
The Roles of Patent Collateral Barriers



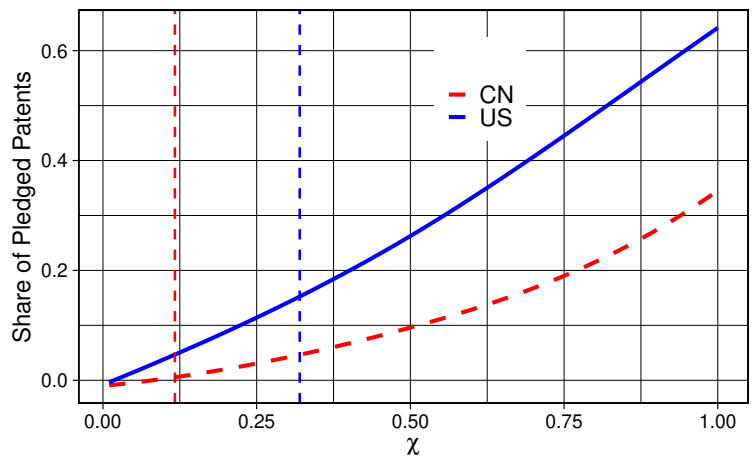
(a) Role of Inspection Cost



(b) Role of Inspection Cost

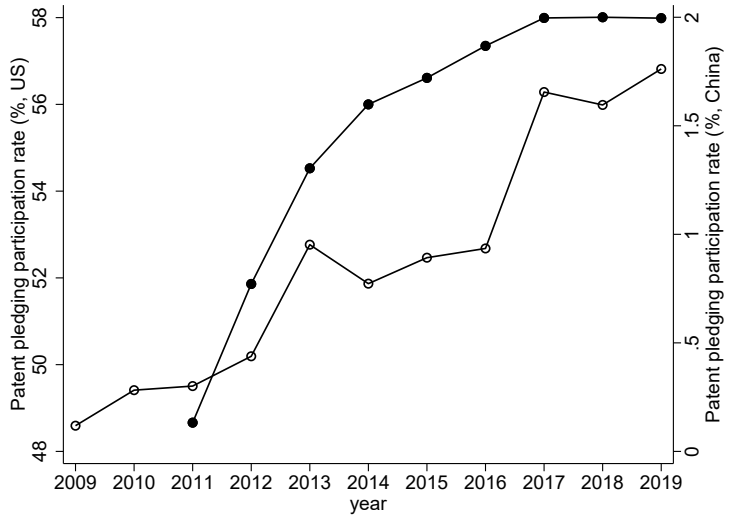


(c) Role of Liquidation Value

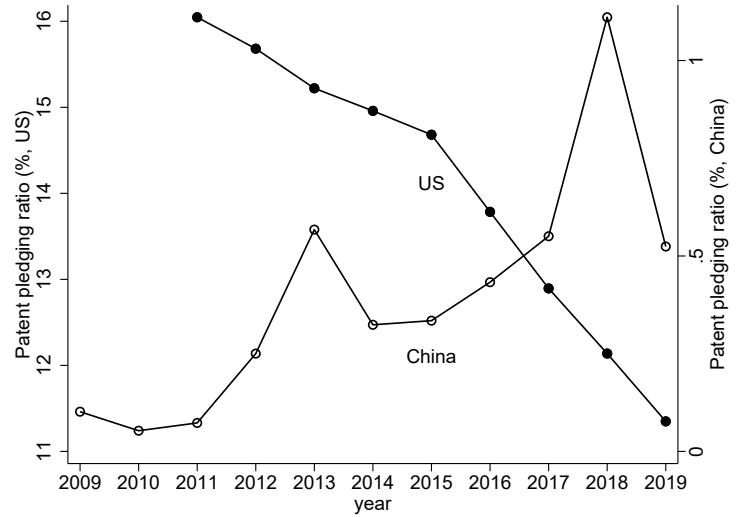


(d) Role of Liquidation Value

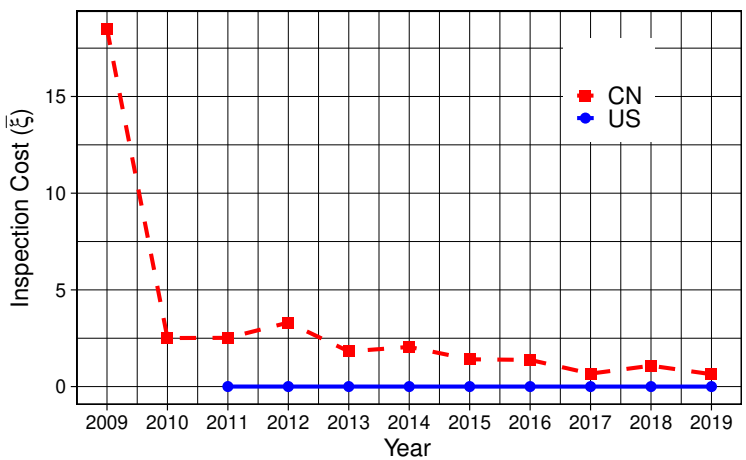
The Dynamics of Patent Collateral Barriers



