調査資料 － 203

科学における知識生産プロセス：
日米の科学者に対する大規模調査からの主要な発見事実

(Knowledge creation process in science:

Key comparative findings from the Hitotsubashi-NISTEP-Georgia Tech

scientists' survey in Japan and the US)

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Knowledge creation process in science: Key comparative findings from the Hitotsubashi-NISTEP-Georgia Tech scientists' survey in Japan and the US

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科学における知識生産プロセス：
日米の科学者に対する大規模調査からの主要な発見事実

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要旨

本調査資料では、日米の科学者に対する科学における知識生産プロセスについての大規模な質問票調査から得られた、日米の共通点や相違点について報告する。日本調査は、2009年末から2010年夏にかけて一橋大学イノベーション研究センターと科学技術政策研究所（NISTEP）が共同で実施した。米国調査は、2010年秋から2011年初頭にかけてジョージア工科大学が一橋大学イノベーション研究センターやNISTEPと連携して行った。

この調査では2001～2006年の論文で、被引用数が上位1%（高被引用度論文）とそれ以外の論文（通常論文）を抽出し、その著者に対して論文を生み出した研究プロジェクトについて尋ねた。日本の科学者からは約2,100件（回答率27%）、米国の科学者からは約2,300件（回答率26%）の回答が得られた。

Knowledge creation process in science: Key comparative findings from the Hitotsubashi-NISTEP-Georgia Tech scientists' survey in Japan and the US

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ABSTRACT

This paper reports the initial findings from large scale surveys of the scientists based in Japan and the US on the knowledge creation process in science from a comparative perspective. The survey in Japan was jointly conducted by the Institute of Innovation Research (IIR) of Hitotsubashi University and the National Institute of Science and Technology Policy (NISTEP) from the end of 2009 to the summer 2010. The survey in the US was implemented by the Georgia Institute of Technology, in collaboration with IIR and NISTEP, from autumn 2010 to early 2011. It collected around 2,100 responses from scientists in Japan and 2,300 responses from scientists in the US on their research projects that generated the scientific papers subjected to the surveys.

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調査の要約

科学の国際競争力を高めるとともに、それを基盤としたイノベーション創出を強化することが世界的に重要な課題となっている。一方で、科学における知識創造過程や科学知識からイノベーションが創出される過程についての、研究プロジェクトを対象とした体系的な実証研究は、日本のみならず世界的にも存在しない。

これを受けて、一橋大学イノベーション研究センターと科学技術政策研究所は、ジョージア工科大学と連携し、日米の研究者を対象とした大規模な質問票調査(「科学における知識生産プロセスに関する調査」)を実施した。本報告書では、質問票調査から得られた知識生産プロセスにおける日米の共通点や相違点について報告する。

日本調査は、2009 年末から 2010 年夏にかけて一橋大学イノベーション研究センターと科学技術政策研究所が共同で実施した。米国調査は、2010 年秋から 2011 年初頭にかけてジョージア工科大学が一橋大学イノベーション研究センターと科学技術政策研究所と連携して行った。

論文データベースから調査対象となる論文を抽出し、その論文の責任著者もしくはそれに類する著者に質問票調査への協力を依頼した。質問票では対象論文を生み出した研究プロジェクトについて、研究プロジェクトの動機、研究プロジェクトの発想に用いた知識源、研究チームの構成(論文著者の地位や専門分野など)、研究プロジェクトで使用した研究資金、研究プロジェクトから生み出された論文等のアウトプットを尋ねた。日本の科学者からは約 2,100 件(回答率 27%)、米国の科学者からは約 2,300 件(回答率 26%)の回答が得られた。

調査対象の約 3 分の 1 は、物理学、化学、生物学など各分野において被引用数上位 1%の高被引用度論文を生み出した研究プロジェクトであり、残りの 3 分の 2 は通常論文(高被引用度論文を除く無作為抽出論文)を生み出した研究プロジェクトである。以下の要約において、高被引用度論文を生み出した研究プロジェクトを高被引用度論文産出群、通常論文を生み出した研究プロジェクトを通常群と呼ぶ。

日米比較を行うにあたっては、世界全体の論文における分野構成を基準値に用いて、両国の分野構成の差異を調整している。以下に主要な結果を述べる。

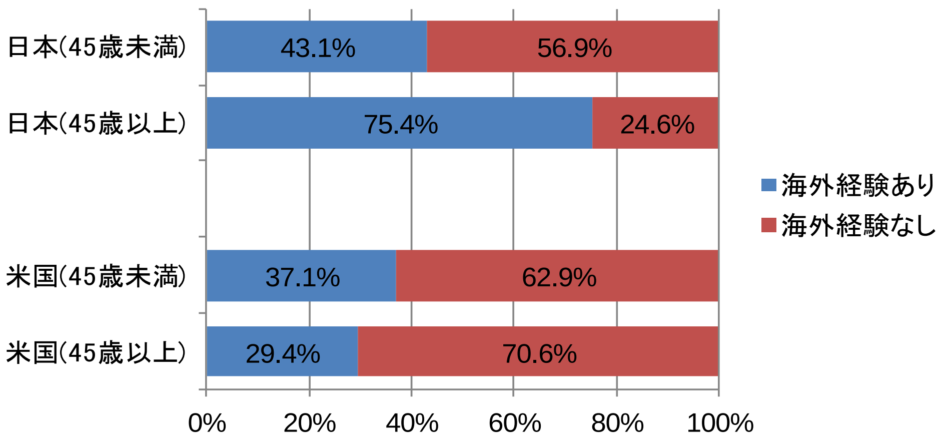
1. 回答者のプロファイル

○ 調査対象論文を投稿した時点の所属をみると、日米ともに回答者[1]の 70%以上が高等教育機関に、10%～20%が公的研究機関に、約 5%が民間企業に所属していた[本文中の Exhibit 5 を参照(以降は本文中の対応する Exhibit 番号のみを示す)]。

○ 回答者の年齢は日本の方が低かった。論文投稿時の平均年齢は、日本の高被引用度論文産出群で 42.8 歳、通常群で 43.7 歳、米国はそれぞれ 45.6 歳、46.7 歳であった[Exhibit 4]。また、およそ90%（日本の高被引用度論文産出群では 89%、米国では 92%）が研究開始時に博士号を有していた[Exhibit 8]。

○ 回答者の海外経験(1 年以上の留学又は研究滞在)については、年齢階層別の違いが日米共に見られた(図表 1 参照)。日本では 45 歳以上の回答者の 70%程度が海外経験を持つ一方で、45 歳未満では海外経験を持つ回答者の割合は 40%程度であった。米国の回答者については、45 歳未満の方が海外経験をもつ回答者の割合が高かった[Exhibit 11、Exhibit 12]。

図表 1 研究あるいは留学で、海外に1年以上滞在した経験（高被引用度論文産出群）



注 1: ここでの年齢は調査対象論文を投稿した年末時点の年齢を示す。研究プロジェクト開始時点における海外経験。
注 2: 日米の分野構成の差異を調整した結果。

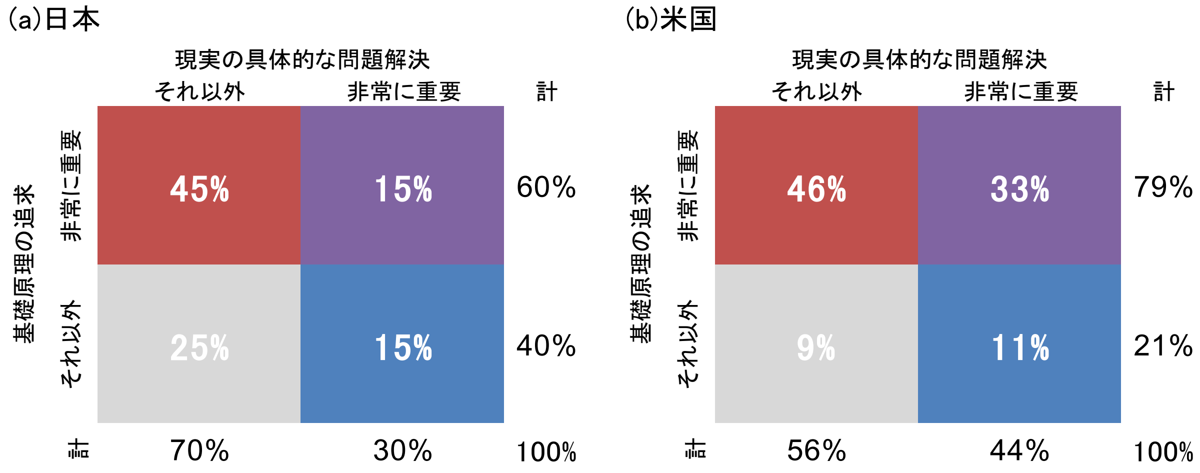
[1] 本調査では調査対象となる論文を抽出し、その論文の責任著者もしくはそれに類する著者に質問票調査への協力を依頼した。

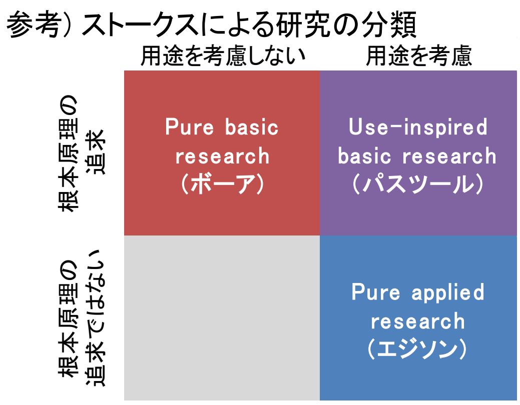
2. 研究プロジェクトの動機と研究における不確実性

○ 研究プロジェクトには、1)基礎原理の追求、2)現実の具体的な問題解決という 2 つの基本的な動機がある。この 2 つの動機を用いて研究プロジェクトを分類すると、パスツールの象限(2 つの基本的な動機の両方が非常に重要とされたもの)に当てはまる研究プロジェクトが、日米ともにかなりの割合存在した。高被引用度論文産出群におけるパスツールの象限の割合をみると、米国は日本の 2 倍以上となっている(33%対 15%、図表 2 参照)[Exhibit 16、Exhibit 17]。

○ 日米ともボーアの象限(「基礎原理の追求」のみが非常に重要な動機とされた研究プロジェクト)が最大の割合を占めた。その割合は、日本の高被引用度論文産出群では 45%、米国では 46%であった。エジソンの象限(「現実の具体的な問題解決」のみが非常に重要な動機とされた研究プロジェクト)は、日本では高被引用度論文産出群の 15%、米国では 11%を占めた[Exhibit 16、Exhibit 17]。

図表 2 ストークスに従った研究プロジェクトの分類(高被引用度論文産出群)





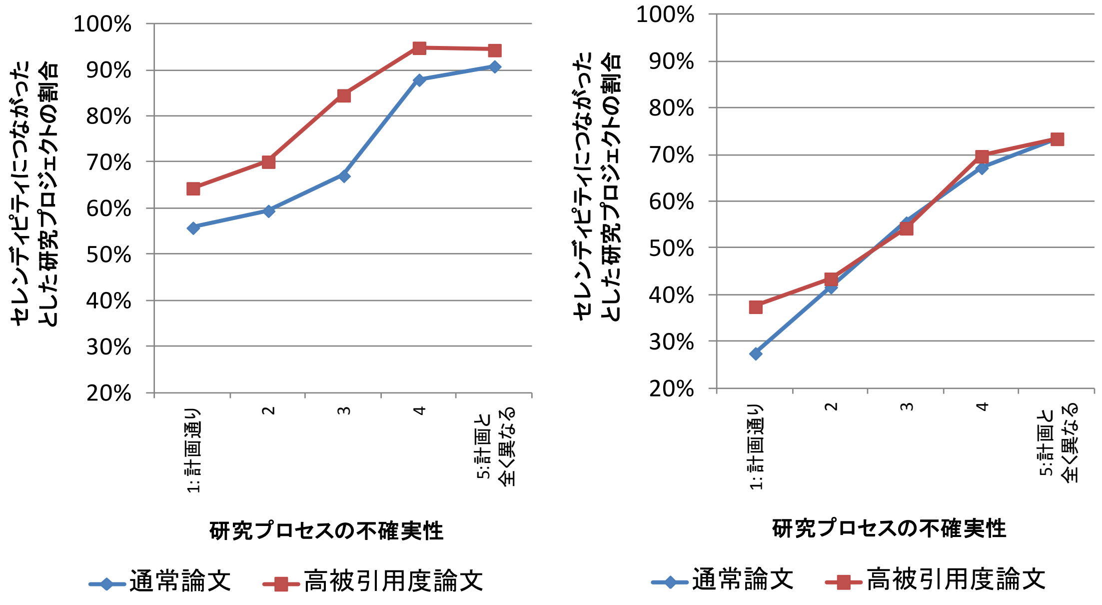
注 1: 日米の分野構成の差異を調整した結果。

○　日米ともに調査対象論文を生み出した研究には高い割合で不確実性が伴っていた。調査対象論文の主たる成果が当初の予想通りであり、研究プロセスも計画通りであったのは、日本の高被引用度論文では 11%、米国では 14%のみであった。日米ともに高被引用度論文には、かなりの割合(約30%)で、科学者の予想を大きく上回るような研究成果が含まれていた。また、パスツールの象限とボーアの象限に分類される研究プロジェクトにおいて、当初の計画と全く異なるプロセスから主たる研究成果が得られたとの回答割合が高かった[Exhibit 19、Exhibit 20、Exhibit 23]。

