University-Industry Co-Publication and Its Link to University Technology Commercialization Performance

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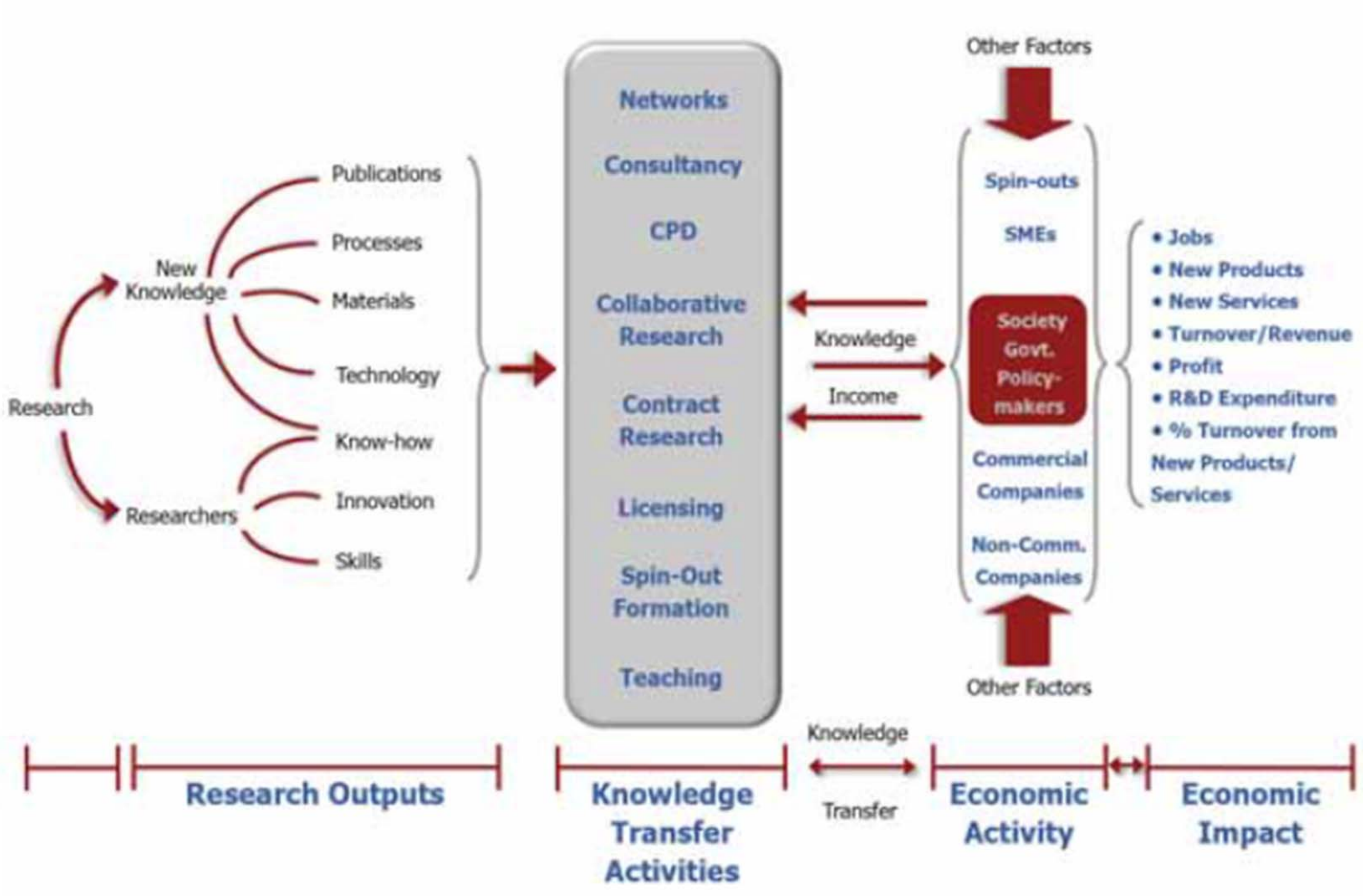
Introduction

- Growing interest in the role of universities in national and regional innovation systems – “Third Mission”, “Triple Helix” and “Entrepreneurial University Model”
- Basic Ways through which University transfer knowledge & technologies to industry:
  - Publication and other forms of public dissemination
  - Education
  - Personnel mobility
  - University-Industry research collaboration
  - Technology Licensing
  - Spin-off

Forms of University Knowledge Transfer



Source: UNICO(2008), *Metrics for the Evaluation of Knowledge Transfer Activities at Universities*

Forms of University-Industry Collaboration

- Sponsorship of Students, Continuing Professional Dev.
- Informal Exchange
- Visit Attachments, Student Internship/Joint Supervision
- Consulting
- Contract Research
- Technology Licensing Relationship
- **Research Collaboration with varying conditions on publication and resulting IPR**
- **Unrestricted Sponsored Research**
- Gifts and Endowment, Chaired Professorships

University R&D Collaboration and its Measurement

- University-industry R&D collaboration has grown in recent years, and gained increasing policy attention from university administrators and government policy makers
- Measuring university-industry R&D collaboration using input-based indicators…
  - Industry-sponsored R&D as a source of R&D funding for universities
  - Not widely or easily available, comparability issues
- …vs. output-based indicators like co-publications
  - Number and propensity of university-industry co-publications
  - Publicly available/internationally comparable databases (WOS , Scopus)
- Despite limitations, co-publications provide a promising measure of research collaboration outputs, due to its wider availability and comparability (Lundberg et al 2006, Tijssen 2006)

UI Co-publication Data

- Since 2002, CWTS at Leiden University, The Netherlands has been publishing an annual ranking of the top 500 universities in the world in terms of their propensity to co-publish with external organizations
- Data are derived from Thomson ISI Web of Science (WOS). From the set of co-published papers, CWTS further eliminated external organizations that are not private organizations to derive the UI co-publications. CWTS defined private organizations to include contract research organizations but excludes private universities and other educational organizations as well as hospitals, medical centers and clinics and other medical practitioners.