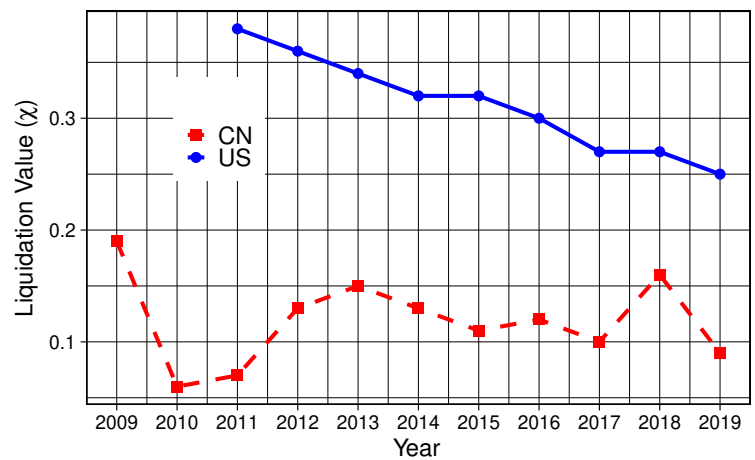
(a) Ratio of Participation (Firm-level)



(b) Ratio of Pledged Patents (Firm-level)



(c) Dynamics of Inspection Cost



(d) Dynamics of Liquidation Value

Financing Innovation with Innovation in the Model

Table: **Responses of Leverage and R&D to Patent Collateral in the Model**

Panel (a) US Model								
	leverage				*log(R&D)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PC	0.0674***	0.0588***	0.0426***	0.0336***	0.2012***	0.2502***	0.0498***	0.0516***
	(0.0004)	(0.0005)	(0.0005)	(0.0006)	(0.0020)	(0.0022)	(0.0015)	(0.0015)
L.log(asset)		0.0011***	-0.0005	0.0847***		-0.1240***	-0.1217***	0.0636***
		(0.0004)	(0.0004)	(0.0012)		(0.0018)	(0.0013)	(0.0042)
L.tobin's Q			0.2588***	0.1890***			3.6309***	3.4030***
			(0.0016)	(0.0019)			(0.0067)	(0.0076)
L.ROE			-1.3473***				-11.1536***	
			(0.0555)				(0.3489)	
L.ROA				-0.8417***				-1.9852***
				(0.0112)				(0.0401)
N	500000	450000	400000	400000	449931	449931	399938	399938
adj. R^2	0.073	0.043	0.123	0.138	0.016	0.030	0.594	0.591

Financing Innovation with Innovation in the Model

Panel (b) Chinese Model								
	leverage				*log(R&D)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PC	0.0235***	0.0255***	0.0257***	0.0265***	0.1407***	0.0636***	0.1113***	0.1065***
	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0081)	(0.0073)	(0.0057)	(0.0056)
L.log(asset)		-0.0001***	0.0001***	-0.0008***		0.1281***	0.1901***	0.1893***
		(0.0000)	(0.0000)	(0.0000)		(0.0015)	(0.0012)	(0.0013)
L.tobin's Q			0.0037***	0.0067***			1.3326***	1.3322***
			(0.0001)	(0.0002)			(0.0040)	(0.0049)
L.ROE			0.1238***				-0.1999***	
			(0.0043)				(0.0720)	
L.ROA				0.0139***				0.0073
				(0.0004)				(0.0078)
N	500000	450000	400000	400000	426936	426936	379459	379459
adj. R^2	0.127	0.134	0.180	0.185	0.002	0.053	0.445	0.445

What if China has US-level Barriers?

Table: **What if China has US-level barriers?**

Model Outcomes	**Benchmark**	$\hat{\bar{\xi}}^{CN} = \bar{\xi}^{US}$	$\hat{\chi}^{CN} = \chi^{US}$	**Both as US**
Financing Innovation				
Ratio of pledged patents	0.47%	5.53%	4.30%	16.69%
Ratio of participation firms	1.09%	29.53%	3.09%	30.71%
Economic Outcomes				
Changes in Total Output	-	1.50%	1.02%	4.67%
Changes in Total Capital	-	1.50%	1.00%	4.68%
Changes in Total Patent	-	2.88%	1.54%	8.97%
Changes in Total Consumption	-	0.44%	0.63%	1.40%
Changes in Total Welfare	-	0.42%	0.13%	1.27%

- Both changes are good for innovation, output, and welfare
- But reducing fixed inspection costs (or subsidizing evaluation) is much more effective than improving the liquidation value of patents

Conclusion

- "Financing innovation with innovation" is possible and beneficial
- The key is the development of evaluation agents in the financial market
- Both fixed inspection costs and liquidation value of patents matters
- Gains in innovation, output, and welfare if further relaxing
- Reducing fixed inspection costs is the first priority for the early-stage economy