○　日米の多くの調査対象論文において、結果として得られた研究成果が、研究プロジェクト開始当初に提起していなかった研究課題に回答を見出すこと(セレンディピティ)につながったとされた。その割合は、研究プロセスが当初の計画と異なっていた度合いと共に高くなる(図表 3)。このように、研究プロジェクトは当初の課題に対する回答ばかりでなく、当初提起していなかった課題に対する回答も見出す。研究評価においては、このような追加的価値が正当に評価されることが重要であろう[Exhibit 25]。

図表 3 研究プロセスの不確実性とセレンディピティの関係

(a) 日本　　(b) 米国



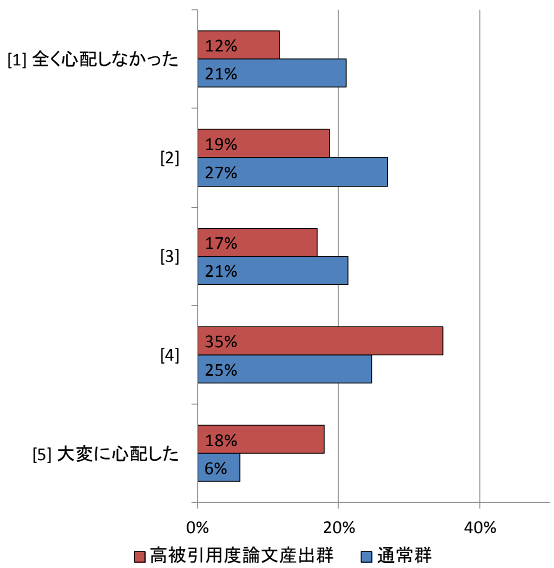
注 1: 日米の分野構成の差異は調整していない。

3. 研究プロジェクトにおける競争

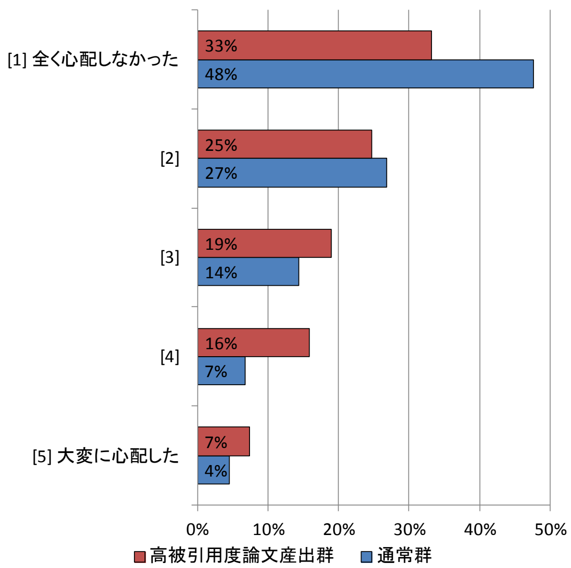
○ 日米における大半の研究者が研究競争の程度を事前に認識していた(研究競争の状況として「不明であった」を選択した回答者はごく少数であった)。また、競争相手によって研究が先行されることを、日米の多くの研究者が心配していた(図表 4 参照、日本の高被引用度論文産出群の 53%、米国の 23%)。通常群よりも高被引用度論文産出群において心配の度合いは高い。また、事前に認識している競争相手の数が増すほど、競争相手によって研究が先行されることを心配する傾向が強まる。研究が先行されることを心配する度合いは米国より日本の方が大きかった[Exhibit 26、Exhibit 27、Exhibit 28、Exhibit 29]。

図表 4 競争相手によって研究が先行されることを、どれくらい心配していたか。

(a) 日本



(b) 米国



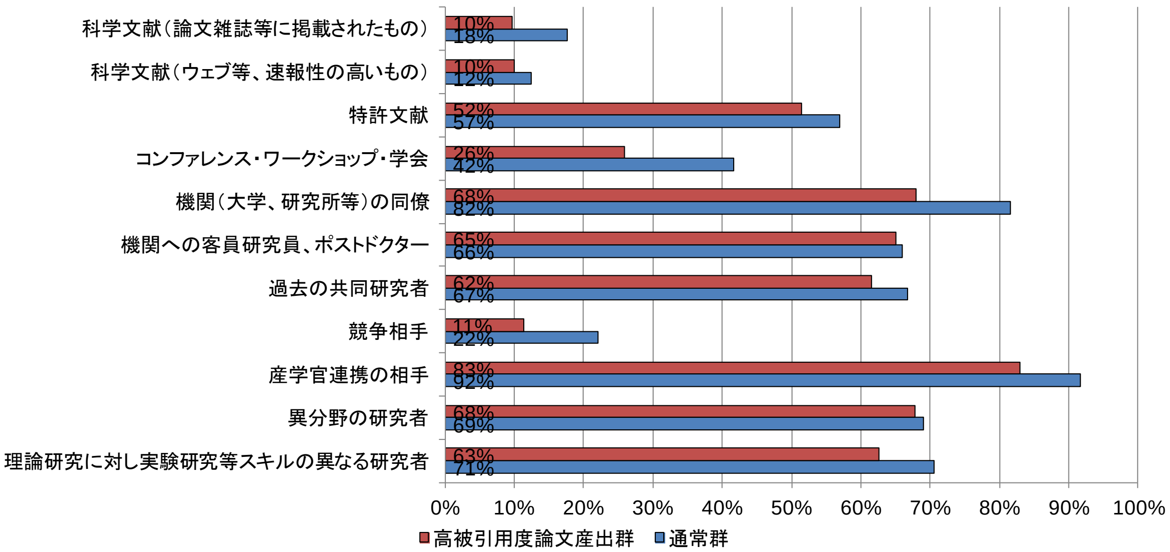
注 1: 研究プロジェクト開始時点の認識に基づく。
注 2: 日米の分野構成の差異を調整した結果。

4. 研究プロジェクトの知識源とマネジメント

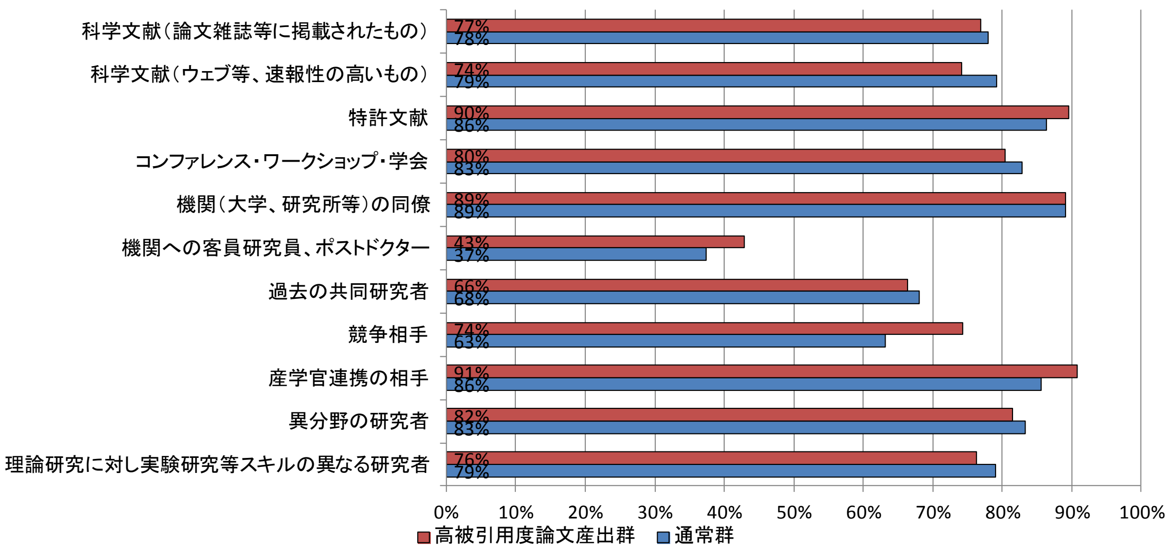
○ 日米ともに研究プロジェクトを着想するための知識源として科学論文が最も重要とされた。米国では、多くの知識源について、重要あるいは非常に重要な知識源の所在は国内（60％以上）であるとされた(図表 5(b)参照)。日本については、産学連携の相手、所属機関(大学、研究所等)の同僚など、人に関連する項目については、国内を最も重要とする比率が大きい一方、科学文献、コンファレンス・学会などについては、国内を最も重要な知識源とする比率は小さい(図表 5(a)参照)[Exhibit 30、Exhibit 31]。

図表 5 各知識源における国内の知識源の重要性

(a) 日本



(b) 米国



注 1: 回答者が、外部知識源として「重要であった」「非常に重要であった」とした項目についての評価。日本については最も鍵となる知識源を日本とした割合、米国については最も鍵となる知識源を米国とした割合を示している。
注 2: 日米の分野構成の差異を調整した結果。

○ 高被引用度論文を生み出した研究プロジェクトの方がより積極的にマネジメントされている。野心的な研究目標の設定、チーム内での情報共有やディスカッション、アウトソーシング等による作業分担、研究設備の改善、研究コミュニティの確立等の研究マネジメントを実施したという研究プロジェクトの割合が、通常群を生み出した研究プロジェクトと比べて高被引用度論文を生み出した研究プロジェクトで高かった[Exhibit 32]。

○ 米国の科学者においては、リサーチツールデータベースを活用する傾向や、インターネットを通じて遠隔地の研究者を参加させる傾向がより強く見られた[Exhibit 33]。

5. 研究チーム

○ ほとんどの科学研究はチームで行われている。高被引用度論文では、単著論文の割合が日本で3.0%、米国で5.4%であり、著者数の中央値は日本が6名、米国が5名である（通常論文では両国とも4名）。研究試料や研究設備・施設のみを提供した研究者が著者に含まれている場合が、日米とも一定割合存在した。これらの研究者が著者に含まれる割合は日本の方が高く、これは日本の論文当たりの著者数が米国より多いという点とも整合的である[Exhibit 34、Exhibit 35]。

○ 日米とも知識生産プロセスにおいて、ポストドクターや博士学生など若手研究者が重要な役割を果たしている(図表 6 参照)。とくに生命科学系において若手研究者の寄与が大きい。ポストドクターは高被引用度論文において筆頭著者として寄与する比率が高い。博士学生は通常群において筆頭著者として寄与する比率が高い[Exhibit 36、Exhibit 37]。

図表 6 対象論文の筆頭著者における若手研究者(学生、ポストドクター)の割合

			回答数	若手研究者の割合	学生	ポストドクター
通常論文	日本	自然科学系	849	35%	25%	10%
		物理科学系	448	31%	22%	9%
		生命科学系	270	45%	34%	11%
	米国	自然科学系	606	49%	31%	19%
		物理科学系	298	53%	38%	15%
		生命科学系	177	60%	33%	27%
高被引用度論文	日本	自然科学系	274	39%	19%	20%
		物理科学系	158	33%	18%	15%
		生命科学系	66	52%	20%	32%
	米国	自然科学系	261	51%	23%	28%
		物理科学系	129	57%	38%	19%
		生命科学系	59	64%	14%	51%

注 1: 高等教育部門の分析結果。筆頭著者については、著者の配列が「調査対象論文への貢献の順番」とされた回答を対象とした。
注 2: ここでは、学生(学部、修士、博士)やポストドクターを若手研究者とした。
注3: 日米の分野構成の差異は調整していない。

○　研究者の生誕国に注目すると、米国のほうが大幅に多様性に富む(図表 7 参照)。米国に注目すると生誕国が米国である若手研究者の割合は 37.8%であり、60%以上の若手研究者は米国以外が生誕国であることが明らかになった。日本の場合、若手研究者の約 3 割、シニア研究者の約 1 割が日本以外の生誕となっている。このように、米国は海外の若手研究者を自国にひきつけることで、その活力を維持している。一方で、日本については、日本生誕の研究者が主である。日本の研究開発システムにおいては人材の需要供給が、主に国内で閉じていることが再確認された[Exhibit 38]。

図表 7 対象論文の筆頭著者の国籍(通常論文、高等教育部門、自然科学系)

大学等		日本	中国	他のアジア	欧州	米国	その他・不明
日本	若手研究者(297)	71.4%	10.1%	7.7%	3.4%	1.3%	6.1%
	シニア研究者(552)	89.5%	2.7%	2.4%	2.7%	1.1%	1.6%
米国	若手研究者(299)	2.7%	14.7%	13.7%	20.4%	37.8%	10.7%
	シニア研究者(307)	3.3%	6.5%	13.4%	13.7%	53.7%	9.4%

注 1: 通常論文の高等教育部門、自然科学系の分析結果。著者の配列が「調査対象論文への貢献の順番」とされた回答を対象とした。
注 2: ここでは、学生(学部、修士、博士)やポストドクターを若手研究者、講師・助教、准教授、教授、その他をシニア研究者とした。
注 3: 日米の分野構成の差異は調整していない。

○　研究チームの構成に注目すると、日米とも高被引用度論文の方が通常論文より多様な著者で構成されている。具体的には、著者の専門分野、専門スキル、生誕国、所属セクター(産学官等)のそれぞれについて、その組み合わせの多様性が高被引用度論文の方が高い[Exhibit 39、Exhibit 40]。

○　女性研究者の研究チームへの参画度は分野によって大きく異なる。日米とも物理科学系と比べて生命科学系の方が、調査対象論文著者における女性割合が高い。日米を比較すると米国の方が、女性研究者の割合が高い。高被引用度論文と通常論文で、著者に占める女性の割合に違いは見られなかった[Exhibit 41]。

6. 研究プロジェクトのインプット

○ 研究プロジェクトの着想から開始までの期間は、日米ともおおむね1年となっているが、米国より日本の方が着想から開始までの期間が長い傾向にある。また、プロジェクト開始から対象論文を投稿するまでの期間も、日米を比較すると日本の方が長い傾向にある[Exhibit 42、Exhibit 43]。