Co-Publication Propensity, Selected universities, 2013

University	Mean Normalized Citation Score	Highly cited Pub share (%)	UI Co-Pub Intensity (%)
MIT	2.15	25.0	8.9
Stanford	1.92	22.0	10.0
U.C. Berkeley	1.86	21.1	6.8
Cambridge	1.5	17.1	6.9
ETH Zurich	1.44	17.1	7.6
Univ of Tokyo	0.93	9.0	8.1
NUS	1.25	13.7	4.9
KAIST	1.05	11.2	10.5
Tsinghua U	1.12	11.7	4.1

Source: http://www.leidenranking.com/ranking

Note: covers publications in 2008-2011, citations counted up to end of 2012

The numbers reported in this table differ slightly from later tables as they exclude some Special Journals

Top 10 Universities Ranked by UICP Propensity: North America

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Reg. Rank	University name	Country	% of University publications co-authored with industry	Mean normalized citation score	% of University publications which are highly cited
1	George Mason University	US	10.9%	1.10	11.5%
2	University of Maryland, Baltimore	US	10.7%	1.20	12.8%
3	University of Utah	US	10.2%	1.31	14.4%
4	Stanford University	US	9.8%	2.10	23.6%
5	Georgia Institute of Technology	US	9.8%	1.57	17.7%
6	Carnegie Mellon University	US	9.7%	1.61	18.6%
7	University of California, LA	US	9.6%	1.66	18.4%
8	University of California, SF	US	9.5%	1.72	21.6%
9	University of Colorado Denver	US	9.4%	1.30	14.3%
10	University of California, SD	US	9.3%	1.71	19.3%

Source: Data from *Leiden Ranking 2013*

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Top 10 Universities Ranked by UICP Propensity: OECD Europe

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Reg. Rank	University name	Country	% of University publications co-authored with industry	Mean normalized citation score	% of University publications which are highly cited
1	Eindhoven University of Technology	Netherlands	15.6%	1.39	14.7%
2	Chalmers University of Technology	Sweden	14.0%	1.13	12.2%
3	Delft University of Technology	Netherlands	13.8%	1.25	13.0%
4	Technical University of Denmark	Denmark	12.8%	1.62	16.7%
5	KTH Royal Institute of Technology	Sweden	12.7%	1.08	11.3%
6	Norwegian University of Sci and Tech	Norway	11.4%	1.12	11.1%
7	Aalto University	Finland	11.4%	1.14	11.2%
8	Paul Sabatier University	France	10.1%	1.01	10.1%
9	Wageningen University and Research Centre	Netherlands	9.9%	1.44	15.9%
10	Medical University of Vienna	Austria	9.9%	1.07	11.3%

Source: Data from *Leiden Ranking 2013*

Top 10 Universities Ranked by UICP Propensity: Asia

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Reg. Rank	University name	Country	% of University publications co-authored with industry	Mean normalized citation score	% of University publications which are highly cited
1	Tokyo Institute of Technology	Japan	12.9%	0.94	8.9%
2	Waseda University	Japan	12.5%	0.65	5.7%
3	Pohang University of Science and Technology	South Korea	10.8%	1.27	14.3%
4	Tohoku University	Japan	10.8%	0.82	7.4%
5	KAIST	South Korea	10.4%	1.14	12.2%
6	Osaka University	Japan	10.3%	0.91	8.5%
7	Hiroshima University	Japan	10.1%	0.73	6.3%
8	Kanazawa University	Japan	9.9%	0.78	6.8%
9	Hanyang University	South Korea	9.8%	0.76	7.3%
10	Keio University	Japan	9.7%	0.77	6.7%

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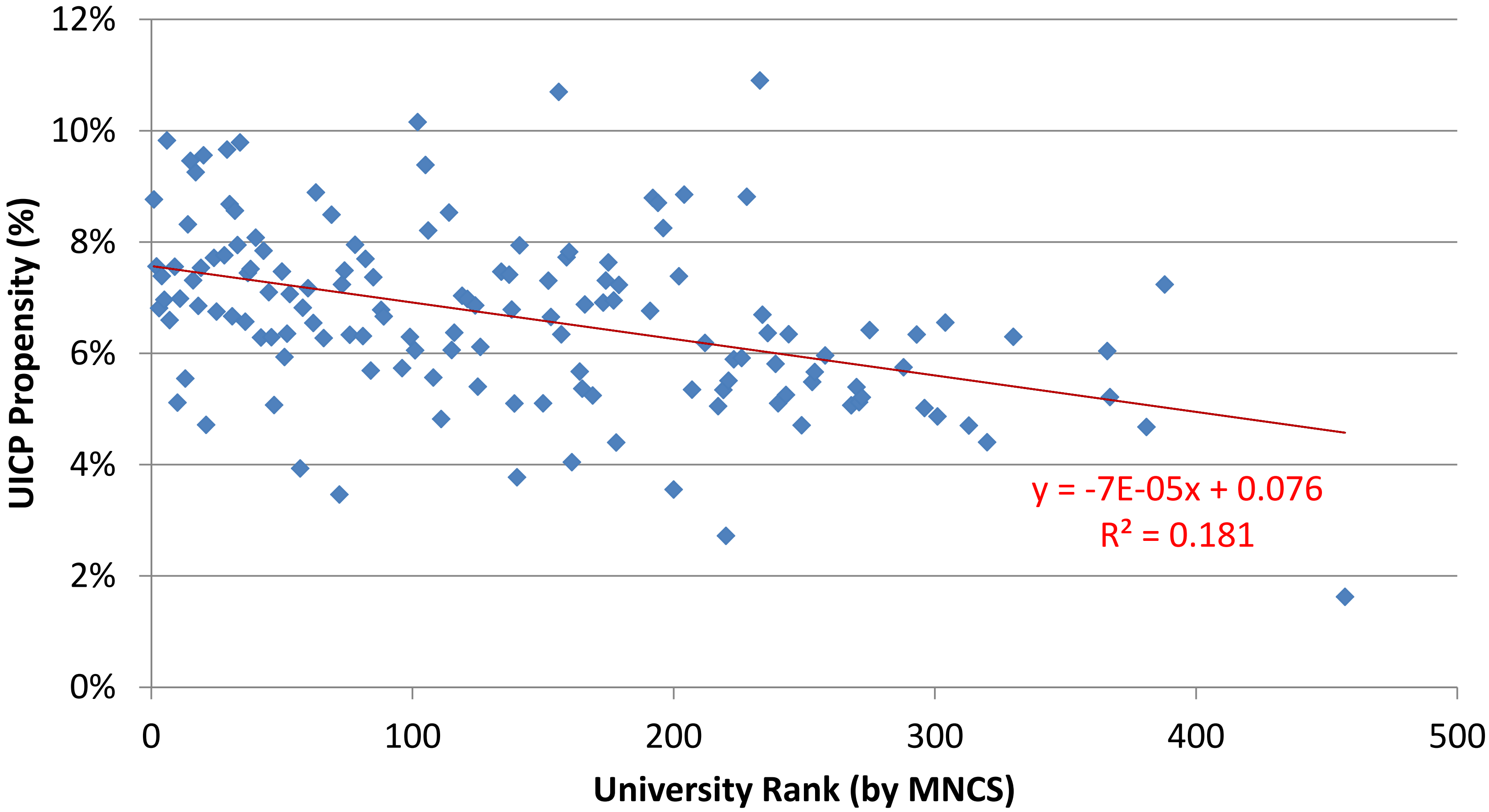
Source: Data from *Leiden Ranking 2013*

