"China's Rising IQ (Innovation Quotient) and Growth: Firm-level Evidence"

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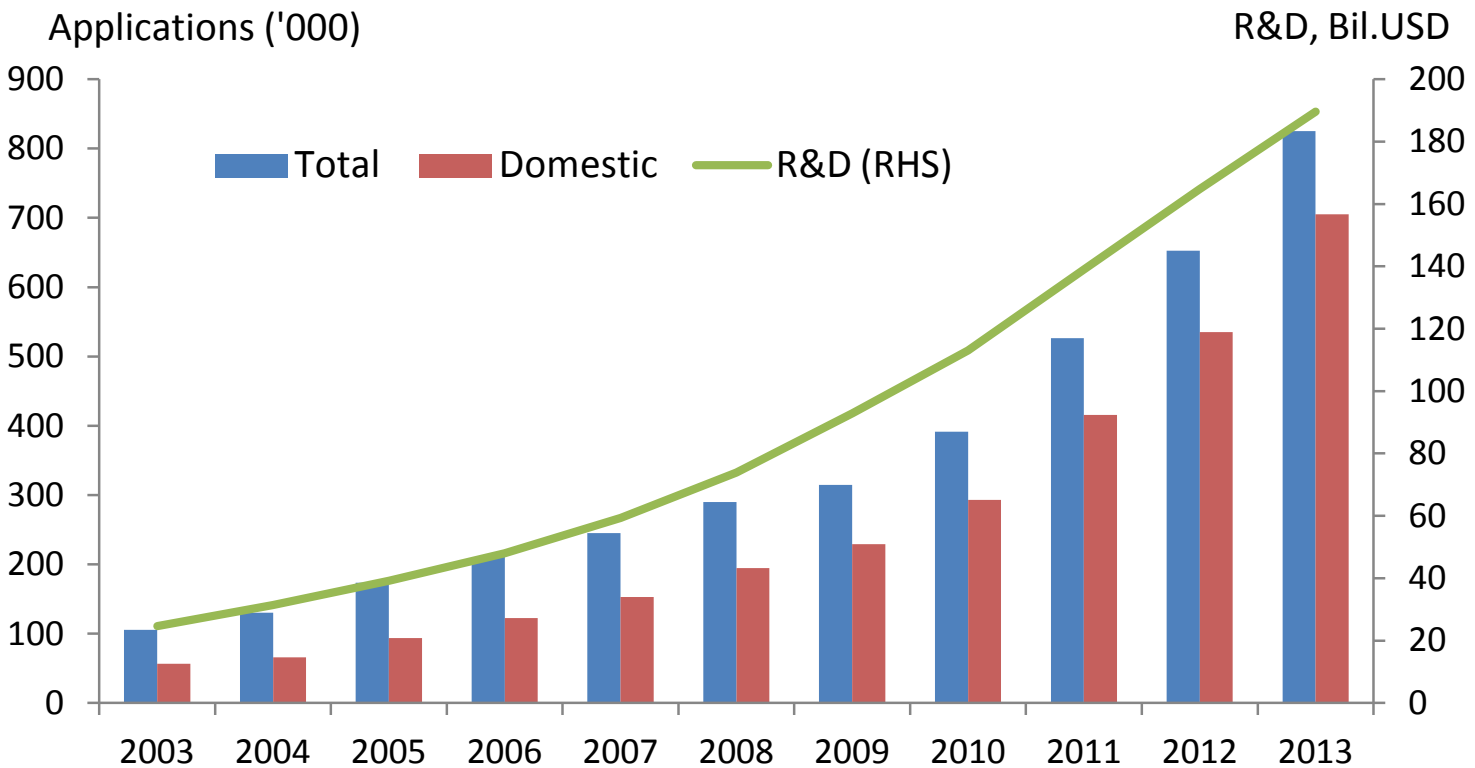
[1] 1The views expressed in this paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