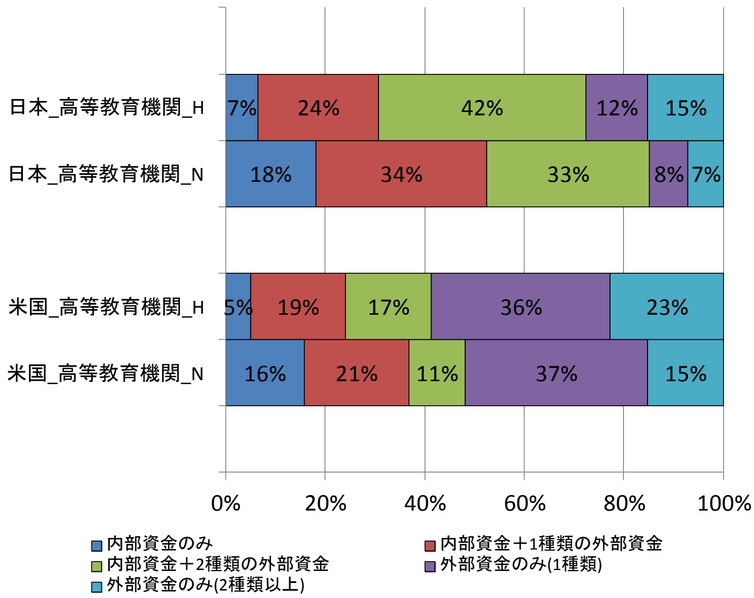
○ 研究プロジェクトで費やした全人月でみると、日本の研究プロジェクトは高被引用度論文産出群、通常群のいずれについても米国の 3 倍程度の人月を費やしている[Exhibit 44]。研究プロジェクトから生み出された論文数をみても日本は米国の約 3 倍であることから、米国においては研究プロジェクトが日本と比べて狭く定義または解釈されていると考えられる。

○ 1人月あたりの研究資金を日米で比較すると、日本は$3,000[1]、米国$4,900(共に高被引用度論文産出群)であり、米国の研究プロジェクトの方が人月当たりの研究資金が高くなっている。この違いの要因については詳細な分析が必要であるが、一部は日米の研究費における人件費の取り扱いの相違に起因すると思われる。

○ 日本の高被引用度論文産出群が使用した研究費は中央値で通常群の 5 倍となっている。一方で、人月における両者の差(中央値)は 1.4 倍となっており、高被引用度論文産出群の方が多くの研究資金を費やしている傾向がみられる。米国における高被引用度論文産出群と通常群の差(中央値)は、人月で 1.5 倍、研究資金で 1.8 倍であり、日本のような大きな違いは見られなかった[Exhibit 45]。

○ 日本の高等教育機関における研究プロジェクトの約 70%は、内部資金と外部資金を複合的に利用することで実施されている。一方、米国の高等教育機関において内部資金と外部資金を共に利用している研究プロジェクトの割合は 30～40%であり、50%以上が外部資金のみによって実施されている(図表 8 参照)[Exhibit 46]。

図表 8 研究資金源の組合せ



注 1: 内部資金とは、運営費交付金等に基づく校費などを指す。
注 2: 各結果とも上に示されている(セクター名の後にHと書かれている)のが高被引用度論文産出群の結果、下に示されている(セクター名の後にNと書かれている)のが通常群の結果である。
注 3: 日米の分野構成の差異は調整していない。

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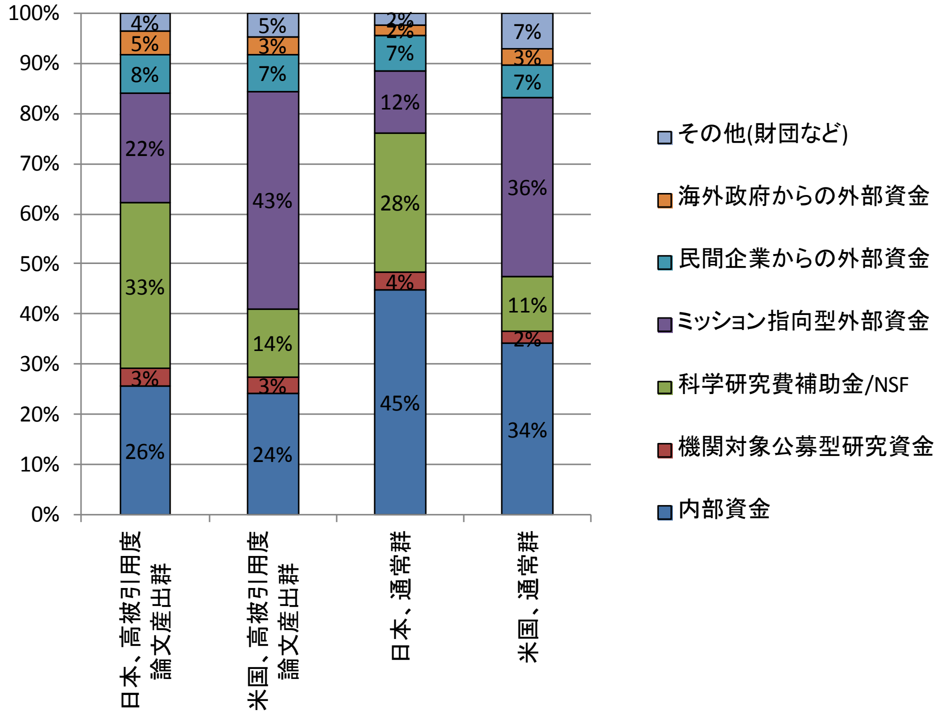
[1] ここでは 1 ドル=100 円として計算した。

○ 日米における主要な研究資金源のうち、科学研究費補助金と米国国立科学財団(NSF)からの外部資金を自由発想型、研究プロジェクトを対象とする他の外部資金をミッション指向型と分類すると、ミッション指向型外部資金が米国において大きな割合を占めることが分かった(図表 9 参照)。

○ 研究プロジェクトで用いたミッション指向型外部資金の割合(研究プロジェクト単位)をみると、米国の高被引用度論文産出群で 43%、日本では 22%であった。民間からの資金については、両国とも比較的少額であり類似した割合を占めている。(研究プロジェクト単位でみると日本の高被引用度論文産出群で 8%に対し、米国では 7%)。物理科学系や生命科学系の高等教育部門における民間資金源の割合をみると、米国より日本で高い傾向にある[Exhibit 47、Exhibit 48]。

図表 9 研究資金源の構造



注 1: 内部資金とは、大学等では運営費交付金等に基づく校費や、企業における自社資金などを指す。
注 2: ミッション指向型外部資金には以下を含めた。
日本: JST や NEDO からの資金、厚生労働科学研究費補助金、その他の公募型研究資金(機関対象公募型研究資金、科学研究費補助金、JST や NEDO からの資金、厚生労働科学研究補助金を除く)、非公募型研究資金(政府主導の国家プロジェクトなど)
米国: NIH、DOD、DOE からの資金、その他の公募型研究資金(機関対象公募型研究資金、NSF、NIH、DOD、DOE からの資金を除く)、非公募型研究資金(政府主導の国家プロジェクトなど)
注 3: 日米の分野構成の差異を調整した結果。

7. 研究プロジェクトのアウトプット

○ 研究プロジェクトの成果は、論文、人材育成、特許出願、研究成果の実施許諾や譲渡、スタートアップ企業と多様である。通常群と比べて高被引用度論文産出群の方が多数の論文を生み出しており、それ以外の成果に結びつく割合も高い(図表 10 参照)[Exhibit 59]。

図表 10 研究プロジェクトのアウトプットの状況（各アウトプットを生み出した研究プロジェクトの割合）

		日本			米国		
		高被引用度論文産出群(a)	通常群(b)	(a)/(b)	高被引用度論文産出群(a)	通常群(b)	(a)/(b)
研究プロジェクトに費やした人月（中央値）		100	72	1.4	36	24	1.5
研究プロジェクトが生み出した査読付き論文数（中央値）		15	8	1.9	5	3	1.7
ポストドクターの育成	全体	61%	37%	1.6	61%	41%	1.5
	国内生誕	50%	28%	1.8	15%	19%	0.8
	海外生誕	36%	20%	1.8	46%	30%	1.5
博士号取得者	全体	73%	65%	1.1	59%	50%	1.2
	国内生誕	66%	58%	1.1	36%	27%	1.3
	海外生誕	32%	21%	1.6	37%	31%	1.2
修士号取得者	全体	49%	47%	1.0	20%	21%	0.9
	国内生誕	47%	45%	1.0	13%	15%	0.9
	海外生誕	11%	8%	1.4	8%	9%	0.9
特許出願		39%	22%	1.8	17%	8%	2.1
スタートアップ企業		2%	2%	1.4	4%	1%	3.1
研究成果の実施許諾や譲渡		14%	7%	1.9	9%	4%	2.0
標準		13%	8%	1.6			
共同研究・受託研究		78%	60%	1.3			
技術指導		39%	27%	1.4			
リサーチツール		50%	41%	1.2			
継続研究		90%	75%	1.2			

注 1: 日米の分野構成の差異を調整した結果。
注 2: 上の表に示すように、米国の研究プロジェクトのサイズ(人月や査読論文数)は日本と比べて小さい。
注 3:「分からない」という回答については、アウトプットにつながっていないと解釈した。

○ 研究プロジェクトから生み出された査読付き論文数の中央値を、高被引用度論文産出群と通常群で比較すると日本では 1.9 倍、米国では 1.7 倍となっている。これは、研究プロジェクトに費やした人月の比率(日本 1.4 倍、米国 1.5 倍)より大きく、費やした研究資金の比率(日本 5.0 倍、米国 1.8 倍)よりは小さい[Exhibit 49]。

○ 研究プロジェクトの教育面でのアウトプットも重要である。特に博士号取得者やポストドクター育成に貢献しており、日本（米国）の高被引用度論文産出群の 73%(59%)が博士号取得者を生み出している。高被引用度論文産出群と通常群を比較すると、日米において前者の方が博士号取得者を生み出す割合が高い傾向にある[Exhibit 50、Exhibit 51、Exhibit 52]。

○ 米国より日本の研究プロジェクトの方が特許出願につながっている（日本の高被引用度論文産出群

で 39%、米国では 17%）［Exhibit 53、Exhibit 54］。また、特許の実施許諾や譲渡についても、日本の研究プロジェクトの方が高い傾向にある(日本の高被引用度論文産出群で 14%であるのに対し、米国では 9%)[Exhibit 55]。ただし、米国と比べて日本の研究プロジェクトが広めに定義されている点に注意が必要である(人月や論文数で約 3 倍)。

○ 両国ともに、特許の実施許諾あるいは譲渡に当たって多くの事例（70%-80%）でノウハウの提供も同時に行われている[Exhibit 56]。これは特許の実施許諾や譲渡に加えて、ノウハウの提供といった研究者側の努力が技術移転を行う上で重要であることを示している。新たなスタートアップ企業につながった研究プロジェクトは、両国ともごく僅かであった（日本の高被引用度論文産出群のうち 2%、米国の 4%)[Exhibit 57、Exhibit 58]。

本編

（裏白紙）

1 Background and Purpose of the Research

Developing systematic and objective data on the knowledge creation process in science at project level has become very important, given that science is expected to play an important role in the innovation process of a nation and the knowledge creation process in science has become more complex in recent years. Science has increasing become teamwork, requiring variety of skills, knowledge and research equipments have become more expensive, while scientific competition has become more global. Active researches based on the bibliographic information have been being conducted in recent years (see for an example, Wuchty, Jones, and Uzzi (2007) and Jones, Wuchty and Uzzi (2008)). However, the information one can retrieve from the bibliographic information is limited. The bibliographic information does not provide the information about motivation for the research project, external knowledge sources that inspired the research project, the history of the research project, research funding, and research outputs and impacts. As one will later see, authors are often not researchers and researchers are often not authors.

The Institute of Innovation Research of Hitotsubashi University and the National Institute of Science and Technology Policy of the Ministry of Education, Culture, Sports, Science and Technology have decided to jointly carry out the "Survey on the Knowledge Creation Process in Science". The purpose of this survey is to collect the objective data that show structural characteristics in the knowledge creation process in science and the process of creating innovation from scientific knowledge based on comprehensive questionnaire surveys for researchers in all fields of science both in Japan and in the United States (more than seven thousand researchers each in the two countries). Japanese survey was conducted from the end of 2009 to the early summer of 2010 and about 2,100 researchers responded to the survey. The survey in the United States was implemented from the autumn of 2010 to March 2011, in collaboration with Georgia Institute of Technology and about 2,300 researchers responded to the survey. This report covers the initial comparative findings from the two surveys.

The survey tries to answer the following basic questions about scientific research. The structural understandings of these issues will be valuable for designing of science policy, too.

1. What percentage of research projects conducted by researchers is in pure basic research ("Bohr's quadrant" in the classification of Stokes), use-inspired basic research (Pasteur's quadrant), and pure applied research (Edison's quadrant)?
2. How long does it take from the conceiving of the research projects to internationally recognized research outputs? What kind of research funds do researchers rely on in the research project?
3. To what extent do researchers recognize *ex-ante* the status of global competition in research and how seriously are concerned over priority loss?
4. How important is the serendipity in research and which kind of research is more likely to spawn the serendipity?
5. To what extent research teams are interdisciplinary and international? How frequent do researcher move across the organizations?
6. What kind of research management was implemented in research projects?

7. What percentage of the research outputs result in patents and how frequently the provision of knowhow is involved? What about the production of the research tools.
8. What kinds of commercialization paths are pursued in the innovation processes based on the outputs of scientific research?

We have constructed comprehensive and standardized micro-data set from the two surveys, covering the characteristics of research projects, the composition of the research team, research funding used in the research projects, external knowledge sources that inspired the research project, serendipities in the research projects, outputs yielded by the research projects among others. This report summarizes the basic findings from comparative tabulation of the survey results of Japan and the US.

