Migration of High Skilled Immigrants and Ideas in a World of Global Education and Research Collaborations

1) Global Expansion of Education/Knowledge creation in the modern economy

2) High skilled immigrants: brain drain, knowledge outflow, or mutually beneficial collaborative exchanges?

3) Issues and questions for policy

Richard Freeman (Harvard, NBER) National Academies Board of Science, Engineering, and Medicine High Skill Immigration Sept 22, 2014

Much of the data on China are from Freeman and Wei, "China's Great Leap Forward in Science and Engineering", 2014

Theme

- **Development and dissemination of S&E-based knowledge is t**he "one ring that rules them all" in modern economy.
- Research that produces **scientific papers and R&D** spending to support basic research and apply it to economy drives modern economic growth.
- Increased **university** enrollments within a country and international students and return migrants drive knowledge creation and dissemination.
- Collaboration in science and "**migration of ideas**" are critical in high-skilled immigration and policy

Modern Economy Lives on Production and Dissemination of Knowledge

Production:

- University-based basic R&D -->stock of S&E knowledge
- Firm-based applied R&D → innovative products/ processes
- Engineering/technology work by university graduates outside R&D to make things work.

Dissemination:

- Growth of higher education – globalization bcs use similar texts, English language. And the MOOCs
- International students and immigrants and returnees as "carriers of basic knowledge" in knowledge pandemic
- Multinational corporations as "carriers of applied knowledge" in global economy

1.Globalization? It's the Knowledge flows, Stupid!

In knowledge economy globalization's main impact is through the spread of knowledge via higher education; international students; migration of high-level workers, supported by R&D; and spread of ideas through modern ICT and collaborations and migration, as much (more than?) through trade and capital flows stressed bythe obsolete Washington Consensus /World Bank/IMF vision.

Spread of Modern technology

- Consumption: cell phones and Internet
- 
- 

- Production: Global chains of production mean that even low skilled workers in low income countries contribute but bulk of value added comes from high skilled work
- Knowledge: World R&D increases more than world GDP with China raising RD/GDP ratio; Scientific papers increase largely in developing countries

Expansion of S&E papers is developing countries/China

Table 5-20
S&E articles in all fields, by country/economy: 2001 and 2011

Rank	Country/economy	2001	2011	Average annual change (%)	2011 world total (%)
-	World	629,386	827,705	2.8	na
1	United States	190,597	212,394	1.1	25.7
2	China	21,134	89,894	15.6	10.9
3	Japan	56,082	47,106	-1.7	5.7
4	Germany	42,678	46,259	0.8	5.6
5	United Kingdom	45,588	46,035	0.1	5.6
6	France	30,602	31,685	0.3	3.8
7	Canada	21,945	29,114	2.9	3.5
8	Italy	22,093	26,503	1.8	3.2
9	South Korea	11,008	25,593	8.8	3.1
10	Spain	15,324	22,910	4.1	2.8
11	India	10,801	22,480	7.6	2.7
12	Australia	14,484	20,603	3.6	2.5
13	Netherlands	12,117	15,508	2.5	1.9
14	Taiwan	7,912	14,809	6.5	1.8
15	Russia	15,658	14,151	-1.0	1.7
16	Brazil	7,052	13,148	6.4	1.6
17	Switzerland	7,950	10,019	2.3	1.2
18	Sweden	10,022	9,473	-0.6	1.1
19	Turkey	4,151	8,328	7.2	1.0
20	Iran	1,035	8,176	23.0	1.0

Keys for US:(1) Inevitable decline in US share of R&D/S&E; (2) Currently linked to rise of China

	2000	2011	Change in share US	China
1, R&D spending for "world"*	45%	38%	-7	+13
2. Researchers	21	16	-5	+4
3. S&E papers	31	26	-5	+8
4 articles in upper 1% citation	57	46	-11	+6
5. S&E bachelor's	14.0	9.8	-4	+14
6. S&E PhDs	22	16	-6	5

Source: National Science Board, Science and Engineering Indicators, 1982, 1987, 2002, 2014

*"World" limited to EU, US, Japan, South Korea, and China

Necessary for global spread of S&E knowledge: expansion of university education

Exhibit 1: Millions of Enrollments and Shares of enrollment (in parentheses) in Tertiary Education, by Area of the World, 1970-2010

Area	1970	1980	1990	2010
World	29.4	55.3	67.6	177.6
Developing	16.0 (54%)	35.0 (63%)	41.0 (61%)	136.5 (76%)
China	<0.1	1.7	3.8	30
India	2.5	3.5	5	20.7
US	8.5 (29%)	12.1 (22%)	13.7 (20%)	20.4 (11%)
Other adv	4.9 (17%)	8.2 (15%)	12.9 (19%)	23.7(13%)

Source: UNESCO, Institute for Statistics, on line files,2010 from tables 15, 20A

GLOBAL

Worldwide student numbers forecast to double by 2025

Geoff Maslen

19 February 2012 University World News Global Edition Issue 209

The number of higher education students worldwide is forecast to more than double to 262 million by 2025. Nearly all this growth will be in the developing world, with more than half in China and India. Students seeking study abroad could rise to eight million. The number of students around the globe enrolled in higher education is forecast to more than double to 262 million by 2025. Nearly all of this growth will be in the developing world, with more than half in China and India alone. The number of students seeking study abroad could rise to eight million – nearly three times more than today.