UICP Propensity vs University Ranking for Mean Normalized Citation Score: North America



Source: Data from *Leiden Ranking 2013*

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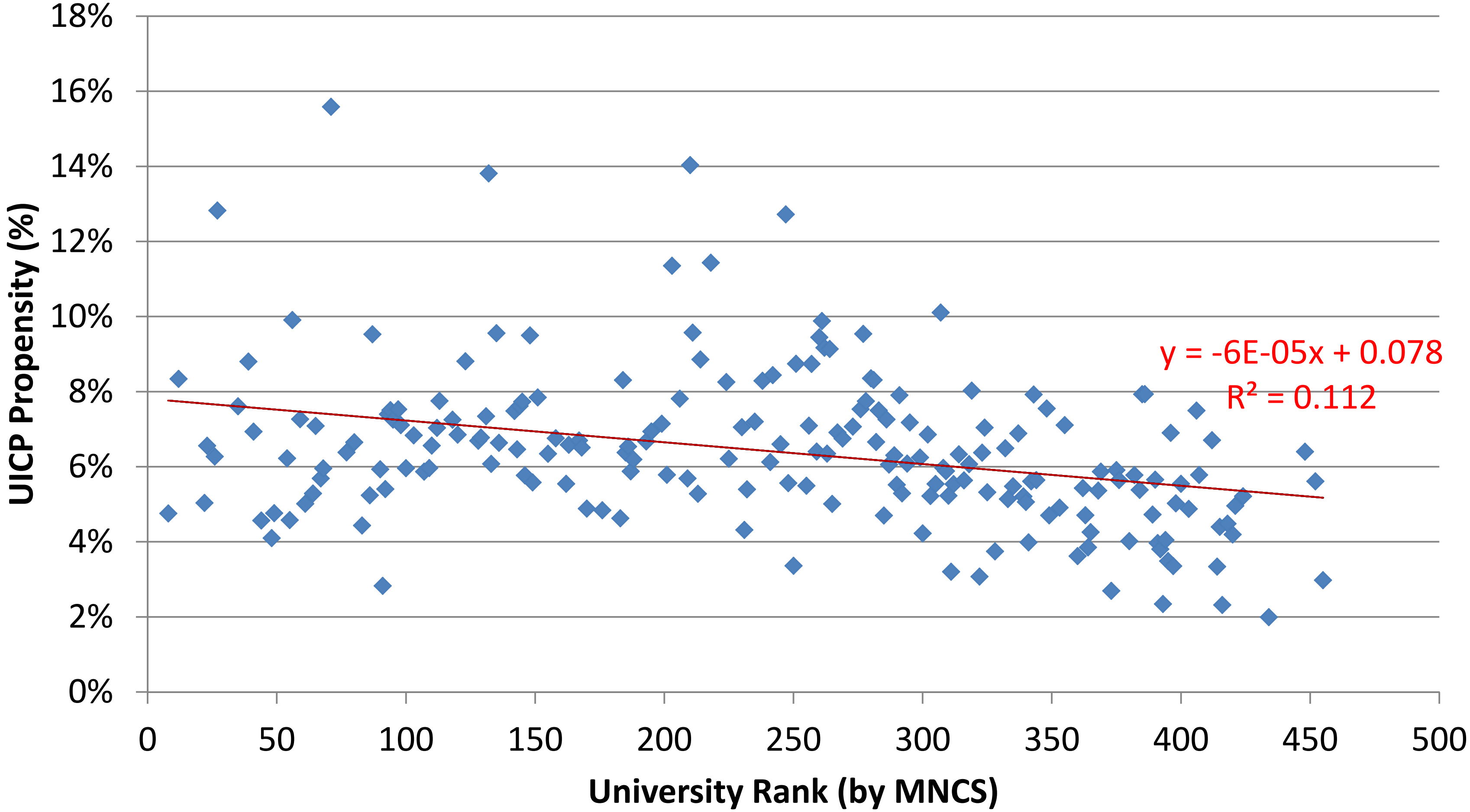
UICP Propensity vs University Ranking for Mean Normalized Citation Score: OECD Europe