The rest of the paper consists of the following 9 sections. Section 2 provides an overview of the survey method. Section 3 provides the characteristics of the focal papers. Section 4 provides the results of the survey on the motivations for the research and uncertainty in research both in the process and in the output. Section 5 discusses the results on research competition. Section 6 discusses the results on knowledge sources and research management. Section 7 discusses the characteristics of research teams, based on the survey results on the authors of the focal paper. Section 8 discusses the results on the labor and the other inputs for research projects. Section 9 discusses the outputs and the channels of impacts of the research projects on industrial innovation. Section 10 concludes.

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We would like to also thank those who provided comments and suggestions to the project at various stages of the research. In particular, we would like to thank the researchers who kindly became subject to pre-testing and provided very useful comments to the design of questionnaires and Terutaka Kuwahara, the director of the NISTEP, who provided strong supports to the project. The research team of this project consists of the following.

Sadao NAGAOKA(PI)	Professor, Institute of Innovation Research, Hitotsubashi University Affiliated Fellow, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology Research Counselor, Research Institute of Economy, Trade and Industry
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Manabu ETO	Professor, Institute of Innovation Research, Hitotsubashi University
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Paula E. STEPHAN	Professor, Georgia State University

	Fellow, National Bureau of Economic Research
John P. WALSH	Professor, Georgia Institute of Technology
	International Affiliated Fellow, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology

(As of March 31 2011)

2 OVERVIEW OF THE SURVEY METHOD

2－1 SELECTION OF THE SURVEY TARGETS

The survey targets were selected through the following procedures. Details in the selection process in Japanese survey were shown in the report of the Japanese survey[1]. The same selection procedure was adopted in the US survey.

(1) Identification of possible focal papers

The population of the survey was articles and letters in the Web of Science database of Thomson Reuters. Reviews were excluded from the population. The objective of the review papers is to conduct the survey of the existing studies, thus they are not likely to cover a research project. The time window of the papers for the survey is from 2001 to 2006 (database year). Database year refers to the year when the documents are recorded into the database. The bibliographic information and the number of citations as of the end of December 2006 were used in the survey. Two sets of the possible focal papers were selected from the population.

1. Highly Cited Papers (approximately 3,000 in each survey)
   Top 1% highly cited papers in each journal field (22 fields in total) and in each database year; at least one organization of authors should be located in Japan for the Japanese survey and in the US for the US survey. All highly cited papers in the time window were selected for the Japanese survey and approximately 3,000 highly cited papers were randomly selected from the highly cited papers in the US survey.

2. "Normal" Papers (approximately 7,000 in each survey)
   Randomly selected papers in each journal field and in each database year from the population of the survey, excluding the above highly cited papers; at least one organization of authors should be located in Japan for the Japanese survey and in the US for the US survey.

In this report, highly cited papers are described as "H papers" and normal papers are described as "N papers." The journal field refers the 22 scientific fields in the *Essential Science Indicators* ("ESI" hereafter) of Thomson Reuters (see Exhibit 1). We covered all fields, including the social science, although the coverage of social science journals by the database is not comprehensive and we have got a relatively small number of the publications by Japanese authors in this field.

(2) Identification of possible survey targets and research projects for the survey

Corresponding authors or equivalents of approximately 20,000 possible focal papers were searched and identified as survey targets. If multiple papers were assigned to a single author, one paper was randomly selected as a focal paper while the priority was given to the H papers in the selection process.

As a result, totally 7,652 survey targets were identified for Japanese survey. Of those, there

[1] There is a corresponding Japanese Working Paper with detailed statistical tables, published in November 2010 on which this paper is based (available from http://www.iir.hit-u.ac.jp/iir-w3/file/WP10-07NagaokaIgamiEtoIjichi.pdf).

are 1,932 researchers whose focal paper is the H paper; and there are 5,720 researchers whose focal paper is the N paper. Totally 8,864 survey targets were identified for the US survey. Of those, there are 2,882 researchers whose focal paper is the H paper; and there are 5,982 researchers whose focal paper is the N paper.

This report describes the research projects that are from H papers as "H projects" and describes the research projects that are from N papers as "N projects." The project is defined as a series of research activities in which the specified focal paper and the other closely related research outcomes were produced.

2—2 IMPLEMENTATION OF THE SURVEY

The questionnaire survey was conducted on the Web. A request of the cooperation to the survey, the web address of the questionnaire survey website, user ID, and password were sent to the researchers by either e-mail or post mail. If a researcher recommended another researcher, the request of cooperation was sent again to the recommended researcher. The basic time-lines of the Japanese survey and the US survey were shown below.

Japanese survey

- Survey launch: December 21, 2009
- Initial due date: February 7, 2010
- Reminders were sent twice (mid of Jan., mid of Feb.)
- Final due date: April 11, 2010

US survey

- Initial mail-outs: September - November, 2010
- Reminder emails: November - December, 2010
- Second (final) reminders: January, 2011

2—3 FIELD CLASSIFICATION FOR THE ANALYSIS

Most results of the survey to be presented in this paper are based on 10 fields, aggregated from 22 ESI journal fields. Some results are based on large 3 fields obtained by a further aggregation of the 10 fields. Natural sciences represent the aggregation of the large 3 fields. The relation between the 22 ESI journal fields, the 10 fields, and the large 3 fields is shown in Exhibit 1. Papers of multidisciplinary fields are reclassified into one of 21 fields based on the backward citations of the multidisciplinary papers.

Exhibit 1 Relation between the 22 ESI journal fields, the 10 fields, and the large 3 fields

<table>
<tr><th>22 ESI journal fields</th><th>10 fields</th><th>large fields</th></tr>
<tr><td>Chemistry</td><td>1_Chemistry</td><td rowspan="9">Physical Sciences</td></tr>
<tr><td>Materials Science</td><td>2_Materials Science</td></tr>
<tr><td>Physics</td><td rowspan="2">3_Physics&Space_Science</td></tr>
<tr><td>Space Science</td></tr>
<tr><td>Computer Science</td><td rowspan="2">4_Computer Science&Mathematics</td></tr>
<tr><td>Mathematics</td></tr>
<tr><td>Engineering</td><td>5_Engineering</td></tr>
<tr><td>Environment/Ecology</td><td rowspan="2">6_Environment/Ecology&Geosciences</td></tr>
<tr><td>Geosciences</td></tr>
<tr><td>Clinical Medicine</td><td rowspan="2">7_Clinical Medicine&Psychiatry/Psycholog</td><td rowspan="2">Medicine</td></tr>
<tr><td>Psychiatry/Psychology</td></tr>
<tr><td>Agricultural Sciences</td><td rowspan="2">8.1_Agricultural Sciences&Plant & Animal Science</td><td rowspan="8">Life Sciences</td></tr>
<tr><td>Plant & Animal Science</td></tr>
<tr><td>Biology & Biochemistry</td><td rowspan="6">8.2_Basic Life Sciences</td></tr>
<tr><td>Immunology</td></tr>
<tr><td>Microbiology</td></tr>
<tr><td>Biology & Biochemistry</td></tr>
<tr><td>Neuroscience & Behavior</td></tr>
<tr><td>Pharmacology & Toxicology</td></tr>
<tr><td>Multidisciplinary</td><td>Either of 22 ESI journal fields was assigned based on the analysis of the backward citations</td><td>Either of 22 ESI journal fields was assigned based on the analysis of the backward citations</td></tr>
<tr><td>Economics & Business</td><td rowspan="2">S_Social Sciences</td><td rowspan="2"></td></tr>
<tr><td>Social Sciences, general</td></tr>
</table>

2－4 SECTOR CLASSIFICATION FOR THE AFFILIATION OF RESEARCHERS

The survey asked a researcher to identify the sector of the organization with which he/she was affiliated when the focal paper was submitted. This sector is used for analysis. The five-sector classification shown below is used in this report.

(1) Higher education institutions
(2) Public research institutions
(3) Private firms
(4) Private non-profit organisations
(5) Others

In Japanese survey, the higher education institutions include universities, inter-university research institutions and colleges of technology. The public research institutions include national experimental and research institutions, independent administrative corporations for research, special corporations and experimental and research institutions of local governments.

In addition to the five-sectors, "Hospitals" were explicitly included in the type of organization in the US survey. No guideline exists about the treatment of hospitals in the sector classification in the R&D statistics, because of the differences in the healthcare system across countries. In this report, we incorporated the hospitals in the US surveys into the higher education institutions.

2－5 RESPONSE RATE BY FIELD

Out of 7,562 survey targets, we got 2,081 responses in the Japanese survey. The total response rate is 27%. The response rate is 29% for the H papers and 27% for the N papers. The total response rate in the US survey is 26%. We got 2,329 responses out of 8,864 survey targets. The response rate is 28% for the H papers and 26% for the N papers.

The response rate in the H papers is higher than that in the N papers in both countries. Response rate by field is shown in Exhibit 2. The fields shown in Exhibit 2 include multidisciplinary field. In this survey, the papers of multidisciplinary field, those published in the journals like *Nature* and *Science*, were reclassified into either of 10 fields based on the references in the papers. There are, however, 13 papers in Japanese survey and 78 papers in the US survey that could not be reclassified. These papers were excluded from the analysis by field.

The response rate in both countries exceeds 30% in environment/ecology & geosciences; and agricultural sciences & plant & animal science. In additional to these fields, the response rate in Japanese survey exceeds 30% in chemistry and materials science.

The response rate in clinical medicine & psychiatry/psychology is 21% in both countries and is the lowest among the 10 fields excluding the residual multidisciplinary field. Comparison between H papers and N papers by field shows that the response rates in the H papers are higher than or equal to those in the N papers in almost all fields.

Exhibit 2 Response rate by field

(a) Japan

	All Focal Papers			H papers			N papers			
	Survey targets	Responded	Response rate	Survey targets	Responded	Response rate(A)	Survey targets	Responded	Response rate(B)	(A) - (B)
1_Chemistry	837	257	30.7%	208	71	34.1%	629	186	29.6%	4.6%
2_Materials Science	472	142	30.1%	127	43	33.9%	345	99	28.7%	5.2%
3_Physics&Space_Science	1407	380	27.0%	400	127	31.8%	1007	253	25.1%	6.6%
4_Computer Science&Mathematics	323	77	23.8%	66	16	24.2%	257	61	23.7%	0.5%
5_Engineering	707	206	29.1%	197	68	34.5%	510	138	27.1%	7.5%
6_Environment/Ecology&Geosciences	361	115	31.9%	81	30	37.0%	280	85	30.4%	6.7%
7_Clinical Medicine&Psychiatry/Psycholog	1278	264	20.7%	325	66	20.3%	953	198	20.8%	-0.5%
8.1_Agricultural Sciences&Plant & Animal Science	597	192	32.2%	165	60	36.4%	432	132	30.6%	5.8%
8.2_Basic Life Sciences	1504	404	26.9%	351	83	23.6%	1153	321	27.8%	-4.2%
9_Multidisciplinary(*)	13	2	15.4%	0	0	-	13	2	15.4%	-
S_Social Sciences	153	42	27.5%	12	2	16.7%	141	40	28.4%	-11.7%
Total	7,652	2,081	27.2%	1,932	566	29.3%	5,720	1,515	26.5%	2.8%

(b) US

	All Focal Papers			H papers			N papers			
	Survey targets	Responded	Response rate	Survey targets	Responded	Response rate(A)	Survey targets	Responded	Response rate(B)	(A) - (B)
1_Chemistry	663	184	27.8%	204	66	32.4%	459	118	25.7%	6.6%
2_Materials Science	261	72	27.6%	82	22	26.8%	179	50	27.9%	-1.1%
3_Physics&Space_Science	993	259	26.1%	347	96	27.7%	646	163	25.2%	2.4%
4_Computer Science&Mathematics	508	131	25.8%	165	39	23.6%	343	92	26.8%	-3.2%
5_Engineering	571	162	28.4%	186	57	30.6%	385	105	27.3%	3.4%
6_Environment/Ecology&Geosciences	522	193	37.0%	183	68	37.2%	339	125	36.9%	0.3%
7_Clinical Medicine&Psychiatry/Psycholog	2165	446	20.6%	718	155	21.6%	1447	290	20.0%	1.5%
8.1_Agricultural Sciences&Plant & Animal Science	508	157	30.9%	181	60	33.1%	327	97	29.7%	3.5%
8.2_Basic Life Sciences	1954	506	25.9%	602	159	26.4%	1352	348	25.7%	0.7%
9_Multidisciplinary(*)	78	11	14.1%	2	0	0.0%	76	11	14.5%	-14.5%
S_Social Sciences	641	208	32.4%	212	76	35.8%	429	132	30.8%	5.1%
Total	8,864	2,329	26.3%	2,882	798	27.7%	5,982	1,531	25.6%	2.1%

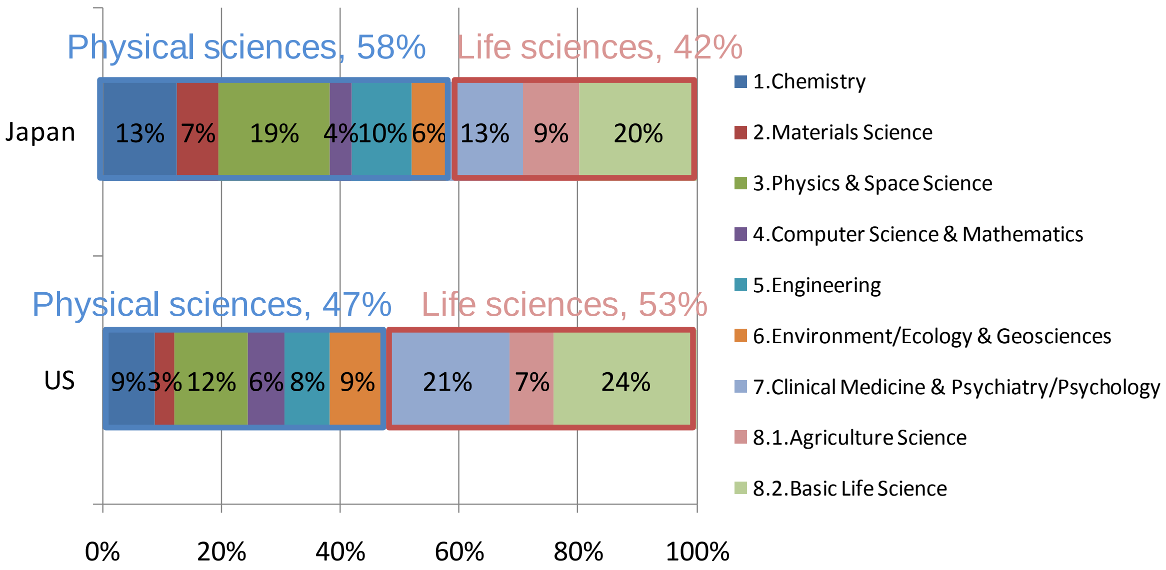
Note1: (*) Papers in multidisciplinary field that could not be reclassified.