“Human Resource Leapfrogging” in China: number of graduates

	Bachelors		Masters		PhDs	
Year	Total	S&E	Total	S&E	Total	S&E
2012	3,038,473	1,258,643	434,742	191,048	51,713	27,652
2011	2,796,229	1,163,643	379,705	165,450	50,289	27,584
2010	2,590,535	1,082,271	334,613	145,266	48,987	27,066
2009	2,455,359	1,028,129	322,615	145,380	48,658	26,956
2008	2,256,783	956,214	301,066	138,441	43,759	24,229
2007	1,995,944	861,834	270,375	127,357	41,464	22,530
2006	1,726,674	770,441	219,655	104,282	36,247	19,371
2005	1,465,786	680,301	162,051	80,084	27,677	14,885
2004	1,196,290	576,627	127,331	61,042	23,446	12,572
2003	929,598	454,946	92,241	44,279	18,806	10,278
2002	655,763	324,550	66,203	31,884	14,638	8,060
2001	567,839	283,080	54,700	25,715	12,867	7,647
2000	495,624	262,119	47,565	25,421	11,004	7,019
1999	440,935	237,705	44,189	25,119	10,320	6,450
1998	404,666	222,103	38,051	22,443	8,957	5,711
1997	381,647	214,552	39,114	22,729	7,319	4,803
1996	347,194	199,754	34,026	20,613	5,430	3,564
1995	325,484	186,873	27,123	17,591	4,641	3,091
1994	310,291	178,380	24,181	15,443	3,723	2,481
1993	298,959	142,536	25,167	16,263	2,940	2,054
1992	.	.	23,015	.	2,528	1,769
1991	323,434	156,461	29,193	18,672	2,610	1,727
1990	307,865	148,886	31,505	20,303	2,457	1,626
1989	308,930	153,032	32,890	21,169	2,046	1,890
1988	279,791	137,065	34,732	.	1,538	.
1987	252,973	121,802	20,307	13,629	464	350
1986	227,764	109,101	15,221	9,704	284	228

Note: Official China data; # Bachelors refers to four year normal degree recipients; larger reported numbers include persons on short cycle courses. In 2012 the 6,247,338 undergraduate degree recipients consisted of 3,038,473 in normal courses; and 3,208,865 in Short-cycle courses. See: http://www.moe.edu.cn/publicfiles/business/htmlfiles/moe/s7567/201309/156896.html

Developing countries use international students to access superior US/other advanced country higher education

Int'l Students, World

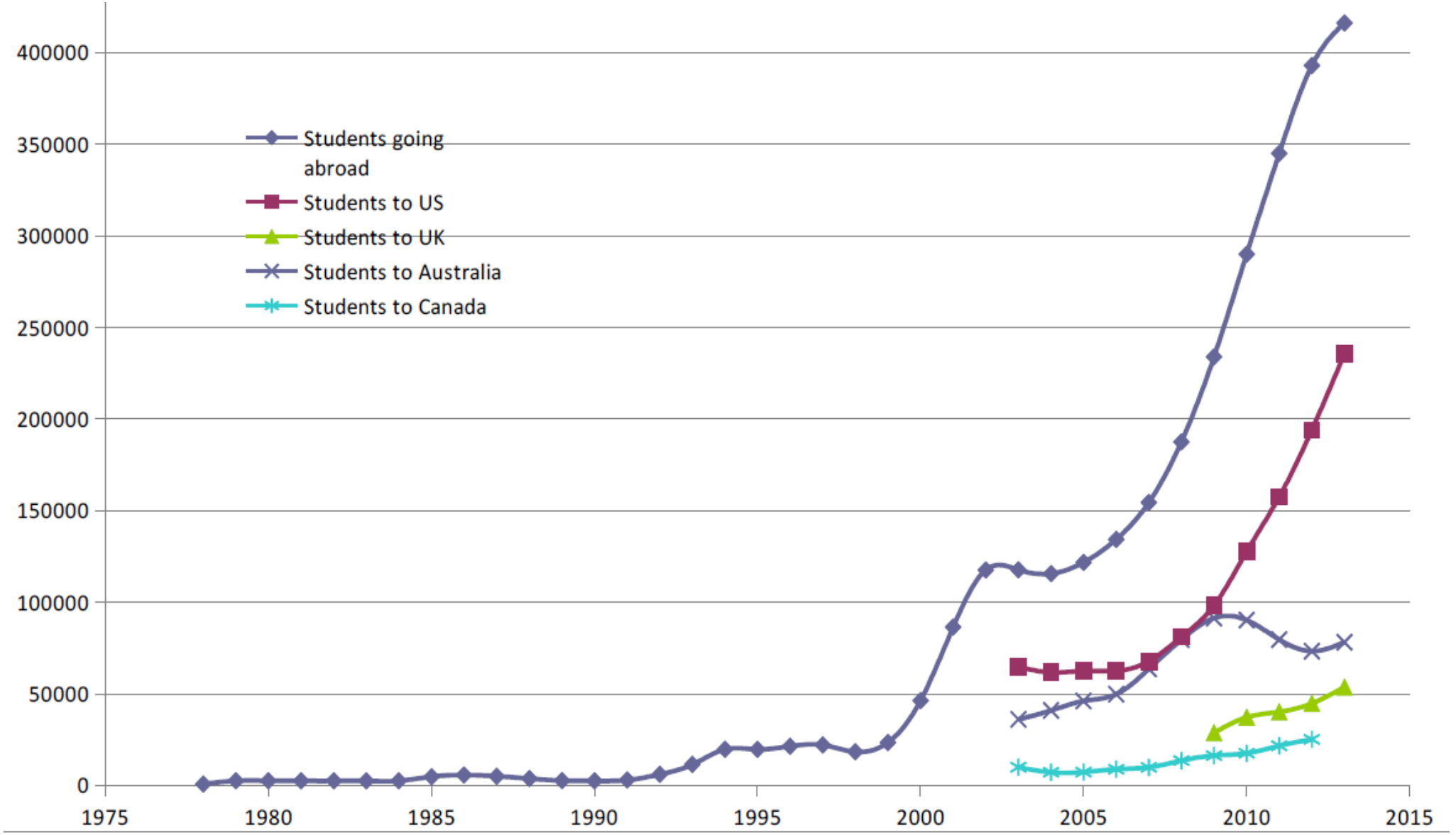
1975	600,000
1980	800,000
1990	1,200,000
2000	1,900,000
2012	4,500,000

Top countries to US, 2013 (total 819, 614)

1	China	235,597
2	India	96,754
3	South Korea	70,627
4	Saudi Arabia	44,566
5	Canada	27,357
6	Taiwan	21,867
7	Japan	19,568
8	Vietnam	16,098
9	Mexico	14,199
10	Turkey	11,278

Source: OECD, Education at a Glance, 2014 p 344 and IIE, International Students and Mobility
http://exchanges.state.gov/universitysummit/mobility_report.pdf

China Growth of International Students Fastest In USA



Data of students going abroad is from www. eol.cn. Data source is Ministry of Education of the PRC.
Data of US students are from open door data
Data of UK is from https://www.hesa.ac.uk/. Higher Education Statistics Agency
Data of Canada is from Australian Government Department of Immigration.
Data of Australia is from Australian Government Department of Immigration and Border Protection.