Motivation

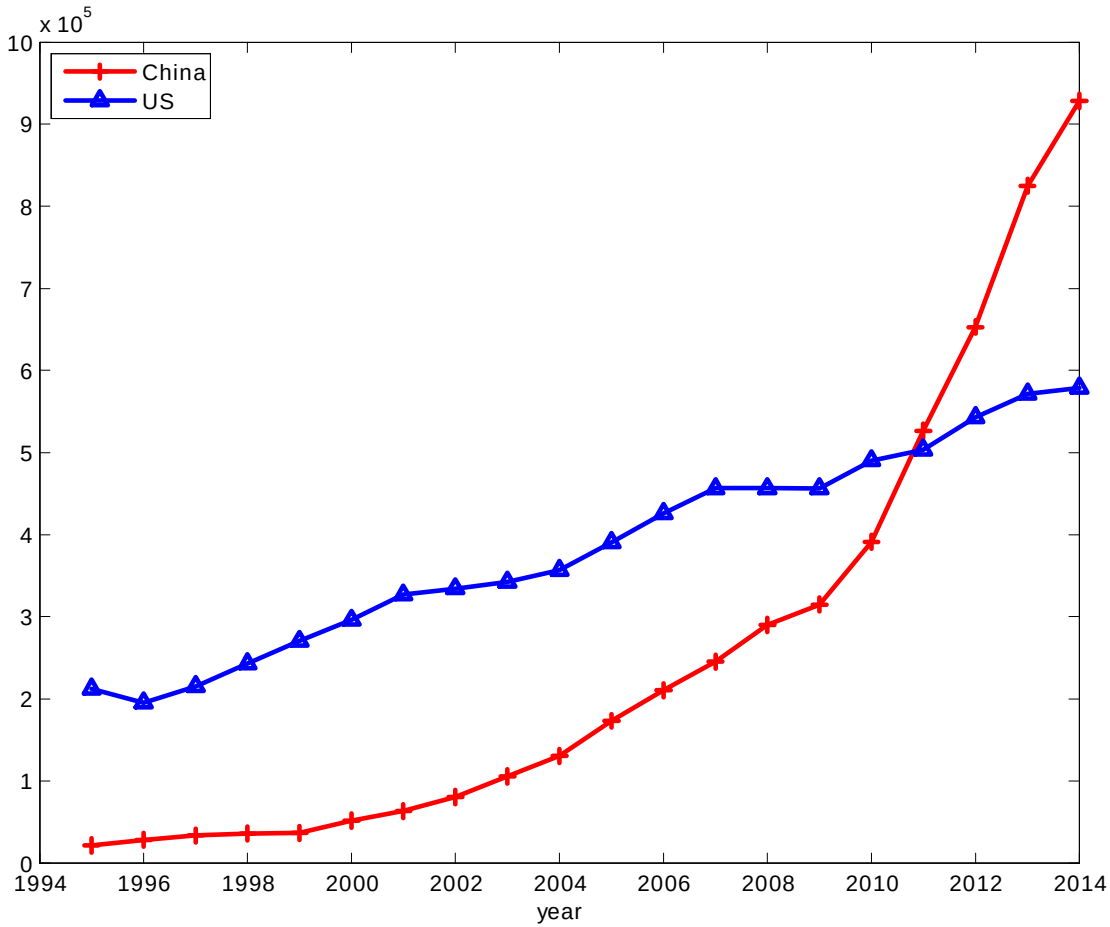
- TFP growth has been an important source of the astonishing economic growth in China after 1978, accounting for 78% of the per capita GDP growth for 1978-2007 (Zhu, 2012)
- Important to the driving force of the TFP growth
- Innovation has been traditionally viewed as an important source of TFP growth