2－5－1　Field Composition of the Respondents

The field composition of the respondents is shown in Exhibit 3.　The exhibit shows the results of the all respondents and social sciences are excluded from the total.　In Japan, the fields related to physical sciences account for 58% and the fields related to life sciences account for 42% of the total.　In contrast, the former accounts for 47% and the latter accounts for 53% of the total in the US survey.　The results exemplify the dissimilarity in the national portfolio in the scientific activities.　Japan put more emphasis on physical sciences compared to the US.

Since the activities in the research projects varies across the fields of science, the international comparison between Japan and US should be done after eliminating the influence of the dissimilarity in the field composition.　In order to adjust the differences in the field composition, we adopted the field composition in the world as the baseline.　Weighted natural sciences in this report represents results in which each respondent's answer were weighted in order to adjust the field composition in Japanese (or the US) samples to the field composition in the world.

Exhibit 3 Field composition of the respondents in natural sciences



Note1:　Results of all respondents. Social sciences are excluded from the total.

2－6 CHARACTERISTICS OF THE RESPONDENTS

2－6－1 Age

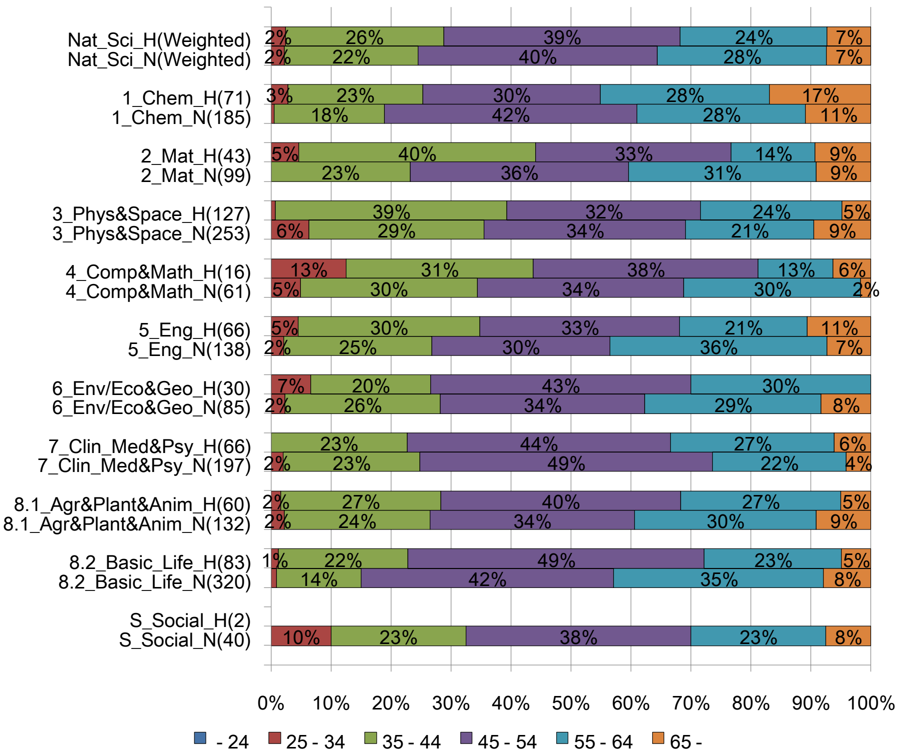
Exhibit 4 summarizes the age distribution of the respondents, at the time when the survey was conducted (2010) and when the focal paper was submitted. There exist around 7 years' difference between the two average ages, which reflect both the lag between the submission and the publication as well as that between the publication and the survey.

Average ages of respondents in natural sciences when the survey was conducted are 50.3 (H papers) and 51.3 (N papers) in Japanese samples and 53.4 (H papers) and 54.4 (N papers) in the US samples. The average ages are approximately 3 years higher in the US samples compared to Japanese samples in both H and N papers.

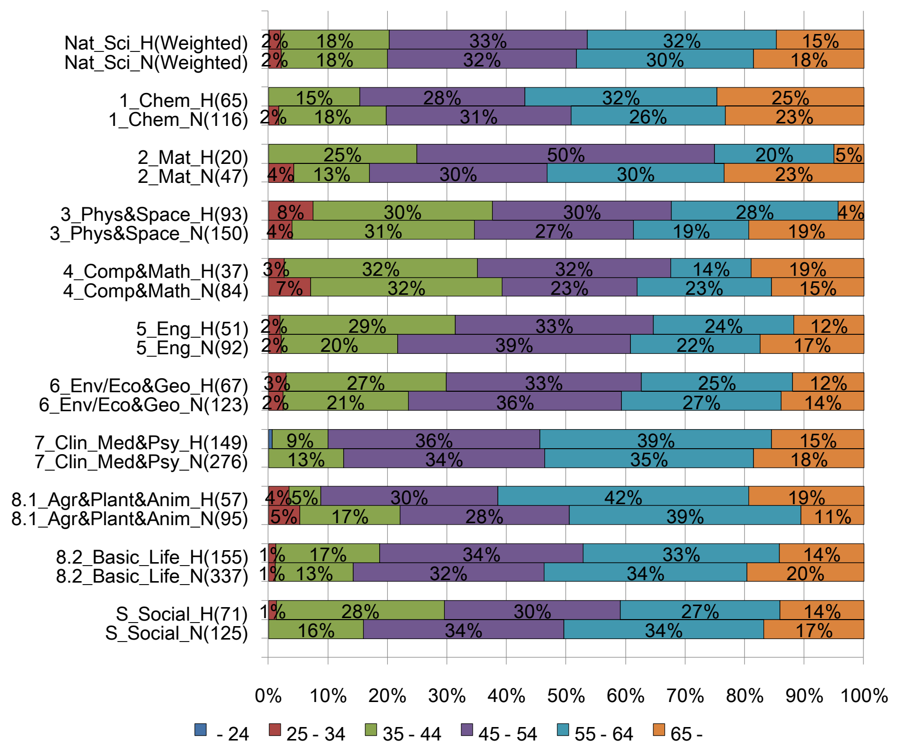
As for the submission age, the average ages of respondents in natural sciences are 42.8 (H papers) and 43.7 (N papers) in Japanese samples; and 45.6 (H papers) and 46.7 (N papers) in the US samples. The average ages of both types of papers at the submission are about 7 years younger compared to the average age when the survey was conducted, i.e., average ages in 2010. The focal papers were published between 2001 and 2006. Considering around one year time-lag between the submission and the publication of the focal papers, it could be said that there would be 5 - 10 years time-lag between the submission of the focal papers and 2010. This will explain the differential between the average ages of respondents when the focal paper was submitted and when the survey was conducted. The ratio of respondents whose age is 34 or less is relatively high in physics & space science and computer science & mathematics in both Japanese and the US samples.

Exhibit 4 Age distribution of respondents

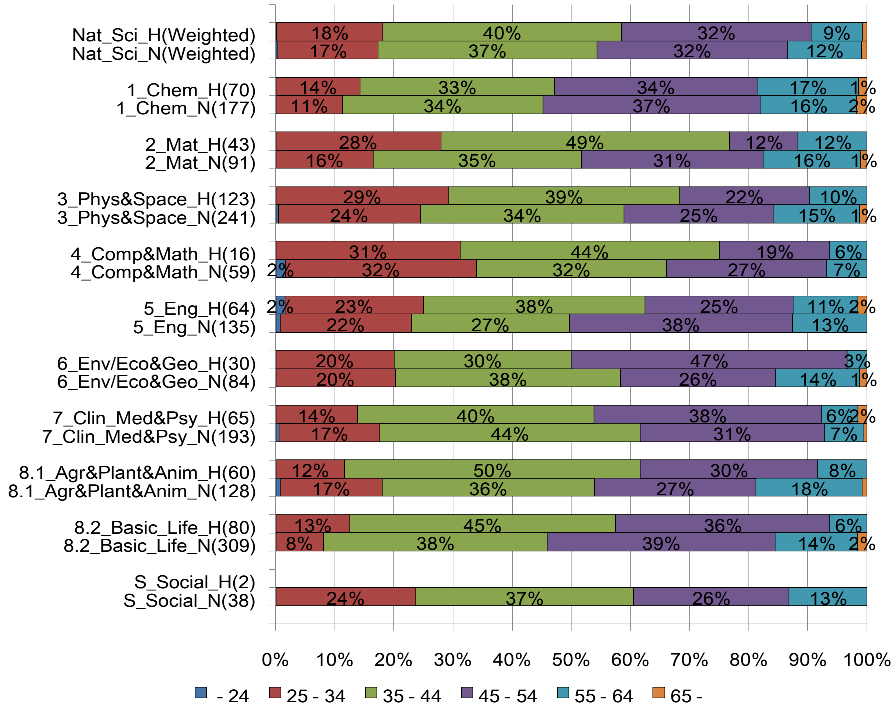
(a) Ages when the survey was conducted, Japan



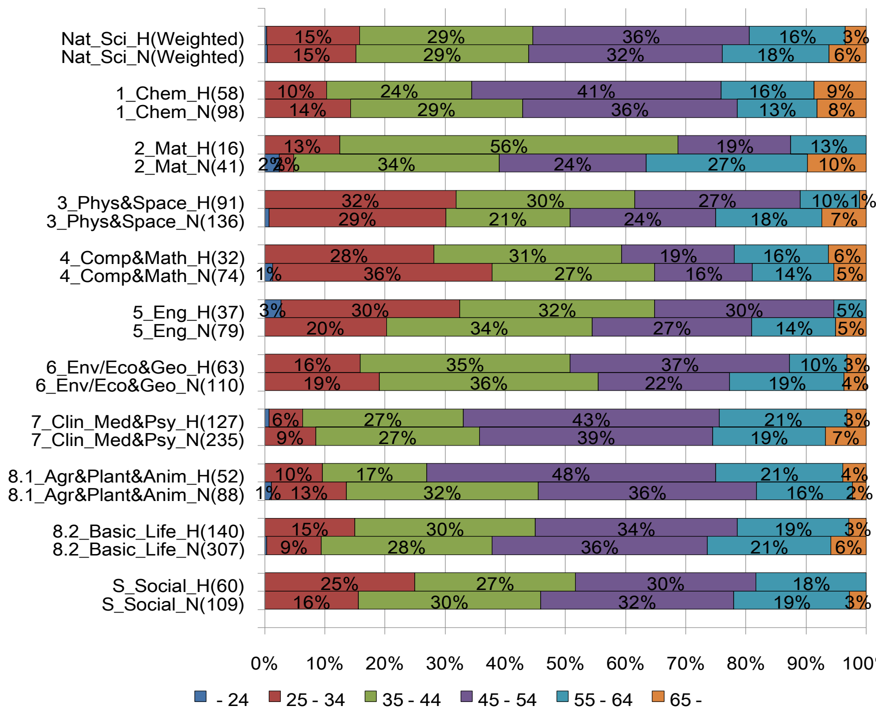
(b) Ages when the survey was conducted, US



(c) Ages when the focal paper was submitted, Japan



(d) Ages when the focal paper was submitted, US



Note1: In each field, the upper figure is for the H papers and the lower figure is for the N papers.
Note2: Result of social sciences in Japanese H papers was not shown due to the small number of responses.

2－6－2 Sector Composition of the Respondents When the Focal Paper Was Submitted

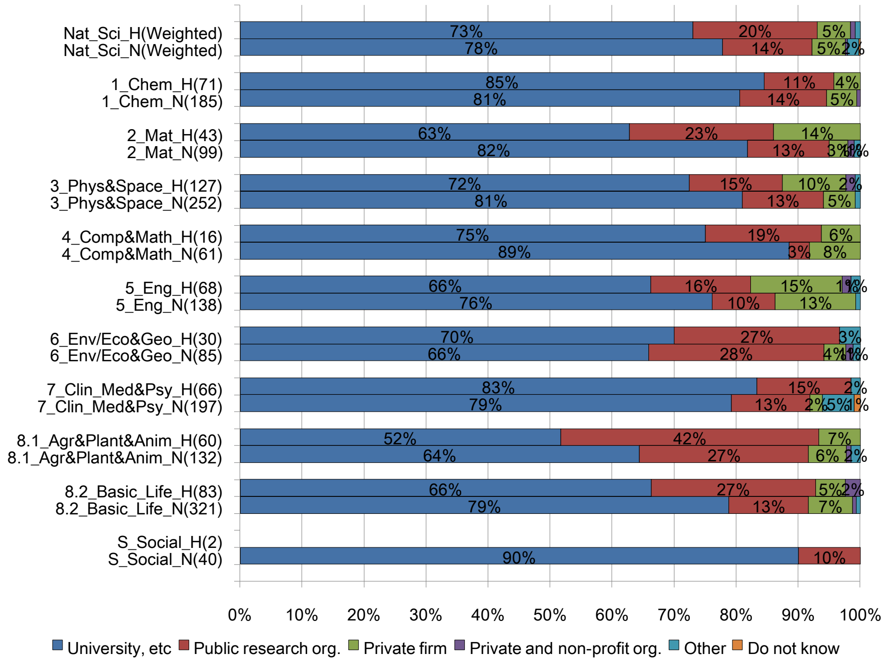
Exhibit 5 shows the sector composition of the organizations with which the respondents were affiliated when the focal paper was submitted. Higher education institutions (HEIs) have the largest share in both Japanese and the US samples, followed by the public research institutions (PRIs). The share of the two sectors combined accounts for 90% of the total. It is, however, important to note that the response rates of private firms; and private and non-profit organizations were substantially lower (by around 30 % in Japanese samples).