China-US Special Relation in International Education

Table: Most of the Chinese students choose the United States

Year	Number going abroad	Number going to the US	Proportion: going to US of total going aboard
2005	14.24	6.3	0.44
2006	14.71	6.7	0.46
2007	16.64	8.1	0.49
2008	17.94	9.7	0.54
2009	22.32	12.1	0.54
2010	28.47	15.8	0.55
2011	33.97	19.4	0.57
2012	39.96	23.6	0.59
2013	41.39		

Table: The proportion of Chinese Students (Mainland) among international students in the US

Year	Proportion
2007	11.6
2008	13.0
2009	14.6
2010	18.5
2011	21.8
2012	25.4
2013	28.7

Source of data: www. eol.cn.

What International Students bring to US science: Science and Engineering Students and Post-docs

Exhibit 2: Percentage Foreign-Born or with temporary visa of US S&E Graduate Enrollments and Degrees, 1970-2011/12

	1970	1980	1990	2000	2011/12
1. Graduate students, full-time, in science and engineering*		22.5%	33.9%	36.3%	36.3%
2. Bachelor's Degrees, Engineering		3.8%	3.6%	3.8	4.4
3. Master's Degrees		16.4	22.6	25.8	26.0
4. Doctorate Degrees,	18.4	26.4	31.8	30.4	34.2
5. All Post-doctoral Workers		38.6	51.1	58.2	62.9
6. Post-doctoral in university jobs for US doctorates only	17.5	18.3	39.1	43.0	49.0

Table 1: Number of papers and distribution of authors by ethnicity, for papers with 2 to 4 authors, US addresses only

Year	Number of papers	Distribution of authors by ethnicity (%)									
		Anglo-Saxon/ English (ENG)	Chinese (CHN)	European (EUR)	Indian/Hindi/ South Asian (HIN)	Hispanic/ Filipino (HIS)	Japanese (JAP)	Russian (RUS)	Korean (KOR)	Vietnamese (VNM)	Not identified
1985	43270	56.56	4.79	13.47	4.23	2.87	2.45	0.71	2.05	0.14	17.15
1986	43790	56.07	4.81	13.35	4.26	3.08	2.31	0.78	2.04	0.16	17.53
1987	44571	55.66	5.27	13.27	4.37	2.99	2.39	0.84	1.98	0.15	17.40
1988	46615	54.83	5.80	13.35	4.42	3.14	2.32	0.92	1.95	0.16	17.32
1989	48218	54.23	6.35	13.14	4.49	3.25	2.32	1.00	2.00	0.17	17.12
1990	49896	53.32	6.98	12.94	4.76	3.33	2.29	1.07	2.09	0.17	17.24
1991	52462	52.34	7.73	12.92	4.82	3.41	2.36	1.14	2.07	0.18	17.15
1992	53134	51.47	8.50	12.67	5.23	3.32	2.28	1.12	2.09	0.18	17.27
1993	53344	50.64	9.55	12.43	5.15	3.43	2.27	1.19	2.28	0.22	16.95
1994	53596	49.56	10.16	12.31	5.43	3.43	2.24	1.31	2.29	0.22	17.02
1995	55886	48.97	10.62	12.16	5.49	3.58	2.13	1.35	2.57	0.25	16.89
1996	62576	48.55	10.91	12.03	5.67	3.64	2.02	1.33	2.55	0.23	16.97
1997	64092	48.37	11.23	11.96	5.74	3.64	1.93	1.38	2.63	0.28	16.80
1998	80914	49.15	11.33	11.97	6.01	3.81	1.50	1.32	2.74	0.32	16.09
1999	78320	48.61	11.48	11.86	6.09	3.96	1.52	1.38	2.86	0.32	16.15
2000	77946	48.22	11.78	11.77	6.04	3.99	1.50	1.49	2.94	0.36	15.96
2001	75443	47.56	12.20	11.73	6.17	4.00	1.54	1.59	3.11	0.33	15.93
2002	74852	46.99	12.49	11.45	6.45	4.02	1.57	1.67	3.18	0.37	15.82
2003	77973	46.20	13.12	11.35	6.80	4.14	1.45	1.69	3.14	0.34	15.74
2004	79872	45.43	13.63	11.13	7.07	4.29	1.47	1.83	3.18	0.35	15.45
2005	82377	44.71	14.16	11.03	7.37	4.28	1.36	1.87	3.20	0.37	15.47
2006	86177	45.21	14.45	11.14	7.64	4.77	1.35	1.89	3.41	0.33	13.21
2007	85018	45.65	14.28	11.21	7.93	5.03	1.33	1.90	3.42	0.36	11.97
2008	77959	45.56	14.16	11.18	7.98	5.05	1.30	1.93	3.41	0.35	12.14
Total	1548301	48.97	10.92	11.99	6.06	3.89	1.79	1.44	2.75	0.28	15.85

NOTES: Sample limited to papers with only US addresses. Because most of the sample contains initials rather than first names as well surnames, the match rate is 84.15%, below rate of matching in patent data when both first and last names are available. For two-author papers, we keep those papers in which both authors are identified; in three- and four- author paper sample, we keep those with at least two authors identified, so that the "not identified" occur only in papers with more than two authors.