Dramatic Increases in China's R&D and Patent Applications

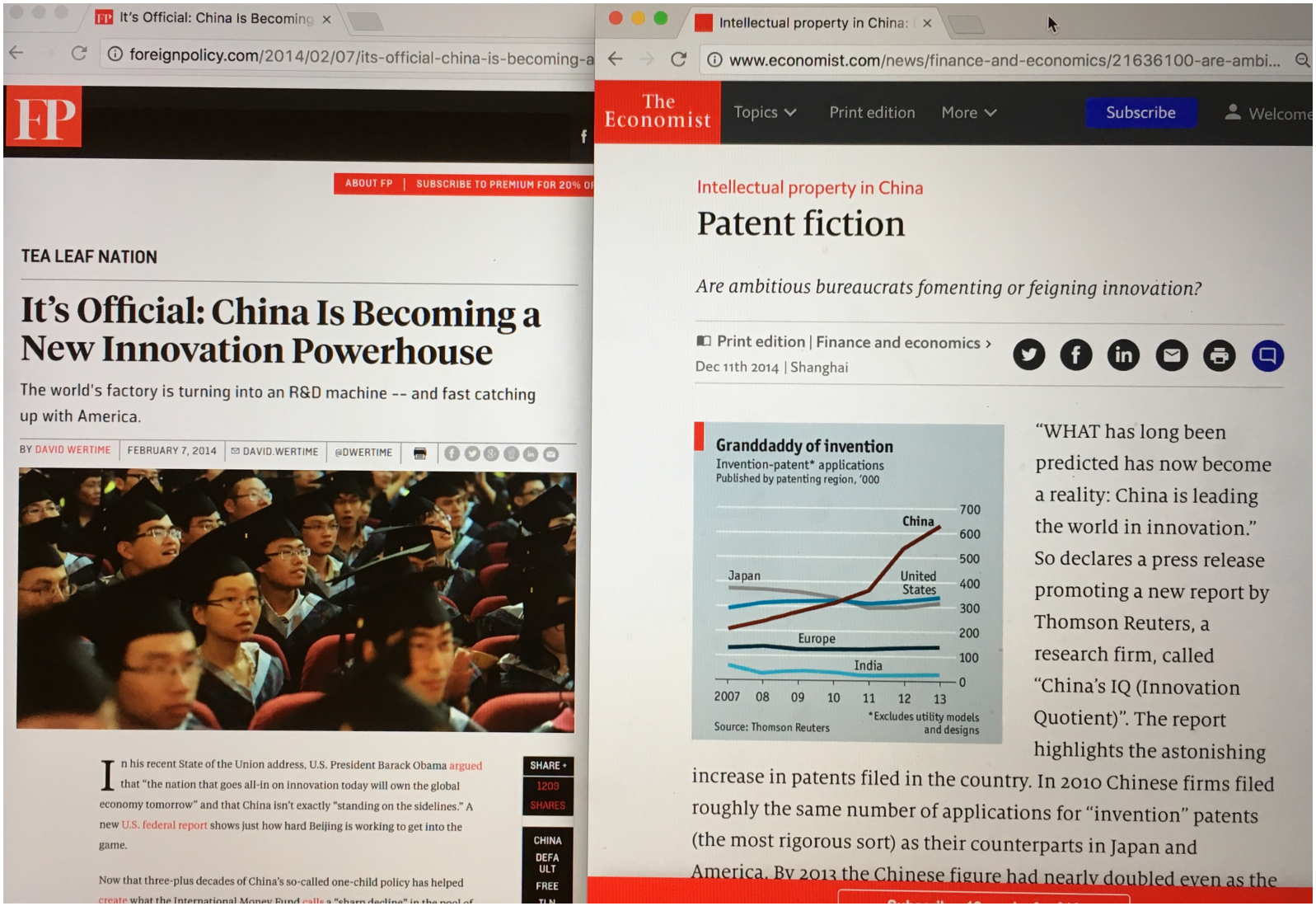


Source: National Bureau of Statistics of China, State Intellectural Property Office of China

Domestic Applications for Invention Patent Surpassing US



New Innovation Powerhouse, or Fiction?



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It's Official: China Is Becoming a New Innovation Powerhouse

The world's factory is turning into an R&D machine -- and fast catching up with America.

BY DAVID WERTIME | FEBRUARY 7, 2014 | DAVID.WERTIME | @DWERTIME

In his recent State of the Union address, U.S. President Barack Obama argued that "the nation that goes all-in on innovation today will own the global economy tomorrow" and that China isn't exactly "standing on the sidelines." A new U.S. federal report shows just how hard Beijing is working to get into the game.

Now that three-plus decades of China's so-called one-child policy has helped create what the International Money Fund calls a "sharp decline" in the pool of

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Intellectual property in China

Patent fiction

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Granddaddy of invention

Invention-patent* applications
Published by patenting region, '000

China
Japan
United States
Europe
India
700
600
500
400
300
200
100
0
2007 08 09 10 11 12 13

Source: Thomson Reuters

*Excludes utility models and designs

"WHAT has long been predicted has now become a reality: China is leading the world in innovation." So declares a press release promoting a new report by Thomson Reuters, a research firm, called "China's IQ (Innovation Quotient)". The report highlights the astonishing increase in patents filed in the country. In 2010 Chinese firms filed roughly the same number of applications for "invention" patents (the most rigorous sort) as their counterparts in Japan and America. By 2013 the Chinese figure had nearly doubled even as the

Questions

- Doubts and sceptics, however, widely spread on real impact and quality of innovation in China
- **Main Question:** Is technology advancement associated with real productivity growth in China?
  - What aspects of economic activity do China's patent statistics actually capture?
  - How is it compared with industrialized countries?
  - SOE vs. POEs.

What We Do?

- Examine *at the micro-level* whether firm patenting is associated with real improvement in firm TFP
  - patenting: patent stock/scope (intensive margin), patent status (extensive margin)
  - other outcomes: size, exports, new product introduction, factor intensity, markup

- Build a unified dataset linking patent applications from China's State Intellectual Property Office (SIPO) to firm production and balance sheet data (Surveys of Industrial Enterprises, SIE).
  - Using information of firm name, address and phone number, we develop an annual link between patent assignees in SIPO data and firms in the SIE
  - Cover more than $260,000$ innovating firms and 1.5 million firm-year observations for 1998-2007.

What We Do?

- Empirical challenges and strategies:
  - Productivity measurement
    - Consider a wide range of measures in the productivity literature (including Ackerberg, Caves and Frazer, 2015).
    - Also examine firm markups
  - Identification:
    - Endogeneity: using prefecture IPR protection as an IV
    - First-time patentees vs. nonpatenting firms: using Propensity-Score Matching (PSM) method with matching variables including TFP and TFP growth

What We Find?

- Patenting firms are "special"—very small fraction of all manufacturing firms, but account for large sales share, more capital intensive and more outward oriented.
- **Within-firm** increases in patent stock are significantly associated with increases in TFP, firm size, exports, and new product revenue share
  - U.S.: firm patenting is strongly associated with new product introduction but less with productivity improvement (Balasubramanian and Sivadasan 2011).
- IV regressions suggest that new patents improve TFP growth
- Event studies based on first-time patentees also demonstrate similar effects following initial patent application.
- Heterogeneity:
  (1) Contrary to conventional perception, SOEs show even stronger association between patenting and production outcomes
  (2) More financially constrained firms show a weaker association.

Take Home Messages

- China's firm innovation is for real
- Firm innovation could be an important source of firm-level TFP growth

China's Patent System and SIPO Patent Data

- China's Patent Law was first introduced in 1984, since then there were several rounds of amendments
- SIPO grants three types of patents: invention patents, utility model patents, and design patents
- The patent data contains detailed information of each patent filing from 1985 to 2011, including
  - patent ID, title, and its technology field (IPC)
  - name and address of the assignee (usually a firm or an institution)
  - agency
  - the date of application received and granted by SIPO
  - Unfortunately, no citation information

Surveys of Industrial Enterprises Data

- Conducted by NBS annually from 1995. Our access is 1998-2007
- Contains detailed balanced sheet variables on firm level for all SOEs and POEs "above scale" (sales >5 million RMB)
- The most comprehensive firm-level dataset in China and has been widely used in the literature (e.g., Hsieh and Klenow 2009, Brandt, Biesebroeck and Zhang 2012, Aghion et al. 2015)
- We cleaned the SIE data following the procedures outlined in Brandt et al. (2012)