Source: Data from *Leiden Ranking 2013*

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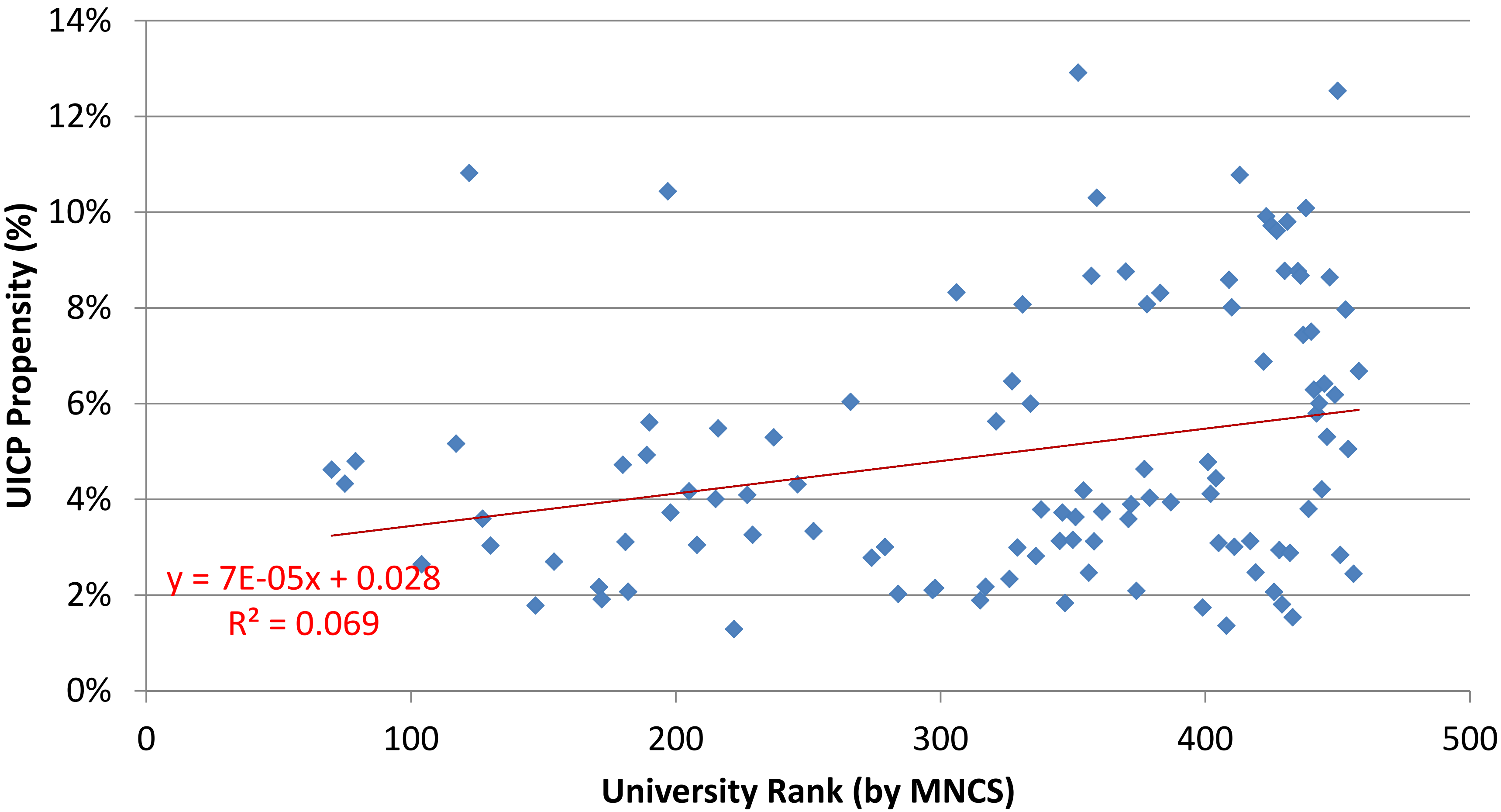
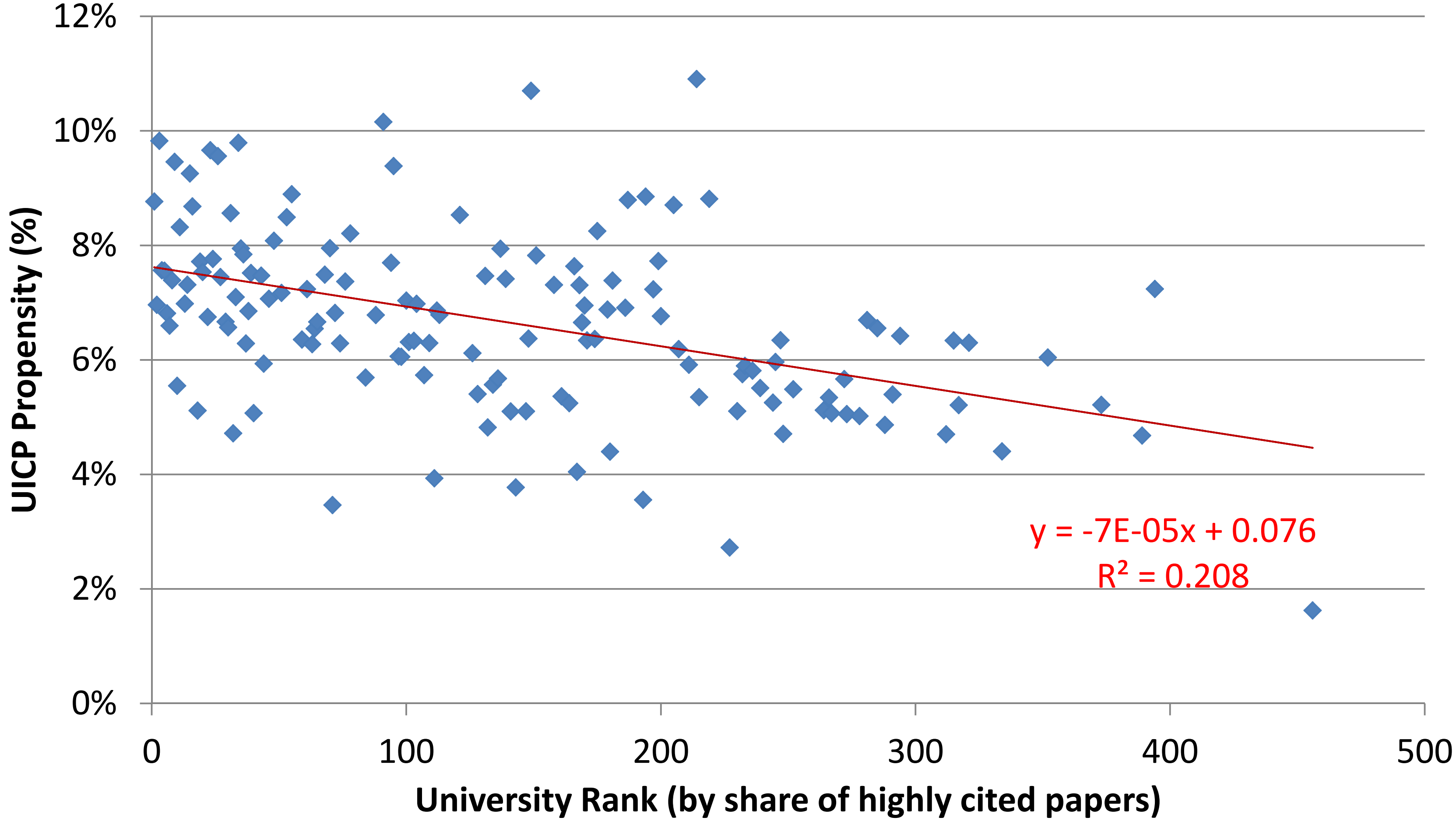
UICP Propensity vs University Ranking for Mean Normalized Citation Score: Asia