International Students Become Immigrants

Exhibit 5: Proportions of US Science and Engineering Workers that are Foreign-Born and th Proportion of the Foreign-Born that Have Highest Degree in the United States, 2005

	Foreign-Born Share of Workers	Share of Foreign-Born with Highest Degree in US
Bachelor's	15.2%	54.3%
Masters	27.2%	68.5%
Doctorates	34.6%	64.00%

EU studies show causal relation between programs to place students short term in another country and location in that country

2.Intn'l Students and S&E Immigrants: brain drain vs knowledge flow in world of scientific collaboration

IN US/RECEIVING COUNTRY

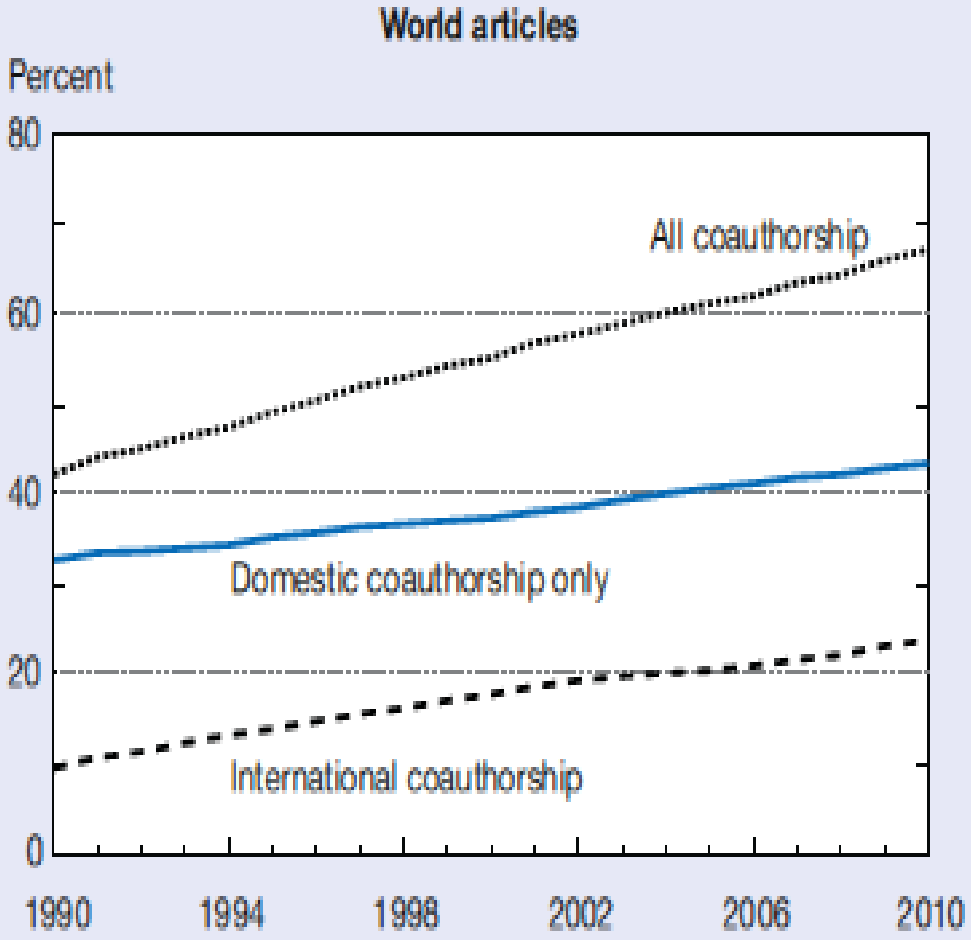
- Immigrant comes and works in receiving country science; contributes to advance.
- But immigrant likely to pass information through ethnic network/speed up flow of ideas via collaboration with person in native country

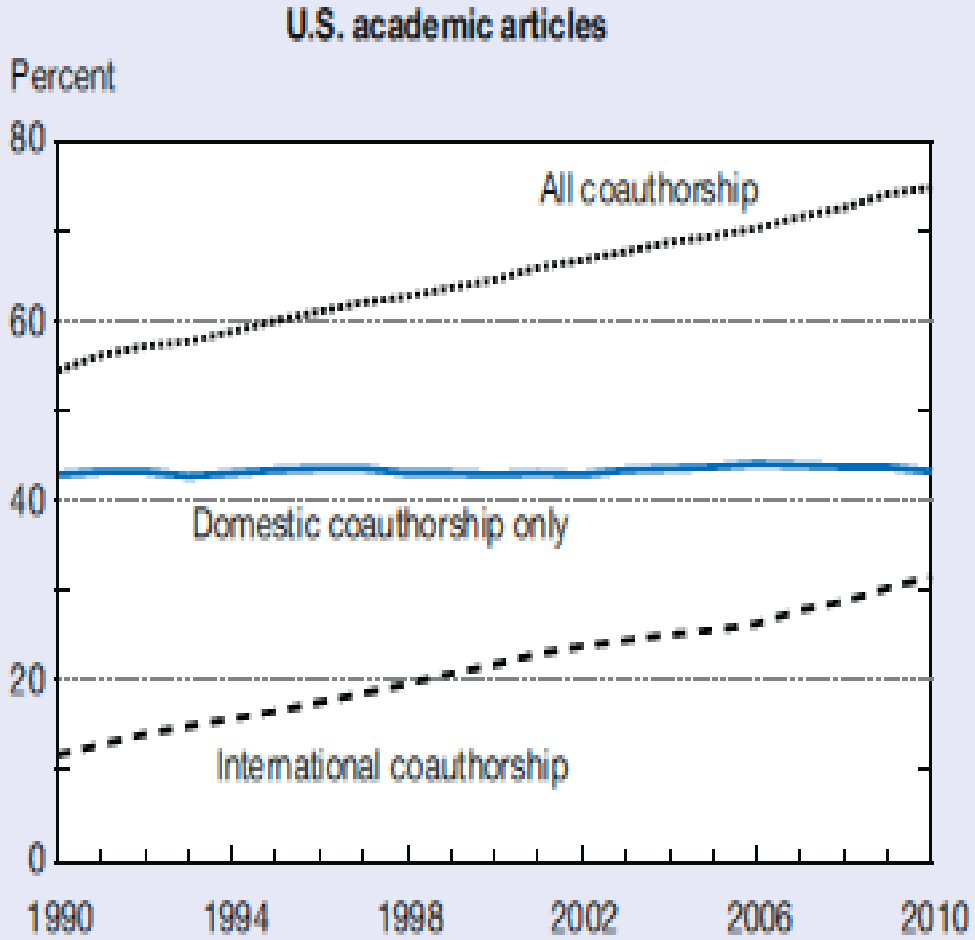
IN SENDING COUNTRY

- Immigrant likely to write papers with persons in home country
- Returnee brings ideas directly and improves science
- Returnee more likely to collaborate with persons from US/country of migration