Merging SIPO Patent and SIE Data

- Different firm identification systems in the two datasets
- Manually match them by firm name (i.e. "firm name" in SIE data and "assignee name" in patent data)
- Verify the match by their location information ("provincial proxy number") and phone numbers.
- Among all the matched firms in our SIE sample, 29,284 firms applied for patent at least once since the patent law establishment in China—we call these firms "patenting firms" or "patentees"

Merging SIPO Patent and SIE Data

Year	Our Sample							NBS CSY
	No. of Firms (1)	No. of filing firms (2)	% (3)=(2)/(1)	No. of patent-Patentees (4)	Total Patents (5)	Patents by matched firms (6)	% (7)=(6)/(5)	Patents by large-median (8)
1998	100,126	1,981	1.98	15,945	91,014	6,638	7.29	6,317
1999	106,312	2,507	2.36	17,924	125,996	9,693	7.69	7,884
2000	106,236	2,875	2.71	18,912	132,160	11,509	8.71	11,819
2001	121,884	3,475	2.85	21,970	151,184	14,728	9.74	15,339
2002	133,919	4,287	3.20	24,445	173,164	22,208	12.82	21,297
2003	155,725	5,196	3.34	27,698	220,019	29,092	13.22	31,382
2004	234,522	6,511	2.78	37,772	236,928	37,820	15.96	42,318
2005	233,505	7,015	3.00	37,668	316,984	46,608	14.70	55,271
2006	262,263	8,814	3.36	40,539	368,536	66,423	18.02	69,009
2007	298,152	10,152	3.41	43,858	485,399	80,270	16.54	95,905

Determinants of Patenting Behavior: Negative Binomial

Dept. Var.	A. Cross-section (2007) S_{2007}		B. Panel (1998-2007) S_t			
	(1)	(2)	(3)	(4)	(5)	(6)
ln $R\&D_{t-1}$	0.054***	0.054***	–	–	–	–
(s.e.)	[0.002]	[0.002]				
ln $sales_{t-1}$	0.375***	0.375***	0.413***	0.095***	0.090***	0.089***
(s.e.)	[0.006]	[0.006]	[0.002]	[0.001]	[0.001]	[0.001]
age_{t-1}	-0.004***	-0.004***	-0.006***	-0.003***	-0.002***	-0.001***
(s.e.)	[0.001]	[0.001]	[0.000]	[0.000]	[0.000]	[0.000]
D_t^{SOE}	-0.068***	-0.068***	-0.110***	-0.020***	-0.001	-0.004
(s.e.)	[0.025]	[0.025]	[0.009]	[0.005]	[0.005]	[0.005]
D_t^{EX}	0.239***	0.238***	0.251***	0.042***	0.039***	0.038***
(s.e.)	[0.017]	[0.017]	[0.007]	[0.004]	[0.004]	[0.004]
D_t^{New}	-0.214***	-0.214***	-0.175***	0.090***	0.075***	0.077***
(s.e.)	[0.021]	[0.021]	[0.008]	[0.005]	[0.005]	[0.005]
$Leverage_{t-1}$		-0.02				-0.019***
(s.e.)		[0.030]				[0.007]
ln S_{t-1}				0.857***	0.860***	0.862***
(s.e.)				[0.001]	[0.002]	[0.002]
Pre-sample FEs					0.103***	0.099***
(s.e.)					[0.005]	[0.005]
Firm FEs	No	No	No	No	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	No	No	Yes	Yes	Yes	Yes
Number of obs	195,366	195,366	1,460,537	1,460,537	1,460,537	1,460,537

Summary Statistics

Variable	Nonpatenting Firms		Patenting Firms	
	Mean	Standard Deviation	Mean	Standard Deviation
Size				
Output	66,909	452,803	265,634	1,694,065
Value added	17,381	100,343	74,104	499,630
Capital stock	20,844	143,504	108,754	902,112
Employment	246	595	690	2,494
Factor				
Capital-labor ratio	85.12	239.31	114.34	387.31
Productivity				
Labor productivity	361.16	876.91	364.20	657.37
Solow residual	2.22	1.12	2.12	1.14
$TFP^{ACF,CD}$	3.58	0.94	3.40	1.04
$TFP^{ACF,Translog}$	2.60	1.43	2.21	1.43
Number of obs	1,263,326		198,414	

Within-firm Change in Patent Stock and Outcomes

$$\ln Y_{it}^{j} = \lambda \ln S_{it}^{j} + \mu_i + \gamma_{j,t} + \varepsilon_{it}^{j}$$