Source: Data from *Leiden Ranking 2013*

UICP Propensity vs University Ranking for Share of Highly-Cited Publications: North America



14 Source: Data from *Leiden Ranking 2013*

UICP Propensity vs University Ranking for Share of Highly-Cited Publications: OECD Europe

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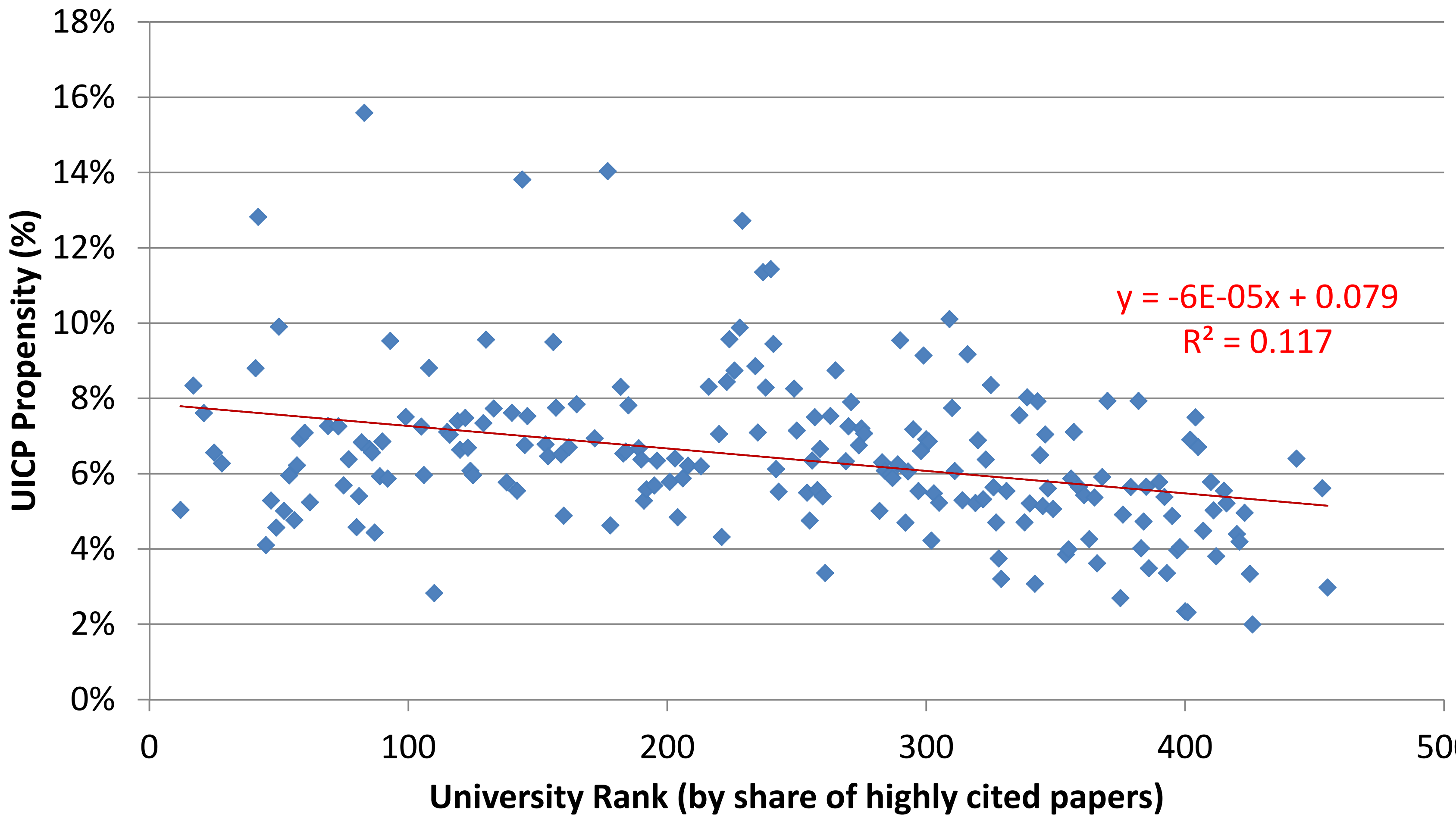