Collaborations Increase Within and Across countries

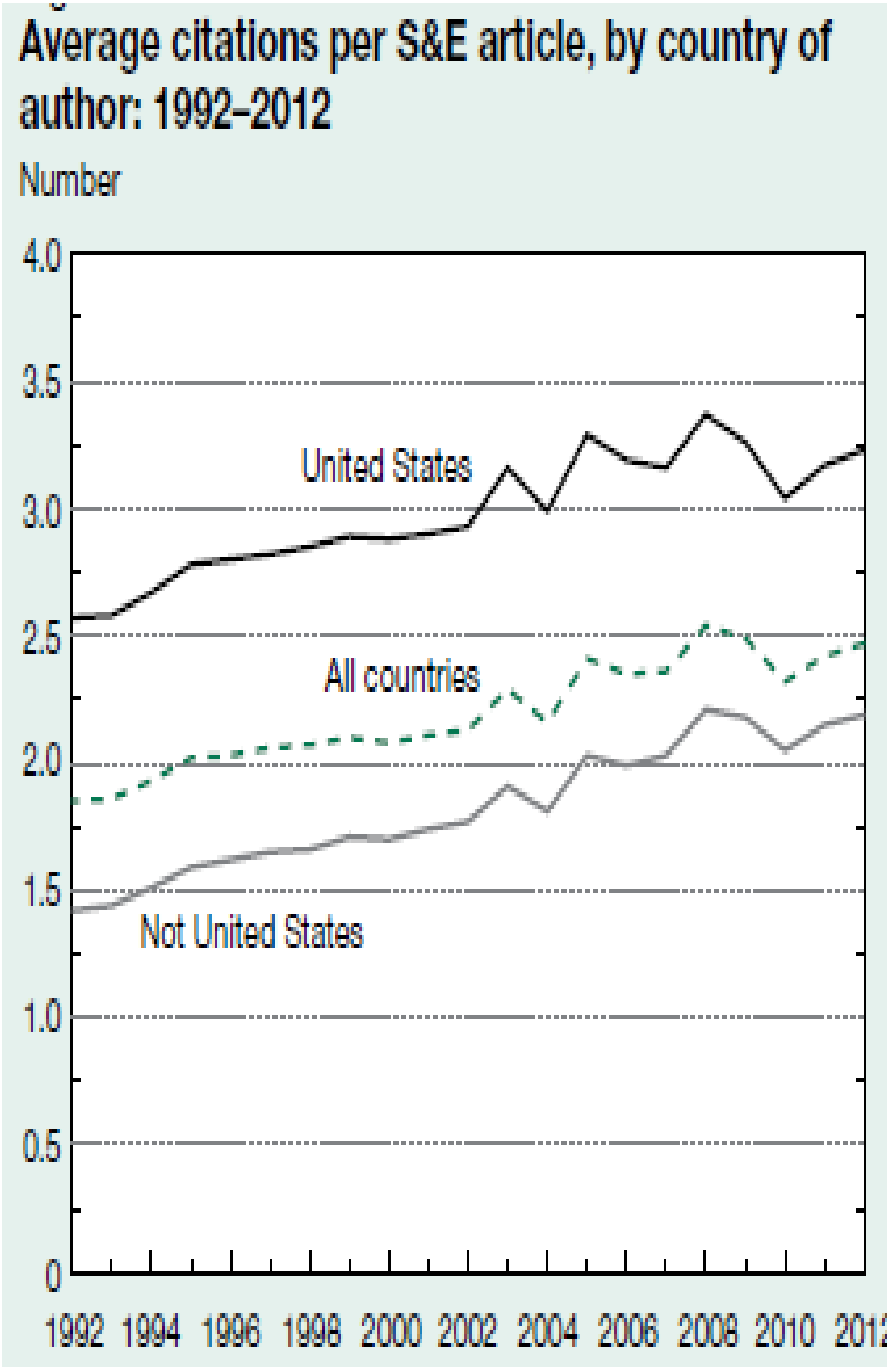
World and U.S. academic S&E articles coauthored domestically and internationally: 1990–2010