	Overall Panel						Balanced Panel					
	Patent Stock			Patent Scope			Patent Stock			Patent Scope		
	ln(S)	(s.e.)	R^2	ln(N)	(s.e.)	R^2	ln(S)	(s.e.)	R^2	ln(N)	(s.e.)	R^2
Size												
Output	0.155***	[0.006]	0.93	0.206***	[0.010]	0.93	0.159***	[0.019]	0.93	0.221***	[0.027]	0.93
Value added	0.152***	[0.008]	0.87	0.200***	[0.011]	0.87	0.160***	[0.022]	0.89	0.221***	[0.031]	0.89
Capital stock	0.142***	[0.007]	0.95	0.182***	[0.010]	0.95	0.137***	[0.018]	0.96	0.182***	[0.025]	0.96
Employment	0.137***	[0.006]	0.93	0.182***	[0.009]	0.93	0.135***	[0.016]	0.93	0.181***	[0.024]	0.92
Factor intensity												
Capital-labor ratio	0.005	[0.006]	0.86	0.000	[0.009]	0.86	0.003	[0.016]	0.84	0.001	[0.023]	0.84
Productivity												
Labor prod	0.018***	[0.005]	0.85	0.024***	[0.008]	0.85	0.025	[0.015]	0.85	0.040*	[0.021]	0.85
Solow Residual	0.014*	[0.007]	0.78	0.018*	[0.011]	0.78	0.024	[0.015]	0.79	0.038*	[0.022]	0.79
OLS-FE	0.051***	[0.007]	0.89	0.067***	[0.010]	0.89	0.062***	[0.016]	0.91	0.089***	[0.023]	0.91
$TFP^{ACF,CD}$	0.020***	[0.005]	0.91	0.031***	[0.007]	0.91	0.025*	[0.013]	0.92	0.036*	[0.019]	0.92
$TFP^{ACF,Translog}$	0.028***	[0.006]	0.94	0.041***	[0.008]	0.94	0.039***	[0.014]	0.95	0.048**	[0.019]	0.95
Other												
New product (share)	1.946***	[0.248]	0.73	2.825***	[0.331]	0.73	2.921***	[0.571]	0.69	4.080***	[0.857]	0.69
Markup	0.044	[0.113]	0.17	0.600	[0.631]	0.17	0.44	[0.485]	0.14	0.477	[0.538]	0.14
Export shipment	0.402***	[0.034]	0.85	0.577***	[0.049]	0.85	0.509***	[0.094]	0.84	0.689***	[0.148]	0.84
Number of obs	142,717						26,310					

TFP Measures

- We consider a range of TFP measures:
  - Labor productivity
  - Solow residuals

$$\ln TFP_{it}^{S} = \ln Y_{it}^{j} - \alpha_{jt} \ln L_{it}^{j} - (1 - \alpha_{jt}) \ln K_{it}^{j}$$

  - OLS firm fixed effect estimates of TFP

$$\ln V_{it}^{j} = \lambda_1 \ln S_{it}^{j} + \lambda_2 \ln K_{it}^{j} + \lambda_3 \ln L_{it}^{j} + \mu_i + \gamma_{j,t} + \varepsilon_{it}^{j}$$

  - Endogeneity and functional dependence issues: Ackerberg, Caves and Frazer (2015)–ACF approach
    - C-D production function
    - Translog production function
- Markup: labor elasticity/labor share in production, De Loecker and Warzynski (2012)

Invention, Utility and Design Patents

	Invention		Utility Model		Design	
	λ	(s.e.)	λ	(s.e.)	λ	(s.e.)
			Patent Stock			
Size						
Output	0.127***	[0.015]	0.170***	[0.008]	0.139***	[0.010]
Value added	0.114***	[0.017]	0.174***	[0.010]	0.129***	[0.012]
Capital stock	0.113***	[0.015]	0.144***	[0.009]	0.137***	[0.010]
Employment	0.113***	[0.011]	0.149***	[0.008]	0.131***	[0.011]
Factor intensity						
Capital-labor ratio	0.000	[0.014]	-0.004	[0.008]	0.007	[0.010]
Productivity						
Labor productivity	0.014	[0.012]	0.021**	[0.008]	0.008	[0.009]
Solow Residual	-0.002	[0.015]	0.027***	[0.010]	-0.005	[0.012]
OLS-FE	0.032**	[0.014]	0.066***	[0.009]	0.031***	[0.012]
$TFP^{ACF,CD}$	0.019**	[0.009]	0.019***	[0.007]	0.008	[0.008]
$TFP^{ACF,Translog}$	0.019*	[0.010]	0.025***	[0.008]	0.024***	[0.009]
Other						
New product (share)	2.165***	[0.639]	2.566***	[0.282]	0.943***	[0.353]
Markup	0.006	[0.192]	0.098	[0.192]	-0.61	[0.571]
Export shipment	0.318***	[0.073]	0.502***	[0.041]	0.346***	[0.053]

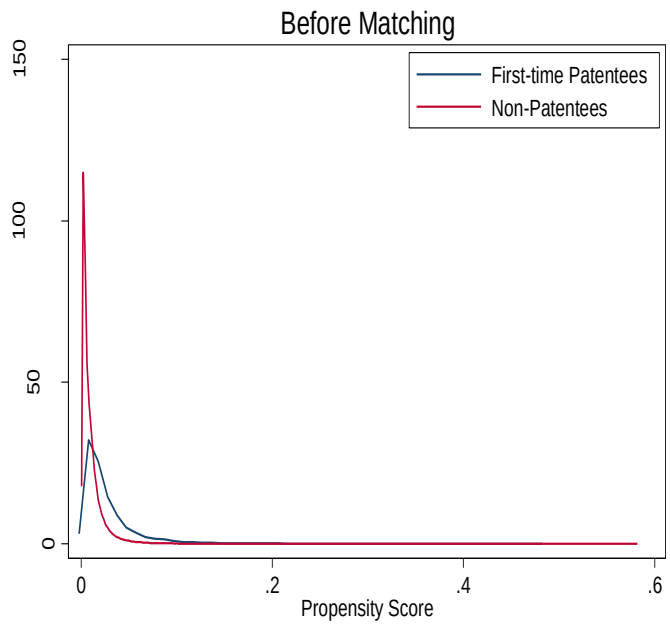
First-time Patenting Firms vs. Nonpatenting Firms: PSM