Source: Data from *Leiden Ranking 2013*

UICP Propensity vs University Ranking for Share of Highly-Cited Publications: Asia

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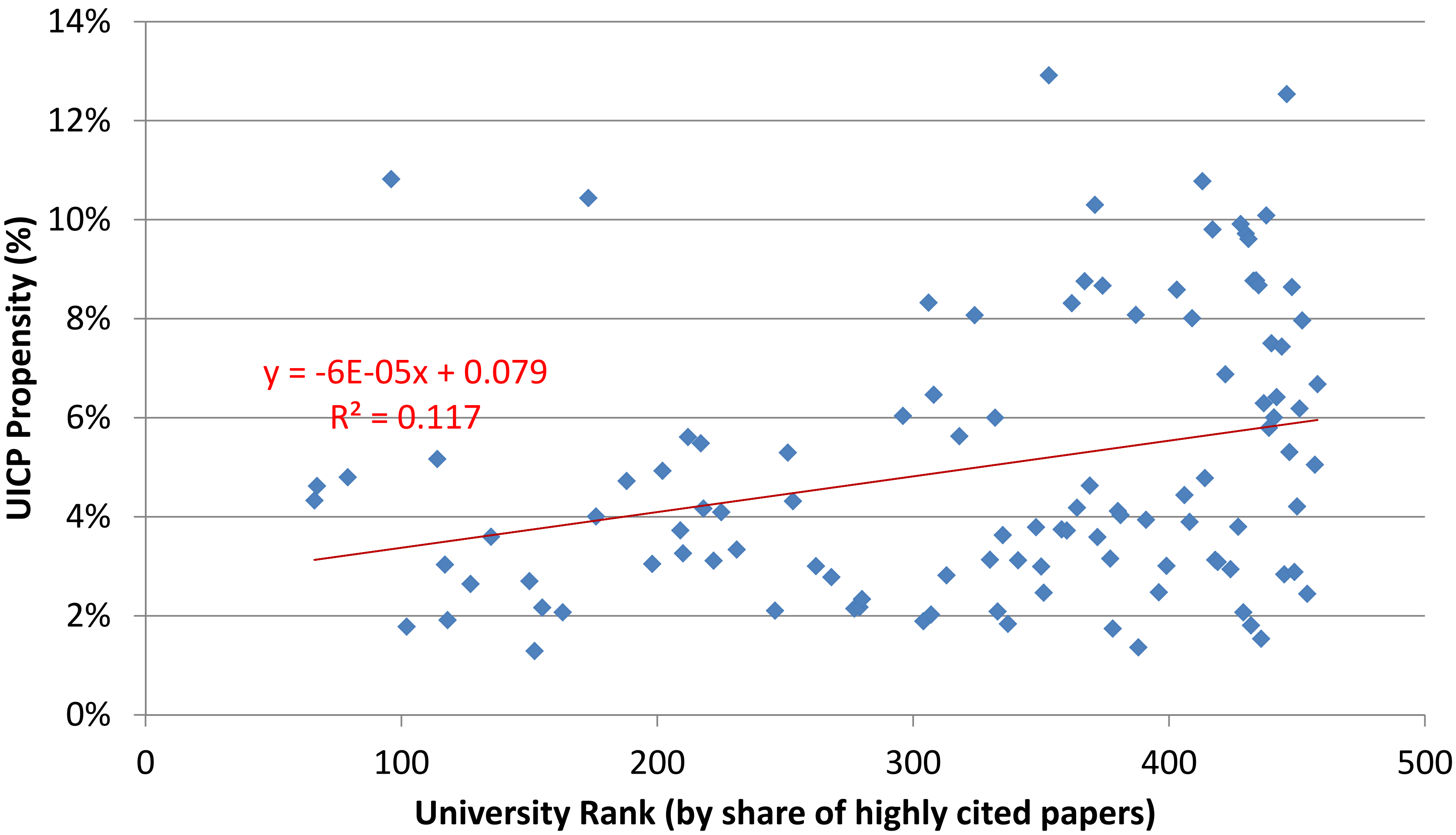

16 Source: Data from *Leiden Ranking 2013*

University R&D Collaboration and University Technology Commercialization

- Traditionally, University-industry R&D collaboration (UIC) has been viewed as an *alternative* university technology transfer pathway to technology licensing (where the licensee has no prior relationship with the university) and spin-off.
- In this view, UIC may lead to patents being granted to the university that are then subsequently licensed exclusively or mainly to the industry collaborative partners concerned
- However, UIC is not expected to contribute to spin-off creation, as the knowledge transfer is expected to be commercialized by the industry collaborative partners concerned

University R&D Collaboration and University Technology Commercialization

- However, we believe that UIC may have potential positive *Indirect (Spillover)* impacts on the other two technology transfer pathways
  - The UIC may provide the industry contacts and market insights useful for the subsequent commercialization of the technology through *licensing to other* companies in the industry or through spin-off formation to develop products for the identified markets
  - The UIC exposure may catalyze the commercialization interest and entrepreneurial orientation of the faculty researchers, leading them to embark on *new* research projects in the future that have more commercialization potential

Prior Empirical Studies on the Relationship Between R&D Collaboration & Tech Commercialization