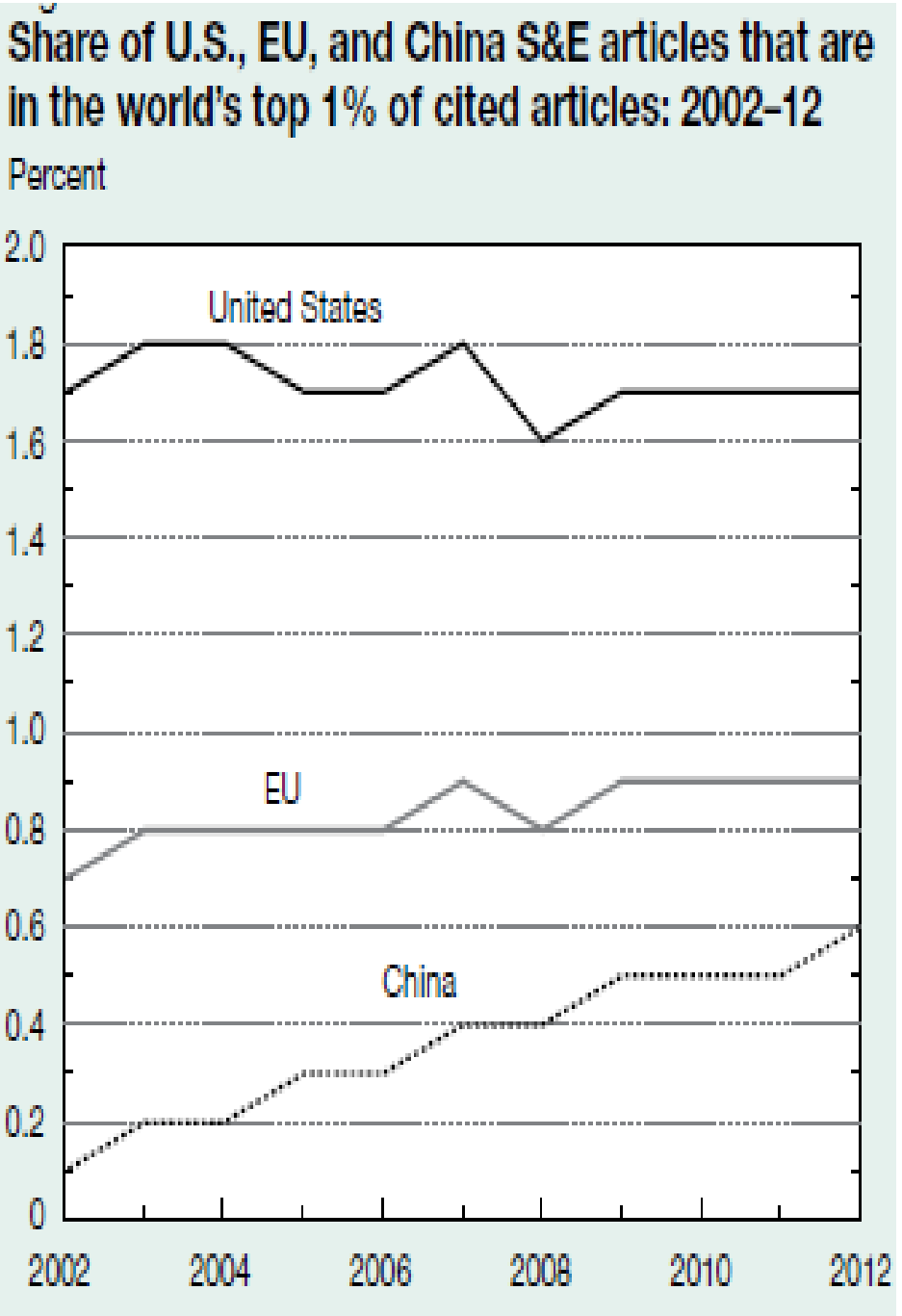




NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating institution or country credited one count. Internationally coauthored articles may also have multiple domestic coauthors.

Quality:US/other advanced countries gain more citations



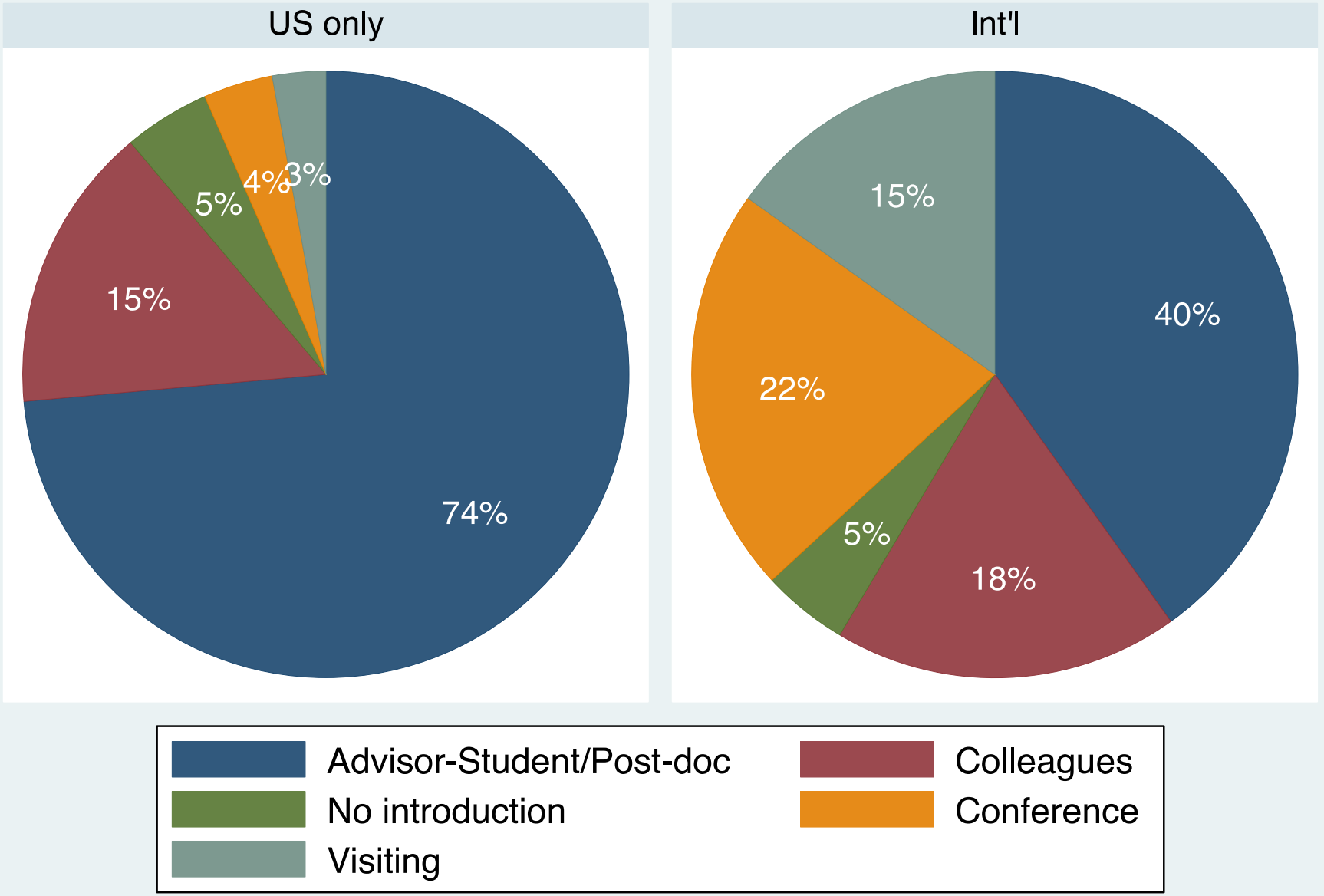


Shares of international collaborations and major US collaborators

	Share of S&E articles internationally co-authored		US share of Country's Intl Collaborations		Country's Share of US In Collaborations	
	1997	2012	1997	2012	1997	2012
World	15.7%	24.9%	43.8	43	---	--
US	19.3	34.7	--	--	---	--
China	25.7	26.7	35.1	47.5	3.2	16.2
UK	31.0	55.1	30.0	35.2	12.4	14.3
Germany	35.5	55.5	29.9	31.0	13.3	13.3
Canada	33.5	50.2	53.0	48.9	12.1	11.4
France	37.3	58.2	28.4	28.5	8.9	8.8
Italy	36.1	51.1	32.2	34.0	6.8	7.4
Japan	16.4	30.0	44.4	37.1	9.9	6.8
Australia	29.4	52.4	36.1	32.9	4.3	6.0
South Korea	27.6	30.8	51.5	53.9	2.8	6.0