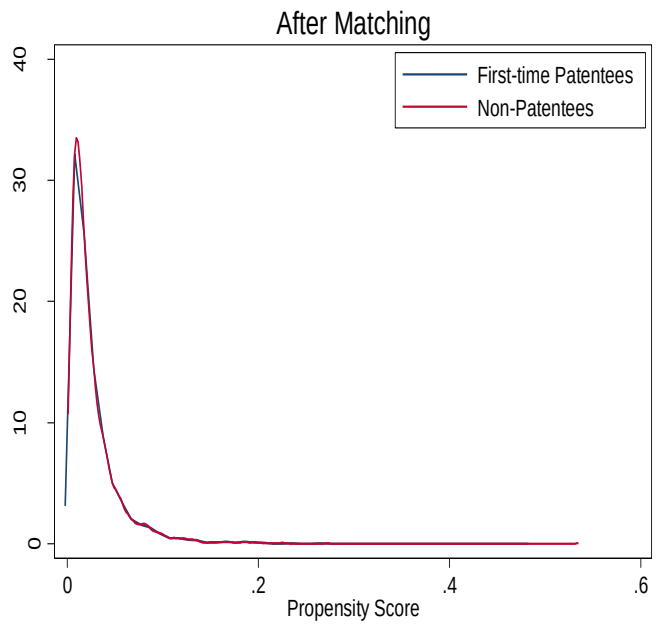
- Construct the control group using nonpatentees, based on firm age, size, SOE and export status, level and growth rate of TFP, industry and year FEs, as matching covariates

Variables	Probit	Balancing Test			
		First Patentee	Non Patentee	Dif	t-value
$\ln(age_{it-1})$	0.025	2.351	2.375	-0.024	0.172
	(0.019)				
$\ln(employment_{it-1})$	0.517***	5.711	5.727	-0.017	0.493
	(0.014)				
SOE_{it-1}	0.058	0.194	0.203	-0.008	0.313
	(0.043)				
EX_{it-1}	0.420***	0.464	0.466	-0.002	0.816
	(0.033)				
$\ln TFP_{it-1}^{ACF,Translog}$	0.287***	2.131	2.092	0.039	0.199
	(0.018)				
$\Delta \ln TFP_{it-1}^{ACF,Translog}$	-0.024	0.045	0.038	0.007	0.564
	(0.024)				

First-time Patenting Firms vs. Nonpatenting Firms: PSM

- Construct the control group using nonpatentees, based on firm age, size, SOE and export status, level and growth rate of TFP, industry and year FEs, as matching covariates





First-time Patenting Firms

	A. Before-and-After			B. Difference-in-Difference		
	φ	(s.e.)	R^2	φ	(s.e.)	R^2
Size						
Output	0.664***	[0.016]	0.87	0.176***	[0.011]	0.90
Value added	0.669***	[0.016]	0.80	0.170***	[0.014]	0.83
Capital stock	0.463***	[0.018]	0.91	0.148***	[0.012]	0.93
Employment	0.216***	[0.013]	0.87	0.148***	[0.010]	0.89
Factor intensity						
Capital-labor ratio	0.247***	[0.016]	0.79	0.000	[0.012]	0.83
Productivity						
Labor productivity	0.448***	[0.014]	0.76	0.028***	[0.010]	0.82
Solow Residual	0.367***	[0.025]	0.63	0.024***	[0.013]	0.73
OLS-FE	0.669***	[0.016]	0.80	0.170***	[0.014]	0.83
$\text{TFP}^{ACF,CD}$	0.439***	[0.013]	0.82	0.039***	[0.009]	0.90
$\text{TFP}^{ACF,Translog}$	0.397***	[0.016]	0.85	0.043***	[0.009]	0.94
Other						
New product (share)	3.257***	[0.301]	0.61	1.673***	[0.333]	0.63
Markup	-0.617**	[0.241]	0.12	-0.501*	[0.304]	0.17
Export shipment	0.961***	[0.066]	0.78	0.490***	[0.061]	0.82
Number of obs	44,379			76,964		

First-time Patenting Firms

	φ_0	(s.e.)	φ_1	(s.e.)	φ_2	(s.e.)	φ_3	(s.e.)	R^2
Size									
Output	0.165***	[0.010]	0.029***	[0.007]	-0.038***	[0.007]	-0.075***	[0.011]	0.85
Value added	0.170***	[0.013]	0.024**	[0.001]	-0.057***	[0.011]	-0.098***	[0.015]	0.77
Capital stock	0.139***	[0.009]	0.024***	[0.008]	-0.036***	[0.006]	-0.115***	[0.011]	0.91
Employment	0.130***	[0.009]	0.029***	[0.006]	-0.008	[0.006]	-0.039***	[0.009]	0.88
Factor intensity									
Capital-labor ratio	0.009	[0.010]	-0.005	[0.009]	-0.028***	[0.008]	-0.076***	[0.009]	0.84
Productivity									
Labor productivity	0.035***	[0.009]	0.000	[0.007]	-0.031***	[0.007]	-0.036***	[0.009]	0.81
Solow Residual	0.039***	[0.012]	-0.004	[0.012]	-0.036***	[0.011]	-0.030**	[0.012]	0.74
OLS-FE	0.170***	[0.013]	0.024**	[0.011]	-0.057***	[0.011]	-0.098***	[0.015]	0.77
$TFP^{ACF,CD}$	0.033***	[0.009]	0.010*	[0.006]	-0.007	[0.005]	-0.003	[0.008]	0.88
$TFP^{ACF,Translog}$	0.034***	[0.009]	0.015**	[0.006]	-0.005	[0.006]	0.007	[0.009]	0.94
Other									
New product (share)	1.151***	[0.348]	0.440	[0.341]	0.483	[0.309]	0.667*	[0.369]	0.58
Markup	-0.544	[0.376]	0.043	[0.152]	-0.073	[0.134]	-0.107	[0.125]	0.17
Export shipment	0.421***	[0.059]	0.039	[0.052]	0.024	[0.049]	0.114**	[0.058]	0.82