- Using input-based measure, prior studies have found industry-funding of university research to have significant impact on university patenting and spin-off formation (Powers and McDougall 2005, O'Shea et al 2005, Powers 2003)
  - Empirical evidence on licensing is less clear, but most find no effect (Powers 2003, Sine et al 2003, Powers and McDougall 2005, Wayne and College 2010)
- However, prior studies that use the co-publication measure have mixed results
  - Studies at the individual/laboratory level found co-publications to generally increase patenting output (Carayol and Matt 2004) or spin-off formation (D'Este and Patel 2007)
  - However, a study at the organizational level found a *negative* relationship between co-publication intensity and patenting activities (Tijssen 2006)
  - No prior studies across multiple institutions have been reported

My Own Research (published in Scientometrics 2013): Data and Methodology

- 82 research-intensive North American universities
  - 70 US universities, 12 Canadian universities
  - Listed in the World University Ranking (WUR)
  - Listed in the Academic Ranking of World Universities (ARWU)
  - Have been granted at least one patent by USPTO since 1976

- Estimation model:

$$\text{University technology commercialization output} = \beta_0 + \beta_1 \text{UIC intensity} + \beta_j(\text{control variables}) + \varepsilon$$

- Multiple regression analysis
  - Separate regression analyses for each of 4 measures of technology commercialization output

Variables in Regression Model

	Construct	Operational variable
Dependent variables	Technology commercialization output	- Average no. US patents issued 2006-2009 - Average no. citation-weighted patents issued 2006-2008 - Average no. licenses executed 2006-2009 - Average no. spin-offs formed 2006-2009
Predictor variable	UIC R&D intensity	- UIC co-publication intensity Indicator 2002-2006 (Tijssen et al 2009)
Control variables (publication related)	Quantity of research output	- Average of normalized score for publication quantity 2002-2005 (ARWU's SCI sub-index)
	Quality of research output	- Average of normalized score for citations/faculty 1996-2005 (WUR's citation/faculty sub-index)
Control variables (university resources for tech commercialization)	University's experience in tech transfer	- Age of the TTO as of 2005
	Personnel resources in the TTO	- No. of licensing professionals in 2005 (FTE)
	Volume of technologies produced by universities*	- Average annual number of patents issued from 2003 to 2005*

* Used in Regressions for licenses and spin-offs only

- Control for both the quality and quantity of research output of the university important (Wong and Singh, 2009)
- Control for University Resources for Tech Commercialization (O'Shea et.al. 2005)

Summary Statistics

	n	Min.	Max.	Mean	Std. deviation
Average no. US patents issued for 2006-2009	82	0	567.0	113.0	112.3
Average no. of citation-weighted US patents issued 2006-08	82	0	293.3	50.3	53.9
Average no. of licenses 2006-2009	82	1.5	186.0	34.6	30.8
Average no. spin-offs formed 2006-2009	82	0	21.3	4.5	3.9
TTO age as at 2005	82	6	80	22.2	13.2
2005 Licensing FTE	82	1.0	20.6	6.9	4.9
Average no. US patents issued for 2003-2005	82	0	142	26.0	27.9
Average of normalized score for publication quantity 2002-2005	82	28.3	100	48.8	13.7
Average normalized score for citations / faculty 1996-2005	82	0	100	14.5	14.7
UIC intensity indicator 2002-06	82	2.6	6.2	4.3	.91

Results I: Regression for Number of US Patents Issued

	1	2	3
Constant	5.16** (0.96)	0.41 (1.42)	-3.42† (2.01)
TTO age as at 2005	0.08* (0.04)	0.06* (0.03)	0.06* (0.03)
No. Licensing FTE	0.37** (0.1)	0.1 (0.1)	0.08 (0.09)
Average of normalized score for publication quantity 2002-2005		0.10** (0.04)	0.10** (0.03)
Average normalized score for citations / faculty 1996-2005		0.14** (0.03)	0.12** (0.03)
UI co-publication intensity 2002-06			1.03* (0.4)
Adj R^2	.252	.547	.578
F	14.66**	25.47**	23.23**
N	82	82	82

Dependent variable: square root of average US patents 2006-09
Standard errors in brackets
** Significant at 1% level * Significant at 5% level † Significant at 10% level

- Hypothesis supported: UIC intensity is a significant positive determinant for patent outputs
- Both publication-related control variables positively influence patenting, as does the age of TTO

Results II: Regression for Number of Citation-weighted US Patents Issued

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	1	2	3
Constant	3.37** (.71)	.11 (1.05)	-3.26* (1.46)
TTO age as at 2005	.06* (.03)	.04† (.02)	.04* (.02)
No. Licensing FTE	.23** (.07)	.05 (.07)	.02 (.07)
Average of normalized score for publication quantity 2002-2005		.07** (.03)	.07** (.03)
Average normalized score for citations / faculty 1996-2005		.11** (.02)	.09** (.02)
UI co-publications intensity 2002-06			.91** (.29)
Adj R^2	.202	.518	.568
F	11.245**	22.762**	22.287**
N	82	82	82

Dependent variable: square root of average citation-weighted US patents 2006-08
Standard errors in brackets
** Significant at 1% level * Significant at 5% level † Significant at 10% level

- Hypothesis supported: UIC intensity is a significant positive determinant for quality-adjusted patents
- Both publication-related control variables and TTO age remain significant

Results III: Regression for No. of Licenses Executed

	1	2	3
Constant	3.10** (.45)	1.02 (.87)	-.64 (1.28)
TTO age as at 2005	.02 (.02)	.02 (.02)	.02 (.02)
No. Licensing FTE	.19** (.05)	.11* (.06)	.10† (.05)
Average annual 2003-05 US patents issued	.02** (.01)	.02 (.01)	.01 (.01)
Average of normalized score for publication quantity 2002-2005		.06** (.02)	.06** (.02)
Average normalized score for citations / faculty 1996-2005		-.01 (.02)	-.01 (.02)
UIC intensity indicator 2002-06			.42† (.24)
Adj R^2	0.355	0.403	0.418
F	15.86**	11.93**	10.71**
N	82	82	82

Dependent variable: square root of average no. of licenses executed 2006-09
Standard errors in brackets ** Significant at 1% level * Significant at 5% level † Significant at 10% level