Source: Tabulated from Indicators 2014, Appendix table 5-41 and 5-56

How Collaborators First Met? (2-author papers)



Graphs by intl

US-China "Special Relation: Changing shares of papers and Collaborations

CHINA TOTAL	1995	2009/2010
SHARE OF PAPERS	1.6	9.4
SHARE OF INTERNATIONAL COLLABORATIONS	3.7	13
SHARE OF COLLABORATIONS WITH US	38.2	30.4
US TOTAL		
SHARE OF PAPERS	34.3	26.5
SHARE OF INTERNATIONAL COLLABORATIONS	46	42.9
SHARE OF COLLABORATIONS WITH CHINA	3.1	13.7

Source: NSF S&E Indicators 2012, Appendix table 5-41, 5-27

Table 1: China and US addresses in Web of Science Paper, 1998-2007

Publication year	(1) Total number of papers	(2) Prop. Of China-based papers	(3) Citation share from China	(4) (3)/(2)	(5) Prop. Of US-based papers	(6) Citation share from US	(7) (6)/(5)	(8) Ave. citations for China-based papers	(9) Ave. citations for US-based papers
1998	667,503	2.49%	1.01%	0.41	28.8%	42.1%	1.46	7.24	26.03
1999	681,608	2.97%	1.32%	0.44	28.0%	40.7%	1.46	7.49	24.55
2000	692,220	3.67%	1.85%	0.50	27.7%	39.9%	1.44	8.03	22.98
2001	695,725	4.31%	2.26%	0.52	27.2%	39.5%	1.45	7.60	21.10
2002	712,491	4.70%	2.73%	0.58	26.7%	38.7%	1.45	7.60	18.93
2003	748,653	5.43%	3.39%	0.62	26.4%	38.3%	1.45	7.00	16.24
2004	787,513	6.36%	4.06%	0.64	26.0%	37.3%	1.43	5.85	13.15
2005	827,385	7.40%	4.79%	0.65	25.7%	36.5%	1.42	4.46	9.78
2006	871,109	8.48%	5.60%	0.66	24.9%	35.5%	1.43	2.89	6.26
2007	904,462	9.02%	6.17%	0.68	24.0%	34.7%	1.45	1.40	2.97

Immigrants and US job market

Exhibit 4 Percent Foreign-Born in S&E Occupations, by education level, 1990-2011

Foreign-Born	1990	2000	2011
All College Graduates in S&E		22.4	26.2
Bachelor's	11.00%	16.5	19.0
Master's	19.00%	29.0	34.3
PhDs	24.00%	37.6	43.2

Source: Science and Engineering Indicators 2014, table 3-27.

Caterpillar China Employment Opportunities
卡特皮勒中国就业机会信息发布会

Richard P. Lavin, Group President, Caterpillar Inc., Peoria, Illinois

11am-1pm, Friday, May 2, 2nd Floor, Levis Faculty Center

(Pizzas, cookies & soft drinks available. Targets: Student/scholars from China)

Caterpillar Team:

Richard Lavin/腊睿智 (JD), Group President
Brian Sun/孙晓波 (PhD), Global R & D Strategy Director
Ulf Lindqwister/林沃福 (PhD), Enterprise Strategy Support Manager
John Balkema/巴强安, Employment Management Manager
Jack Feng/冯常学 (PhD), President, Feng Consulting Inc.

Agenda:

Jack Feng welcome and introduction of Caterpillar team
UIUC CSSA welcome
UIUC Career Service welcome
Self introduction of each participant (name, major, degree in)
Ulf introduction of Rich Lavin
Rich Lavin presentation "Caterpillar and China: A Shared Future"
Comments by other members of Caterpillar and Q & A
Break up into groups (Business, engineering, marketing, others)

Key facts about Caterpillar Inc.:

World headquarter in Peoria, IL
Fortune 100 US company
Revenue $45 billion in 2007
About 20 facilities in Mainland China
Around 300 facilities in 40 countries
100,000 + employees
Over 180 dealers/105,000 dealer employees
Global leader in construction & mining machines
Global leader in diesel and natural gas engines
Global leader in industrial gas turbines

Co-Sponsors:

UIUC Chinese Students & Scholars Association
UIUC Career Services Office
Caterpillar Inc.

MAKING PROGRESS POSSIBLE



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TODAY'S WORK. TOMORROW'S WORLD.™

Hypotheses About Role of Immigrant/Returnee as link in production and flow of ideas

- Immigrant to US produces more/better research in US than in home country (McGarvie and Khan)
- Immigrant more likely to collaborate with people from home country than US-born.
- Returnees more likely to collaborate with US than other scientists in home country.
- Returnees produce more/better research than countries in home country
- Location of research likely to affect location of investment for production.

Researchers with Overseas Experience Have Higher impact in China

Table. Oversea publication experience in China-based & All Chinese-Written papers, PubMed

Year	USA publication experience		Oversea publication experience		No oversea experience	Number of papers
	Prop.	Impact	Prop.	Impact	Impact	
2000	0.06	2.21	0.21	2.22	1.38	1,911
2001	0.05	2.22	0.18	2.14	1.55	2,701
2002	0.06	2.22	0.18	2.27	1.73	3,407
2003	0.07	2.76	0.18	2.60	2.03	4,722
2004	0.08	2.61	0.18	2.54	2.06	5,722
2005	0.09	2.63	0.18	2.62	2.26	7,633
2006	0.11	2.74	0.18	2.69	2.34	10,310
2007	0.12	2.68	0.20	2.68	2.28	12,437

Paper Quality of Chinese Working in US; Chinese with US/foreign experience working in China