As for Japanese survey, the share of the public organization is more than 20% in environment/ecology and geosciences; and agricultural sciences & plant & animal science in both the H and N papers. The share of the public organization is very large, i.e., 42%, in agricultural sciences & plant & animal science of the H papers. The share of the public organization is also more than 20% in materials science and basic life sciences of the H papers. The share of the private firms is more than 10% in materials science; physics & space science; and engineering for in both the H and N papers.

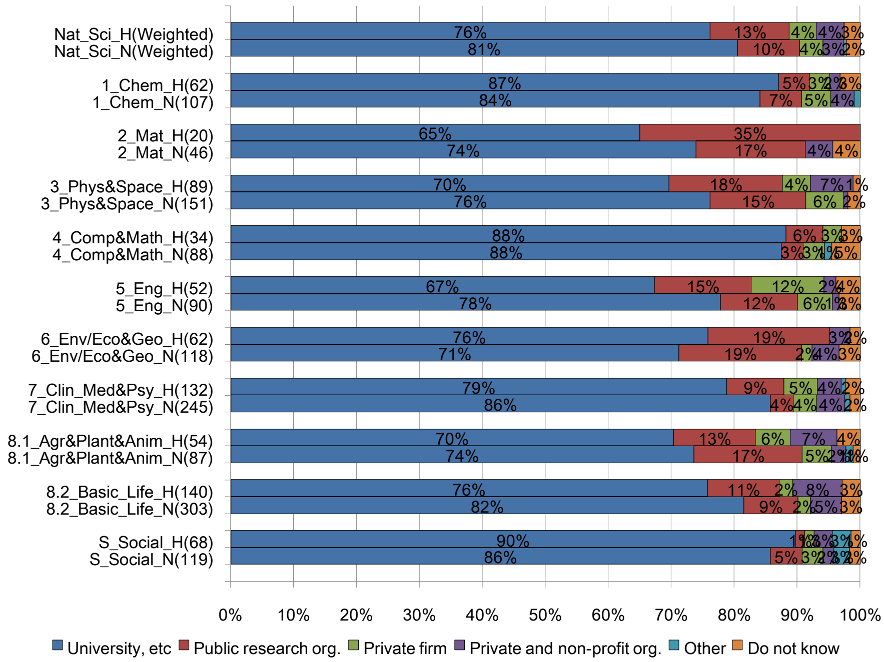
Compared to Japanese survey, the share of the public organization in the US samples is smaller. The public organization has 15% or more share in both H and N papers in materials science; physics & space science; and environment/ecology and geosciences. One characteristic in the US samples is a non-negligible contribution of the private and non-profit organization in the respondents. Their share in natural sciences is 4.3% in the H papers and 3.3% in the N papers. Private and non-profit organization accounts for less than 1% in Japanese samples.

Exhibit 5 Sector of the organization with which the respondents were affiliated when the focal paper was submitted

(a) Japan



(b) US



Note1: In each field, the upper figure is for the H papers and the lower figure is for the N papers.
Note2: The higher education institutions include universities, inter-university research institutions and colleges of technology. The public research institutions include national experimental and research institutions, independent administrative corporations, special corporations and experimental and research institutions of local governments.
Note3: Result of social sciences in Japanese H projects was not shown due to a very small number of responses.

2－6－3 Roles of the Respondents in the Research Projects

This section summarizes 1) the role of respondents in the management and 2) the role of the respondents in the implementation of the research project that produced the focal paper.

As shown in Exhibit 6, in natural sciences of Japanese survey, around 60% of the respondents played the leading role in the management, i.e., the design of the research project, administration of the research project, and application for the research grant. Including the respondents who were a member of the research management but less than that of the leader (around 20%), approximately 80% of respondents from both H and N projects played at least some role in the management. As for the US samples, the figure is approximately 90% in both H and N projects. Around 80% of the respondents in the US samples played the leading role in the management. The share of respondents who played the leading role in the management is considerably higher in the US samples than in Japanese samples.

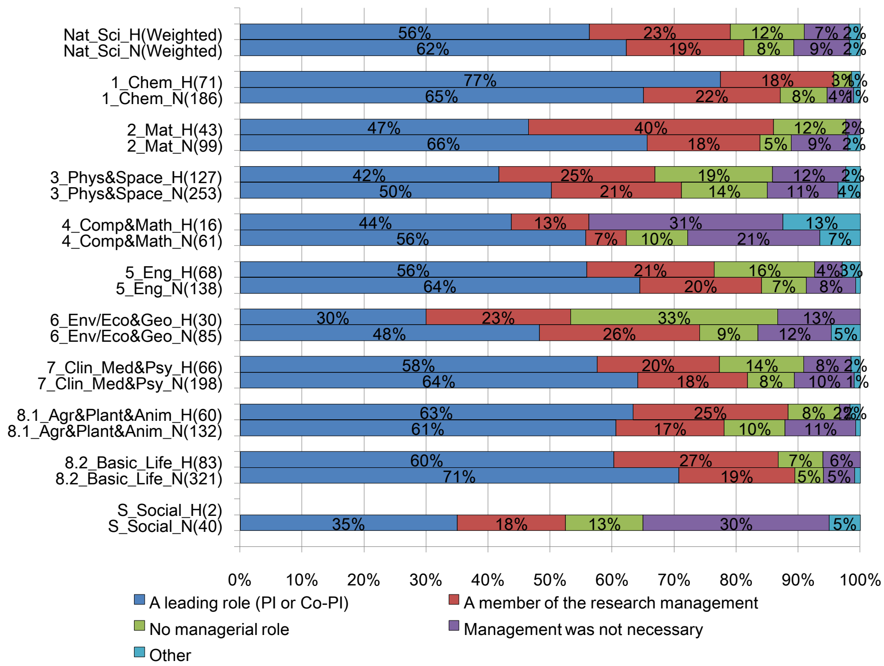
Management was not necessary for a small project, although it is a minority (less than 10% in both types of projects). The share of the response of "Management was not necessary" is large in computer science & mathematics in both Japanese and the US samples. Our survey also revealed that the number of authors and the amount of research funds in these two fields are relatively small, compared to other fields, indicating that management becomes more important as the project becomes larger and more complex.

A fairly large share of the respondents of Japanese samples (20 - 30%) did not play a managerial role in environment/ecology and geosciences and physics & space science of the H projects. One possible explanation of this is that many of the respondents are the researchers who participated in the international research project led by another country. The analysis of the international co-authorship showed that these two fields exhibit relatively high probability of international co-authorship compared to other fields.

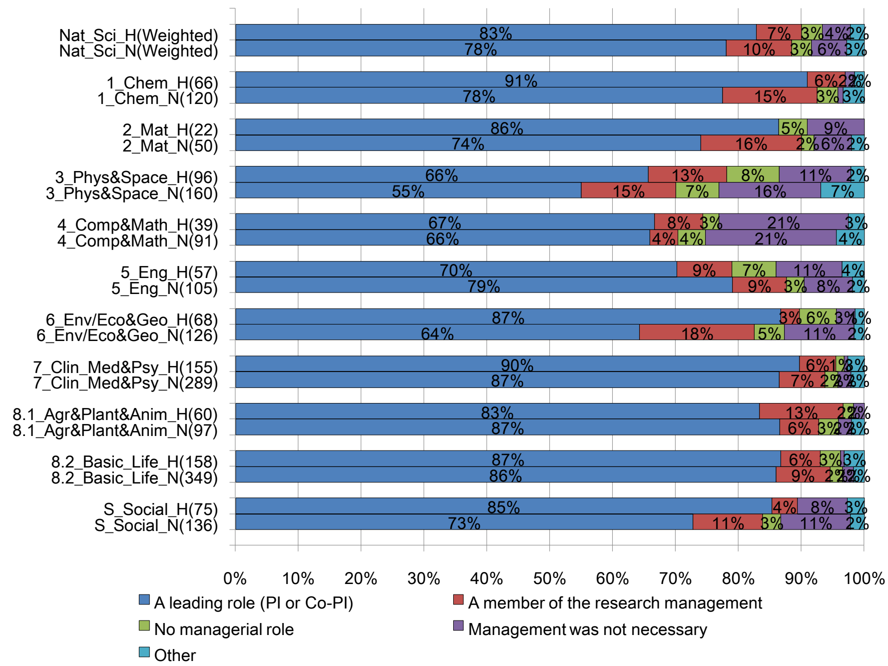
Next we look at the role of respondents in the implementation of research projects, as shown in Exhibit 7. 60 - 70% of respondents in both Japanese and the US samples said they executed the central part of the research and contributed the most to the research output. Including the respondents who took part in the central part of the research but their contribution was not as substantial as the above central researcher; more than 80% of respondents executed the central part of the research in both countries. Thus, we can conclude that most respondents have a very good knowledge of the research project as well as of its management.

Exhibit 6 Role of respondents in the management

(a) Japan



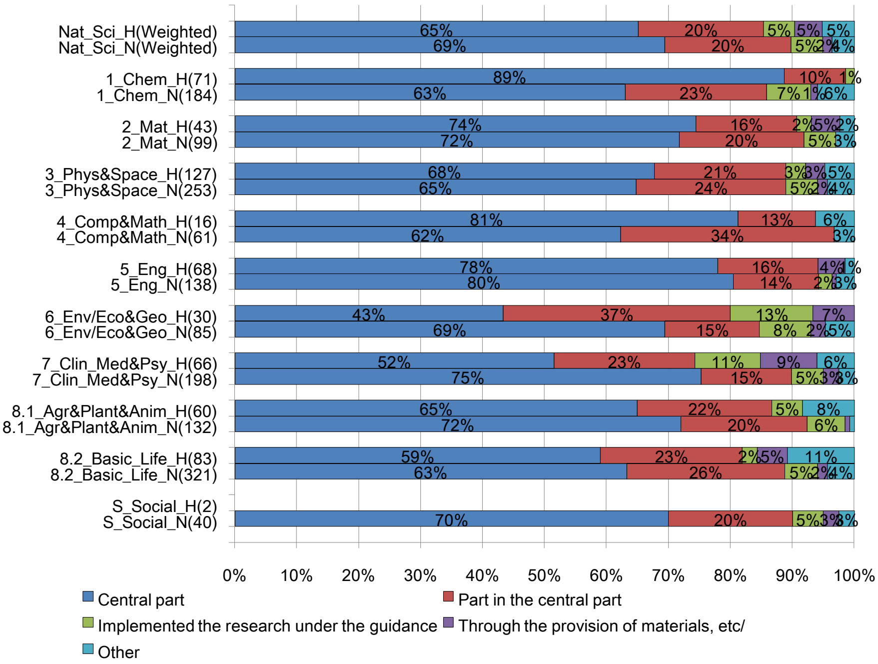
(b) US



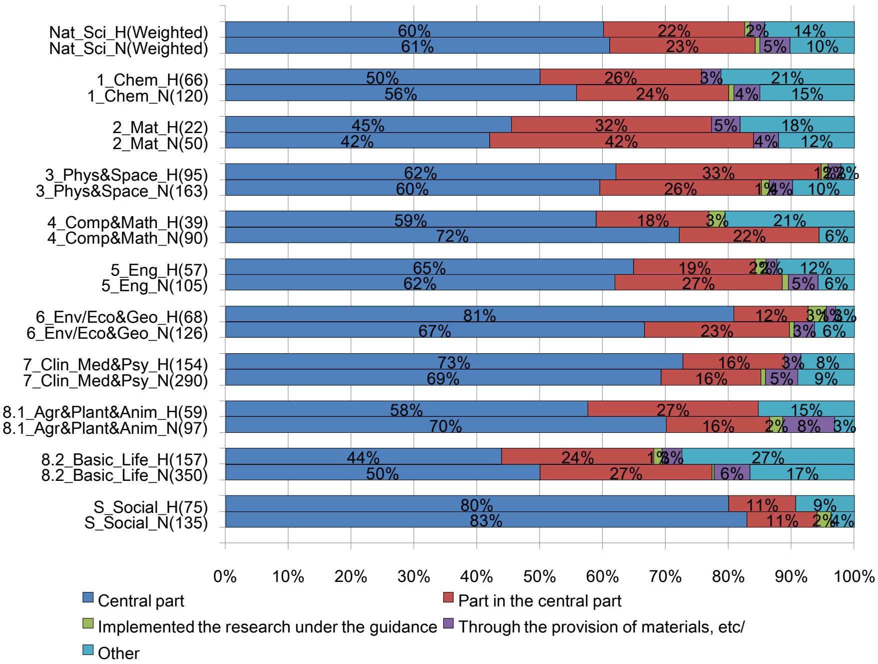
Note1: In each field, the upper figure is for the H papers and the lower figure is for the N papers.
Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Exhibit 7 Role of the respondents in the implementation of the research project