- Hypothesis weakly supported: UIC intensity has positive impact on no. of licenses executed, but only at 10% level
- Of publication-related variables, only publication quantity has significant (positive) effect; Number of licensing professionals sig. at 10% level

Results IV: Regression for No. of Spin-offs Formed

	1	2	3
Constant	1.37** (0.16)	1.25** (0.33)	0.17 (0.46)
TTO age as at 2005	-0.003 (0.01)	-0.003 (0.007)	-0.002 (0.006)
No. Licensing FTE	0.04* (0.02)	0.03 (0.02)	0.02 (0.02)
Average annual 2003-05 US patents issued	0.02** (.003)	0.02** (0.01)	0.01** (0.01)
Average of normalized score for publication quantity 2002-2005		0.004 (0.008)	0.004 (0.007)
Average normalized score for citations / faculty 1996-2005		-0.004 (0.008)	-0.01 (0.01)
UIC intensity indicator 2002-06			0.27** (0.09)
Adj R^2	.340	.327	.397
F	14.912**	8.862**	9.90
N	82	82	82

Dependant variable: square root of average no. of spin-offs formed 2006-09
Standard errors in brackets
** Significant at 1% level * Significant at 5% level † Significant at 10% level

- Hypothesis supported: UIC intensity has significant positive impact on number of spin-offs formed
- Prior patenting performance has positive significant effect; publication-related control variables do not

Summary of Findings

- Our study confirms that University-industry co-publication in North America has a positive, independent effect on university technology commercialization propensity, over and above the effect of quality and quantity of research output (in the case of patenting) or the quantity of patenting (in the case of spin-off formation), and after controlling for the effect of TTO size and experience
- The results suggest that there may be significant spillover effect from UIC participation on future commercialization propensity of the faculty researchers concerned
- Several case studies we conducted suggest that the gestation time between UI co-publication and subsequent patenting could be long (3-8 years)

Two Selected Case Studies

- Two patents co-invented by Professor Paul Wender of Stanford's Chemistry Department, issued in 2006 and 2007, cited an article published in 2002 co-authored by Prof Wender and three employees from CellGate Inc, a pharmaceutical start-up that had a research collaboration agreement with Stanford.
- A 2011 granted patent for drug delivery system invented by Prof Robert Langer from MIT's Department of Chemical Engineering cited a 2004 paper co-authored between Prof Langer, colleagues from MIT and an employee of AP Pharma Inc, a specialty pharmaceutical company.

Implications

- Traditional View of University-Industry Research Collaboration as an *alternative* technology transfer pathway to licensing and spin-off may be too simplistic
  - UIC at one time period could lead to licensing and spin-off in later time periods
  - The knowledge developed through a UIC relationship need not be confined within that relationship, but could have *spillover effects* on other research projects of the university faculty researchers
  - Such indirect *knowledge spillover* is more likely to occur when the UIC relationship is less restrictive, i.e. follow the "Open Science" model of research collaboration

– UICP propensity can be a potential *leading* indicator of future university technology commercialization performance

– Use of UICP to study *Pasteur-Quadrant* and *Edison-Quadrant* Scientists ?

Future Research

- While my research findings pertains to North American universities only, it could be replicated for universities in Europe using EPO data & Asia using national patenting data
- As the analysis so far is conducted at the aggregate level with individual universities as the unit of analysis, I am not able to isolate the actual mechanisms through which research co-publications are translated into technology commercialization outputs, e.g. whether the university patenting outputs are generated from the same research underlying the co-publications (“direct effect”), or are based on new research inspired by the university researchers’ (or their students’ and colleagues’) exposure to industry problems in the course of the prior co-publication research (“spillover effects”).

New Research Initiative

– NUS has initiated a 2-year research collaboration with Leiden University CWTS to investigate:
  – the actual knowledge links between the co-published research and the various university technology commercialization outputs, by focusing on the ***individual*** publication authors, patent inventors and licensee organizations as the units of analysis
  – the potential impact of UI co-publications on the commercialization outputs of the ***co-authoring firms*** themselves
  – Extending data collection and analysis of university-industry ***co-patenting*** and ***patent citation links***
  – Use of UICP to identify ***Pasteur-Quadrant*** and ***Edison-Quadrant*** Scientists

Technology Commercialization Performance of NUS Co-authors of UICPs – Preliminary Findings

	No.	%
Total no. of UICP co-authors 2008-2011	862	
No. of UICP co-authors who have invented technologies which have been patented and/or licensed[1]	47	5.5
No. of UICP co-authors who have invented technologies which have been patented, licensed and/or are being actively marketed[2]	137	15.9

1 Only includes USPTO patents issued between 2009-2012 and licenses (or marketing) of technologies filed as invention disclosures between 2009-2012
2 includes patent applications pending and non-patented forms of knowledge with commercial potential

Source: Data from *Leiden Ranking 2013*

Technology Commercialization Performance of NUS Co-authors of UICPs – Preliminary Findings (contd.)

	No.	%
Total no. of NUS patents issued 2009-2012	59	
No. of NUS patents issued 2009-2012 invented by UICP co-authors[1]	29	49.2

1 Only includes UICP co-authors with articles published between 2008-2011

- Much higher patenting propensity observed among co-publishing professors than non-co-publishing professors
- Professors with UICPs a major contributor to NUS patenting outputs

Source: Data from *Leiden Ranking 2013*

New Research Initiative (continued)

- Similar Research Collaboration Agreement are being established with
  - Tsinghua University
  - Hong Kong University of Science & Technology
  - National Tsinghua University
  - National Taiwan University of Science and Technology
  - Korea Advanced Institute of Science & Technology
  - Kyushu University
- 1st Research Workshop held in Singapore June 2013
- 2nd Research Workshop to be held in Taipei early Dec 2013
- Participation of more Japanese universities welcomed!

THANK YOU