More on TFP and Patent Stock: Endogeneity

- Control for firm and industry-year fixed effect, but there might be other time varying firm-specific factors such as demand or ability that affect TFP and patenting simultaneously.
- Fang, Lerner and Wu (2016):
  - find that IPR protection strengthens firms' incentives to innovate.
  - rank IPR protection based on a survey of legal professionals including judges, IPR lawyers, and corporate executives, such as CEOs and technical heads.
  - questions include time for courts to resolve IP disputes, the cost of resolving the dispute, the fairness of court decisions.
- IV: Survey-based IPR protection ranking, 2002-07, 57 prefectures across 25 provinces
- Alternative, panel GMM method by Arellano and Bond (1991) and Blundell and Bond (1998), using lags of patent stock.

More on TFP and Patent Stock: Endogeneity

First stage		Dependent: log $TFP^{ACF,Translog}$			
	log(S)		OLS		IV
			(1)	(2)	(3)
IPR	0.767***	ln(S)	0.028***	0.038***	0.062***
(s.e.)	[0.025]	(s.e.)	[0.006]	[0.005]	[0.022]
Age	0.007***	*Age*		-0.001***	-0.001*
(s.e.)	[0.001]	(s.e.)		[0.000]	[0.001]
ln(*Emp*)	0.142***	ln(*Emp*)		-0.078**	-0.125***
(s.e.)	[0.008]	(s.e.)		[0.032]	[0.031]
SOE	0.017	*SOE*		-0.029***	-0.003
(s.e.)	[0.018]	(s.e.)		[0.010]	[0.013]
EX	0.060***	*EX*		0.044***	0.031***
(s.e.)	[0.009]	(s.e.)		[0.007]	[0.009]
Obs	80,689	Obs	142,717	142,717	80,689
R^2	0.922	R^2	0.943	0.943	0.952

Role of Credit Constraints: Firms less financially constrained show a stronger association

	FC=Leverage Ratio						
	ln S_{it}	(s.e.)	FC_{it-1}	(s.e.)	ln $S^j_{it} \times FC_{it-1}$	(s.e.)	R^2
Productivity							
Labor productivity	0.011*	[0.006]	-0.026***	[0.006]	0.013***	[0.004]	0.85
Solow Residual	0.009	[0.008]	-0.027***	[0.009]	0.008	[0.005]	0.78
OLS-FE	0.046***	[0.007]	-0.047***	[0.008]	0.011**	[0.005]	0.89
$TFP^{ACF,CD}$	0.016***	[0.005]	-0.007	[0.005]	0.008**	[0.003]	0.91
$TFP^{ACF,Translog}$	0.025***	[0.006]	-0.001	[0.006]	0.007*	[0.004]	0.94
	FC=Sales						
Labor productivity	-0.002	[0.007]	0.079***	[0.008]	0.019***	[0.006]	0.85
Solow Residual	0.003	[0.009]	0.109***	[0.010]	0.008	[0.007]	0.783
OLS-FE	0.036***	[0.008]	0.129***	[0.010]	0.015**	[0.007]	0.888
$TFP^{ACF,CD}$	0.002	[0.006]	0.082***	[0.007]	0.017***	[0.005]	0.913
$TFP^{ACF,Translog}$	0.004	[0.007]	0.091***	[0.008]	0.023***	[0.005]	0.943

Role of SOEs: SOEs have a stronger association

	$\ln S$	(s.e.)	*SOE*	(s.e.)	$\ln S \times SOE$	(s.e.)
Productivity						
Labor productivity	0.006	[0.005]	-0.150***	[0.016]	0.055***	[0.008]
Solow Residual	0.004	[0.007]	-0.104***	[0.021]	0.041***	[0.010]
OLS-FE	0.048***	[0.007]	-0.053***	[0.019]	0.014	[0.009]
$TFP^{ACF,CD}$	0.011**	[0.005]	-0.091***	[0.013]	0.041***	[0.007]
$TFP^{ACF,Translog}$	0.020***	[0.006]	-0.083***	[0.015]	0.035***	[0.008]

SOE: Controlling for Firm Dynamics and Selection Bias

- POEs are more dynamic. Some innovative but small POEs may have dropped out of sample
- SOE reform started from 1997 and gradually phased out after 2002. Unproductive SOEs turned into POEs