Table. Chinese in Non-China Based Papers in PubMed

VARIABLES	Impact factor	5-year citations
First author Chinese	0.101***	0.611***
	(0.00571)	(0.0470)
Last author Chinese	-0.0268***	0.410***
	(0.00782)	(0.0644)
Observations	5,884,586	5,884,586
R-squared	0.388	0.167
Author Number	Yes	Yes
Address Number	Yes	Yes
Reference Number	Yes	Yes
Language	Yes	Yes
Country	Yes	Yes
Publication year	Yes	Yes
Field	Yes	Yes

Table. Overseas experience in China-addressed papers with First and Last authors Chinese

VARIABLES	Impact factor	5-year citations
USA experience	0.730***	1.792***
	(0.0725)	(0.372)
Other oversea experience	0.670***	1.786***
	(0.0592)	(0.289)
English language	0.599***	0.742***
	(0.0296)	(0.221)
Observations	51,802	51,802
R-squared	0.405	0.265
Author Number	Yes	Yes
Address Number	Yes	Yes
Reference Number	Yes	Yes
Publication year	Yes	Yes
Field	Yes	Yes

China-Based Authors with US Experience much more likely to co-author with people in US

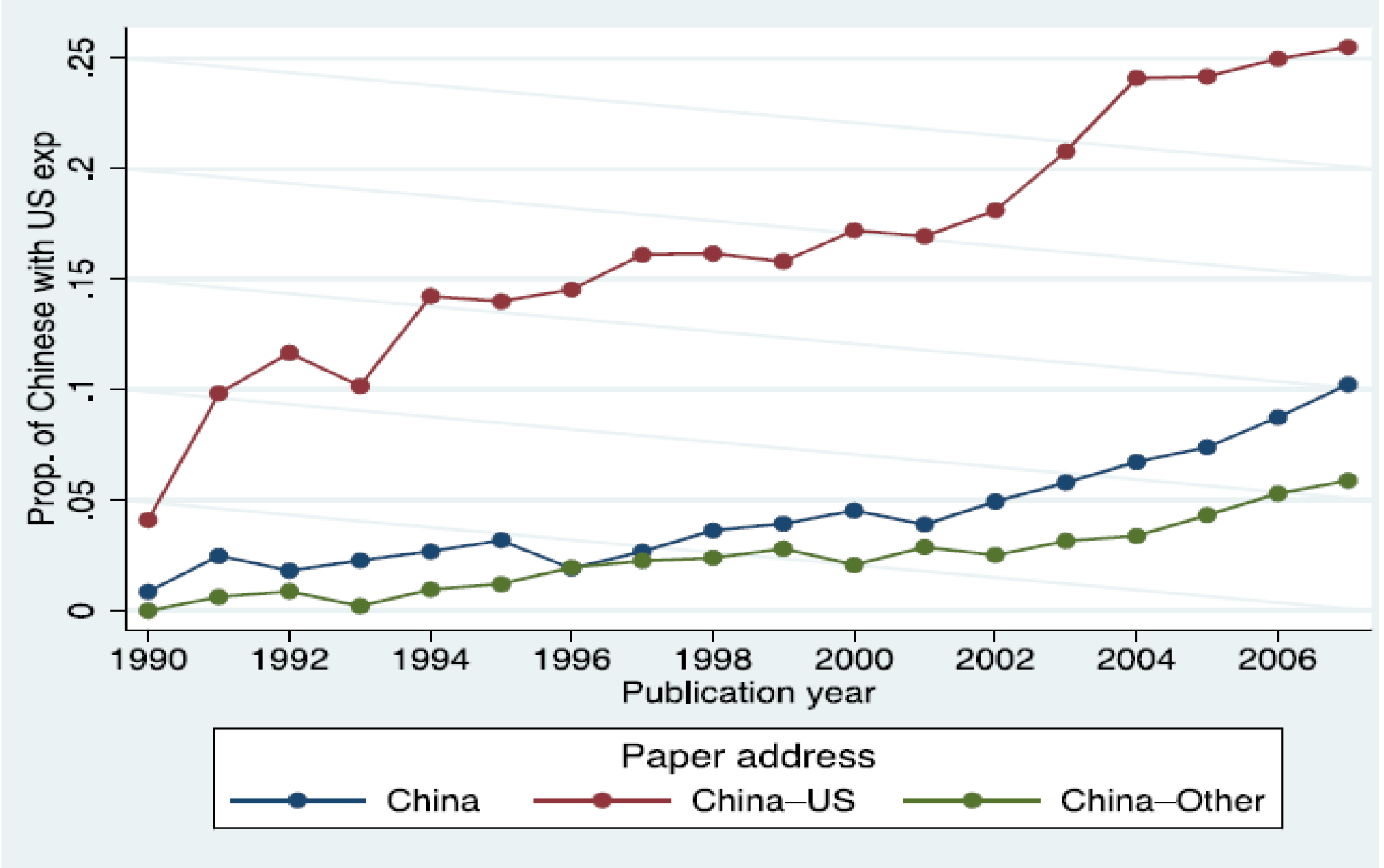

Figure 2. Proportion of Chinese with US experience, by paper address

3.Ideas Migration and Policy

1. International students sizable in US higher education and will grow. They produce lots of US science and are source of immigrants in high-level jobs; who in turn make a large proportion of S&E Workers

2.International Collaborations Across Countries + Collaborations with foreign born in US → Over half of US basic research papers done with foreign born

To the extent that they do better work in US and give more leg up than if they work overseas, more friendly international student and immigration policies makes sense.

3. Research Portfolio – mix as industrial policy.
   US diverges from other big RD countries by being so bio-medical science dominated.

In 2011 the US spent 51.6% of its research moneys on the biomedical fields compared the EU spending 43.3%, Japan spending 42% and China spending just 26% of its research moneys in that area.

Why? Doubling the NIH budget and Senator Arlen Specter; ARRA spending and Senator Arlen Specter

Possible value of shifting balance toward non-bio medical areas

4.Challenge of Making Benefits Sticky.

Citizens benefit from lower-priced high-tech goods but pay taxes for R&D when multinationals produce goods in another country? What policies, if any, can make investments in basic R&D stickier? US Production impact statement?

Suggestion: New set of fellowships for master's or doctorate graduates specializing in the transformation of knowledge into US production. Such a program would produce scientists and engineering specialists in what the NIH calls “translational sciences” (Possibly for MBAs as well?)

Numbers, amounts of support, terms ????