(a) Japan



(b) US



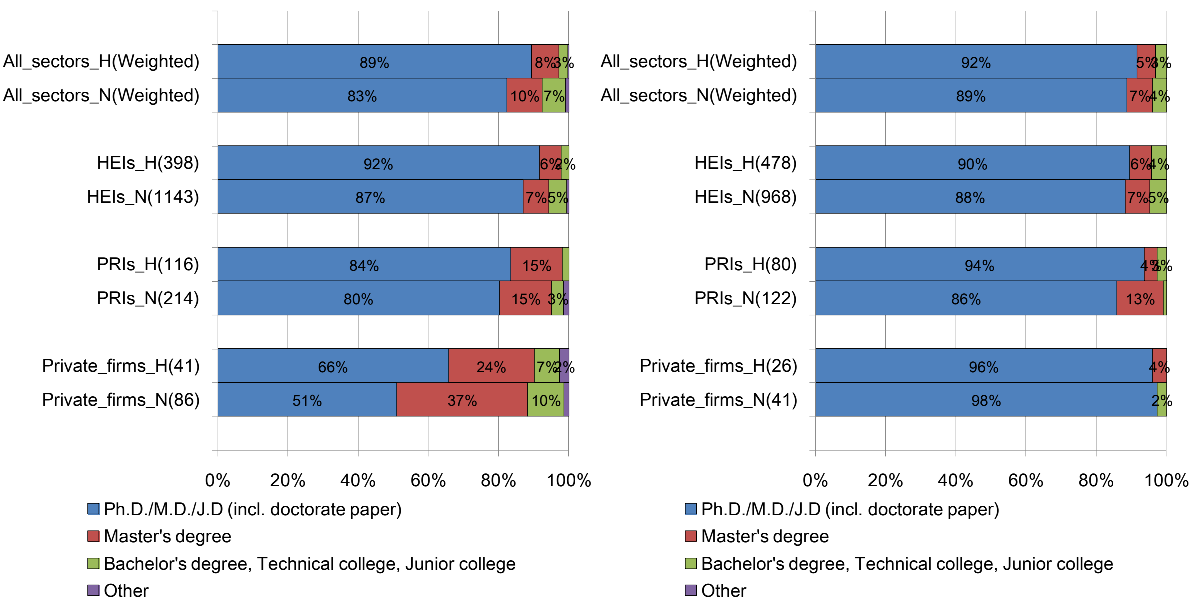
Note1: In each field, the upper figure is for the H papers and the lower figure is for the N papers.
Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

2－6－4 Research Career of the Respondents

An overview of the research careers of the respondents is shown in this section. Exhibit 8 shows the distribution of the highest academic degree of the respondents when the research project was launched. The share of the researchers with a PhD, a M. D., or a J. D. is the largest in all sectors in both countries. As for Japanese samples, the share of respondents whose highest degree was Master’s degree or below is large in the private firms compared to other sectors. In the private firms for the N projects, 37% of the respondents have Master’s degrees as the highest degree and around 10% of respondents have Bachelor’s or lower degree as the highest degree.

Exhibit 8 Highest degree of respondents when the research project was launched

(a) Japan (b) US



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers.

As for Japanese samples, the share of respondents who won a distinguished paper award or a conference award from an academic society is higher in the H projects than in the N projects in the HEIs and the private firms. About 60% of the respondents of the H papers in the HEIs won the award (Exhibit 9(a)). The respondents' award-winning experience does not show big difference by type of project and by sector in the US samples (Exhibit 9(b)).

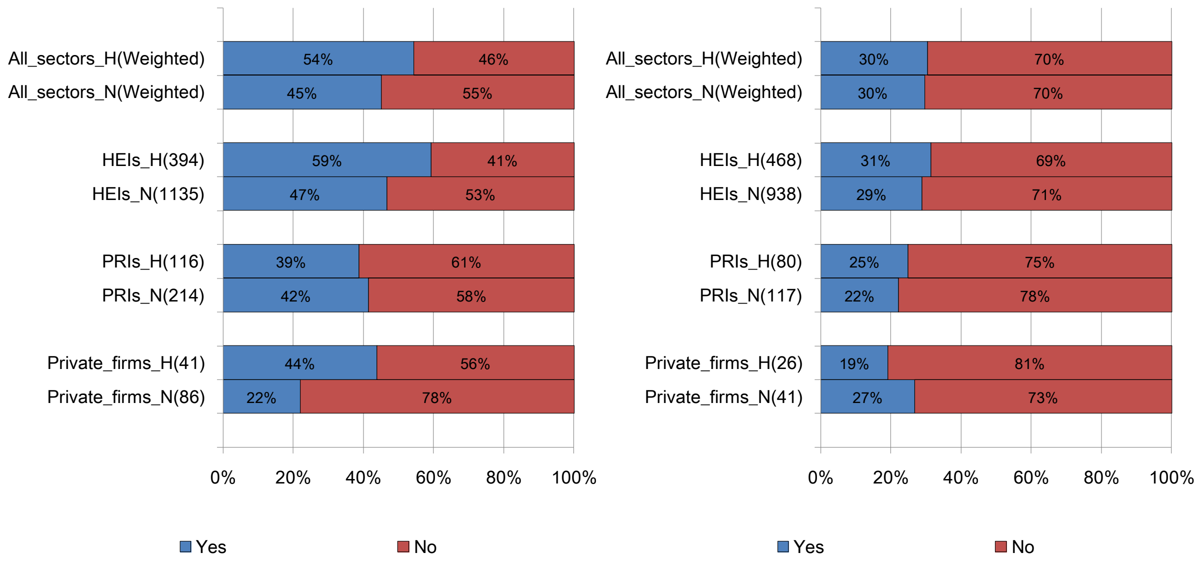
In the HEIs, the share of the respondents who served on an editorial board of an international journal is larger in the H projects, compared to those in the N projects, in both Japanese and the US samples (Exhibit 10). In the private firms, respondents with experience on an editorial board of an international journal are more common in the US samples.

A striking difference in respondents' experiences of staying in abroad by cohort was found. In Japanese samples, more than 70% of respondents at age 45 or over stayed in abroad for one year or more before the initiation of the project (All sectors in Exhibit 11(b)). The share of such respondents is approximately 30% smaller for the respondents younger than age 45 (Exhibit 11(a)). In contrast, the international mobility of the US respondents is seemingly higher in the younger cohort. The share of respondents who stayed in abroad for one year or more is around 40% and 30% for respondents at age under 45 and at age 45 or over, respectively (All sectors in Exhibit 12).

Younger cohort is more mobile in terms of cross-organizational mobility in both Japanese and the US samples (Exhibit 13 and Exhibit 14). The difference by cohort is more clearly noted in the US samples. Mobility of researchers in the private firm differs across country. As for the US samples, the share of respondents who experienced the cross-organizational movement in the preceding five years is more than 50% for respondents at age under 45 in the US samples (Private firms in Exhibit 14(a)). The share of such respondents is approximately 20% in Japanese samples (Private firms in Exhibit 13(a)).

Exhibit 9 Respondents who won a distinguished paper award or a conference award from an academic society

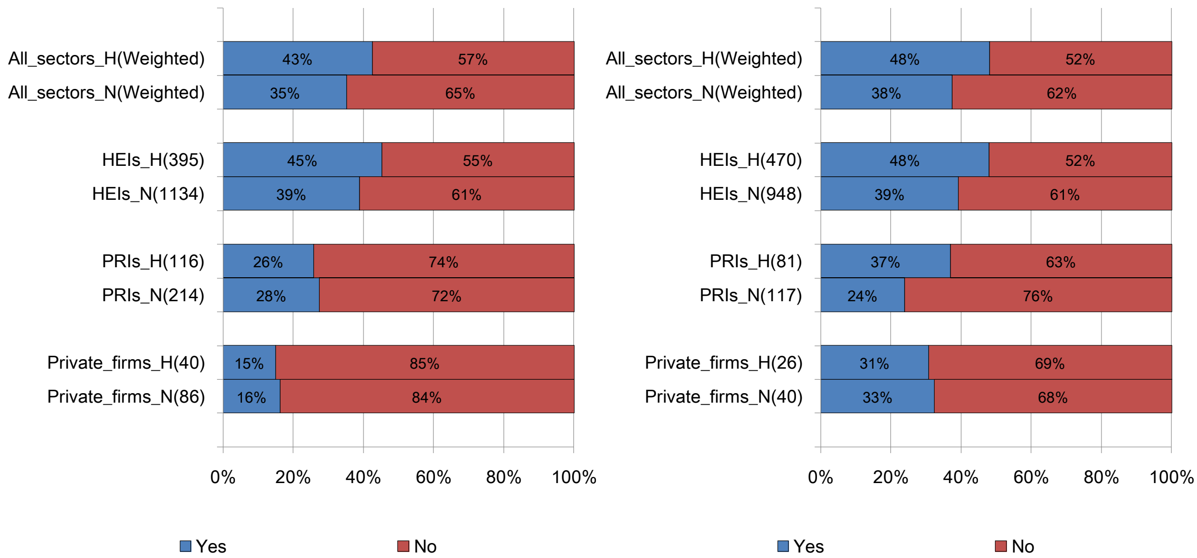
(a) Japan (b) US



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers

Exhibit 10 Respondents who served on an editorial board of an international journal

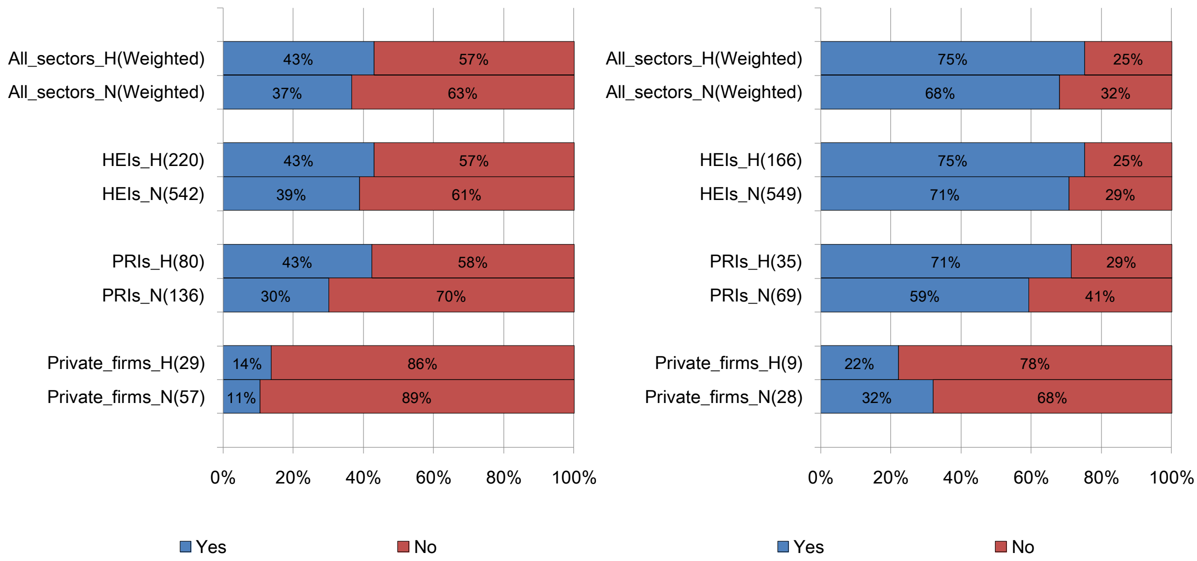
(a) Japan (b) US



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers

Exhibit 11 Respondents who stayed in abroad for one year or more for study or research by age, Japan

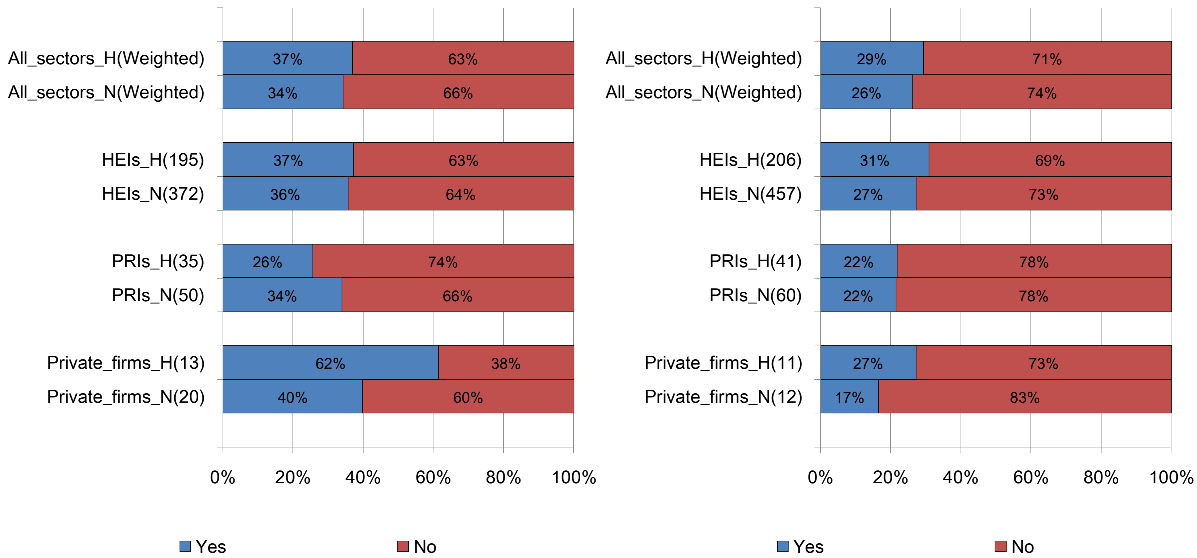
(a) Under 45 (b) Over 45



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers

Exhibit 12 Respondents who stayed in abroad for one year or more for study or research by age, US