Dep. Var.	$TFP^{ACF,Translog}$			
	A. Benchmark Sample	B. Balanced Panel	C. Constant Ownership	D. Balanced & Constant Own.
ln S	0.020***	0.023*	0.015**	0.011
(s.e.)	[0.006]	[0.014]	[0.007]	[0.007]
SOE	-0.083***	-0.135***	–	–
(s.e.)	[0.015]	[0.026]	–	–
ln $S \times SOE$	0.035***	0.051***	0.054***	0.089***
(s.e.)	[0.008]	[0.014]	[0.014]	[0.027]
Number of obs	142717	26,310	121,980	19,620
R^2	0.94	0.95	0.95	0.95

SOE Reform

- To help establish the causal effect on how innovation is transformed into productivity growth, we use SOE reform for 1997-2001 as an *exogenous* event to conduct a DiD analysis

$$\begin{aligned}\ln TFP^j_{it} = {} & \phi_1 \ln S^j_{it} + \phi_2 SOE^j_{it} + \phi_3 Post\_reform_t + \\ & \phi_4 \ln S^j_{it} \times SOE^j_{it} + \phi_5 \ln S^j_{it} \times Post\_reform_t + \\ & \phi_6 SOE^j_{it} \times Post\_reform_t + \\ & \phi_7 \ln S^j_{it} \times SOE^j_{it} \times Post\_reform_t + \mu_i + \gamma_{j,t} + \varepsilon^j_{it}\end{aligned}$$

  with $Post\_reform_t = 1$ for the post-reform period, i.e. $t \geq 2002$

- Most interested in ϕ_7

SOE Reform

Dependent variable	$TFP^{ACF,Translog}$			
	A. Full	B. Balanced Panel	C. Constant Ownership	D. Balanced and Constant Ownership
$\ln S_{it}$	0.142***	0.137***	0.142***	0.127***
(s.e.)	[0.008]	[0.013]	[0.009]	[0.016]
SOE^j_{it}	-0.182***	-0.223***	–	–
(s.e.)	[0.026]	[0.036]	–	–
$Post\_reform_t$	0.258***	0.396***	0.251***	0.385***
(s.e.)	[0.013]	[0.019]	[0.013]	[0.021]
$\ln S_{it} \times SOE^j_{it}$	0.036***	0.043***	0.025	0.046
(s.e.)	[0.011]	[0.016]	[0.020]	[0.034]
$\ln S_{it} \times Post\_reform_t$	-0.015***	-0.038***	-0.015**	-0.037***
(s.e.)	[0.006]	[0.008]	[0.006]	[0.008]
$SOE^j_{it} \times Post\_reform_t$	0.110***	0.081**	0.114***	0.105**
(s.e.)	[0.024]	[0.035]	[0.029]	[0.041]
$\ln S_{it} \times SOE^j_{it} \times Post\_reform_t$	0.005	0.029*	0.021	0.046**
(s.e.)	[0.012]	[0.015]	[0.014]	[0.020]
Number of obs	142,717	26,310	121,980	19,620
R^2	0.93	0.93	0.94	0.93

Ownership Switching

- The reform is a gradual process and some firms were privatized after 2002
- Need a finer analysis
- Use ownership switching at *individual firm level* as identification to do event study–before and after analysis

$$\begin{aligned} Y_{it}^{j} &= \varphi_1 \ln S_{it}^{j} + \varphi_2 Ownership\_switch_{it} + \\ &\quad \varphi_3 \ln S_{it}^{j} \times Ownership\_switch_{it} + \mu_i + \varepsilon_{i,t}^{j} \end{aligned}$$

with $Ownership\_switch_{it} = 1$ if $t \geq t_0$ and $t_0 \in [1998, 2007]$ is the first year that firm i switched its ownership from being a SOE to a POE

- Most interested in φ_3

Ownership Switching

	φ_1	(s.e.)	φ_2	(s.e.)	φ_3	(s.e.)	R^2
Size							
Output	0.198***	[0.039]	0.006	[0.053]	-0.035	[0.033]	0.88
Value added	0.229***	[0.045]	0.014	[0.061]	-0.041	[0.037]	0.81
Capital stock	0.089***	[0.030]	-0.007	[0.030]	0.039**	[0.019]	0.95
Employment	0.126***	[0.032]	-0.150***	[0.041]	0.055**	[0.027]	0.87
Factor intensity							
Capital-labor ratio	-0.037	[0.038]	0.143***	[0.039]	-0.017	[0.024]	0.79
Productivity							
Labor productivity	0.072**	[0.033]	0.156***	[0.044]	-0.090***	[0.025]	0.79
Solow residual	0.143***	[0.044]	0.059	[0.060]	-0.063*	[0.033]	0.64
OLS-FE	0.229***	[0.045]	0.014	[0.061]	-0.041	[0.037]	0.81
$TFP^{ACF,CD}$	0.128***	[0.031]	0.112***	[0.041]	-0.086***	[0.023]	0.83
$TFP^{ACF,Translog}$	0.144***	[0.036]	0.112**	[0.052]	-0.086***	[0.026]	0.86

Conclusion

- Firms' Patent filing in China is associated with real changes in production outcomes, particularly in TFP growth.
- Somewhat surprisingly, SOEs associate patenting with TFP growth better than POEs, especially after the SOE reform in late 1990s
  — It is not related to market power, credit constraint, or subsidy, or different production function of SOE vs POE.
  — Remains an open question
- Future work
  - Direct estimate of the effect of patent stock on TFP based on De Loecker and Warzynski (2012) method.
  - Suggestions?