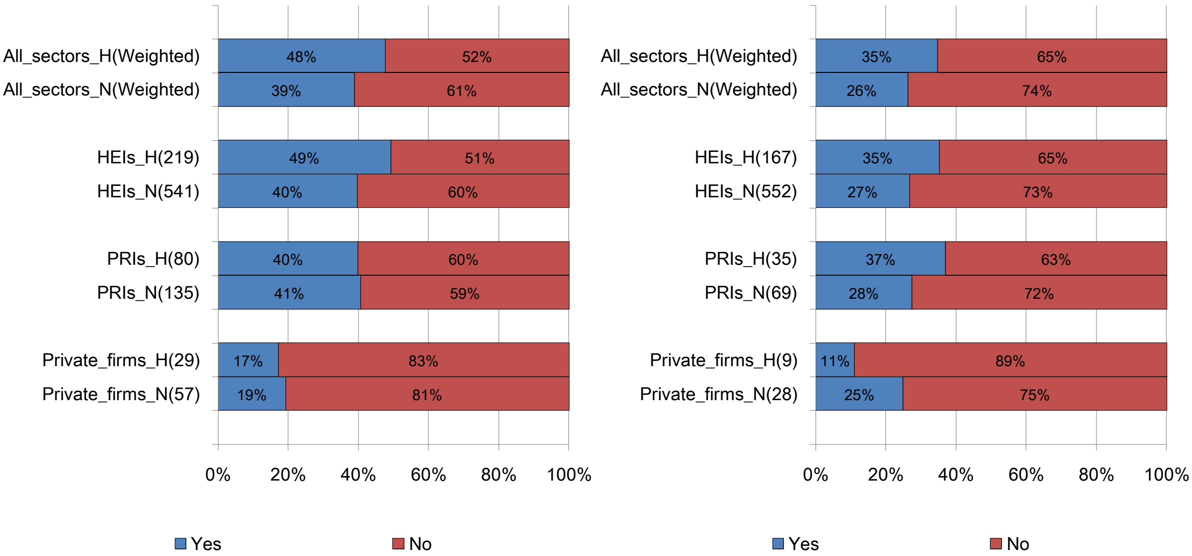
(a) Under 45 (b) Over 45



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers

Exhibit 13 Respondents who changed academic or research positions across organizations in the preceding five years by age, Japan

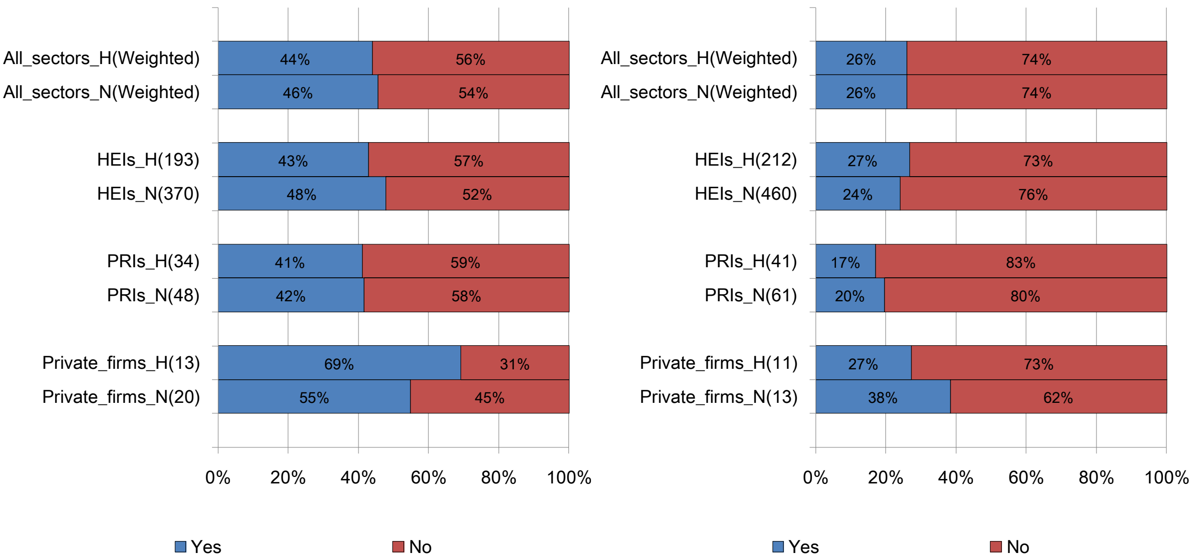
(a) Under 45 (b) Over 45



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers

Exhibit 14 Respondents who changed academic or research positions across organizations in the preceding five years by age, US

(a) Under 45 (b) Over 45



Note1: In each sector, the upper figure is for the H papers and the lower figure is for the N papers

3 Characteristics of the Focal Papers

3－1 Importance of the Focal Paper in the Field

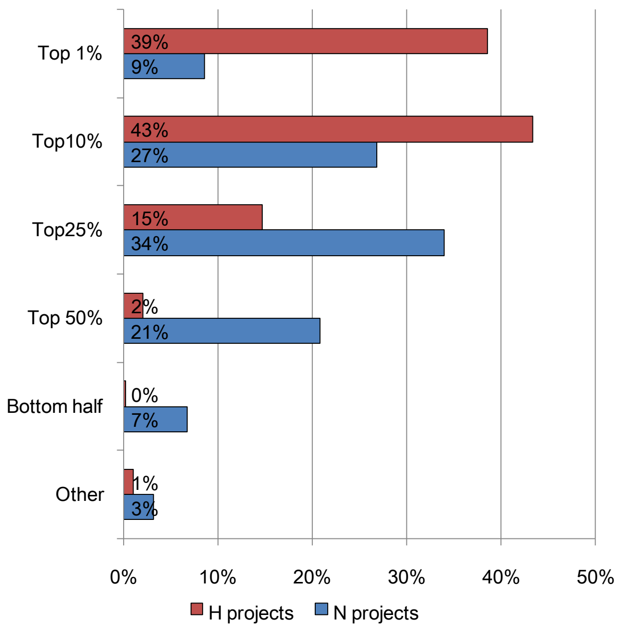
In the design of the target for this survey, we used the number of citations as a proxy to measure the importance of the research papers, and selected the H papers based on that measure. The self-evaluation of respondents also supports our assumption as seen in Exhibit 15. For this exhibit, we asked a respondent to assess the importance of the focal paper compared to the global research findings in the same field during the same time period (published within a year before or after the focal paper was published). H papers have significantly higher shares of being recognized by the respondent as the research papers having relatively high self-evaluation than the N papers.

Looking at the H projects, 39% of respondents in Japanese samples (25% in the US samples) thought that the focal paper was one of the most important papers, ranking within the top 1% in the world and 82% of respondents in Japanese samples (73% in the US samples) thought that the focal papers rank within the top 10% in the world.

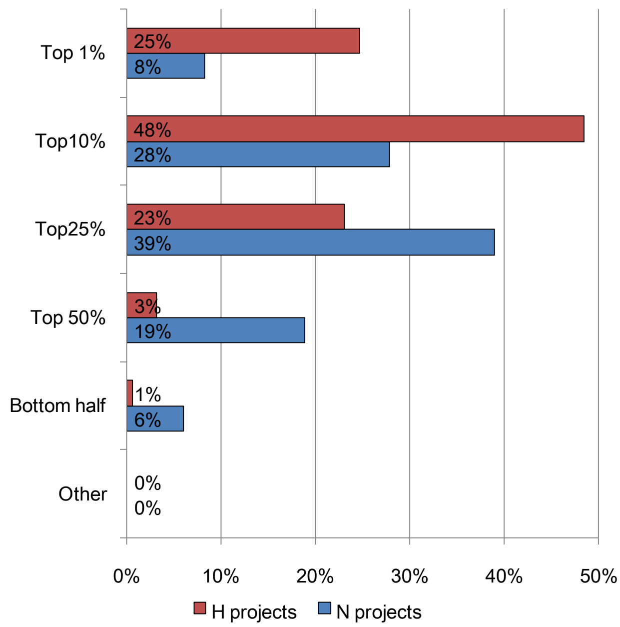
In contrast, 9% of respondents in Japanese samples (8% in the US samples) of the N projects ranked the focal papers in the top 1%, 35% of respondents in Japanese samples (36% in the US samples) ranked the focal papers in the top 10%. The share of “a relatively important paper, ranking within the top 25%” is the largest in the N papers in both Japanese and the US samples. The Web of Science database of Thomson Reuters, from which the focal papers were sampled, collects only those academic journals that fulfill the significance criteria set by Thomson Reuters. Thus, there is a possibility that a paper of relatively important outputs of the research project were sampled as the focal paper of the survey even for N papers.

Exhibit 15 Importance of the focal paper in the global research findings

(a) Japan



(b) US



Note1: The self-evaluation of the importance of the focal paper in the global research findings in the same field during the same time period (published within a year before or after the focal paper was published).

Note1: The weighted result of natural sciences.

4 MOTIVATIONS FOR THE RESEARCH PROJECT AND UNCERTAINTIES IN RESEARCH

4－1 MOTIVATIONS FOR THE RESEARCH PROJECT

According to Stokes (1997), the traditional framework to place a research along one dimension from basic research to applied research is incomplete, since research often has dual motivations. Stokes proposed the "quadrant model of scientific research". In this model a Pasteur's quadrant covers such "use-inspired basic research" exemplified by the research by Pasteur, while Bohr's quadrant covers pure basic research and Edison's quadrant covers pure applied research. Adopting this framework, we asked each researcher to evaluate the importance of the following two basic motivations for initiating the research project that yielded the focal paper and the other closely related papers: (1) pursuit of fundamental principles/understandings and (2) solving specific issues in real life. "Pursuit of fundamental principles/understandings" is defined to be gaining a new knowledge of the principles, underlying natural phenomenon and observed facts, through experiments and/or theoretical analyses and "solving specific issues in real life" is defined to be solving practical and specific problems such as for industrial applications, following *Frascati Manual* of OECD.

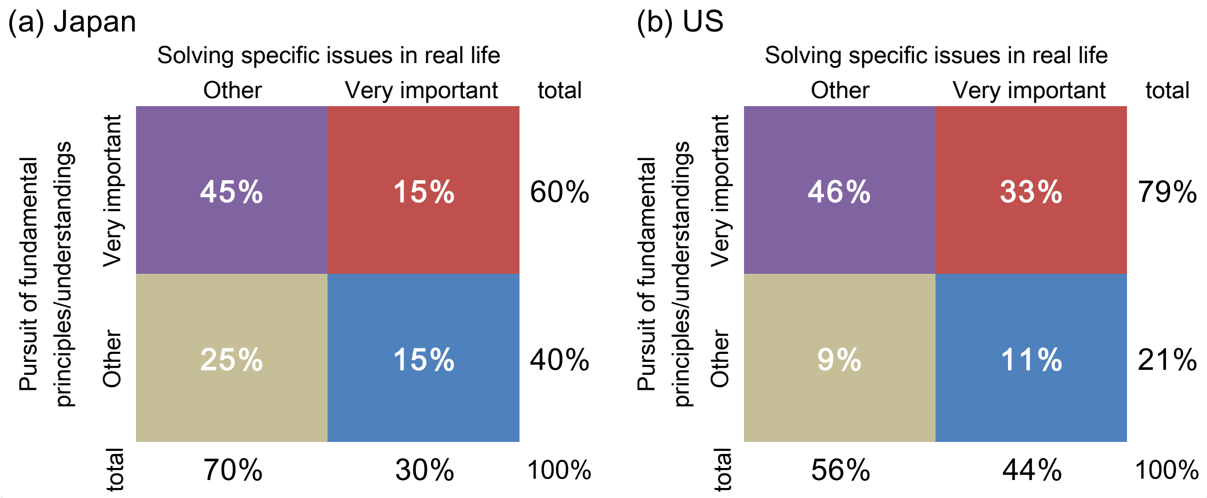
Collecting response to this question on two motivations at project level has allowed us to quantitatively assess how important each quadrant is in each scientific field. Such information would be very important, since the Pasteur's quadrant may play an important bridge between science research and engineering research (Stokes (1997)). As far as we know, there is no systematic quantitative evidence available for the importance of Pasteur's quadrant (see however, Comroe and Dripps (1976), for a very detailed study on the key papers for open-heart surgery from this perspective).

Exhibit 16 the aggregate results of the H projects for Japan and the US. 60% of the researchers for H projects, that is, the projects which produced the top 1% highly cited papers, in Japan regard the pursuit of fundamental principles/understandings as a very important motivation for the project, while the corresponding share is 79% in the US. 30% of the researchers for H projects in Japan regard solving specific issues in real life as very important motivations for the project, while the corresponding share was 44% in the US. The projects for which both motivations are very important amount to 15% and 33% of the H projects in Japan and the US. Thus, even if we define "Pasteur's quadrant" relatively narrowly as the group of the projects for which both motivations are very important (not just important), it constitutes a significant share of the research projects in the two countries, especially in the US. If we define "Bohr's quadrant" as a group of the projects where only "pursuit of fundamental principles/understandings" is very important, it covers 45% and 46% of the H projects in Japan and the US. If we define "Edison's quadrant" as a group of the projects where only "solving specific issues in real life" is very important, it covers 15% and 11% of the H projects in Japan and the US respectively. Thus, "Bohr's quadrant" as well as "Edison's quadrant" is of similar size in the two countries and "Bohr's quadrant" is the most important, while "Pasteur's quadrant" is much smaller in Japan

According to Exhibit 17, the similar patterns can be identified for N projects. "Pasteur's quadrant" is important especially in the US (26% of the projects) and it is less important in Japan

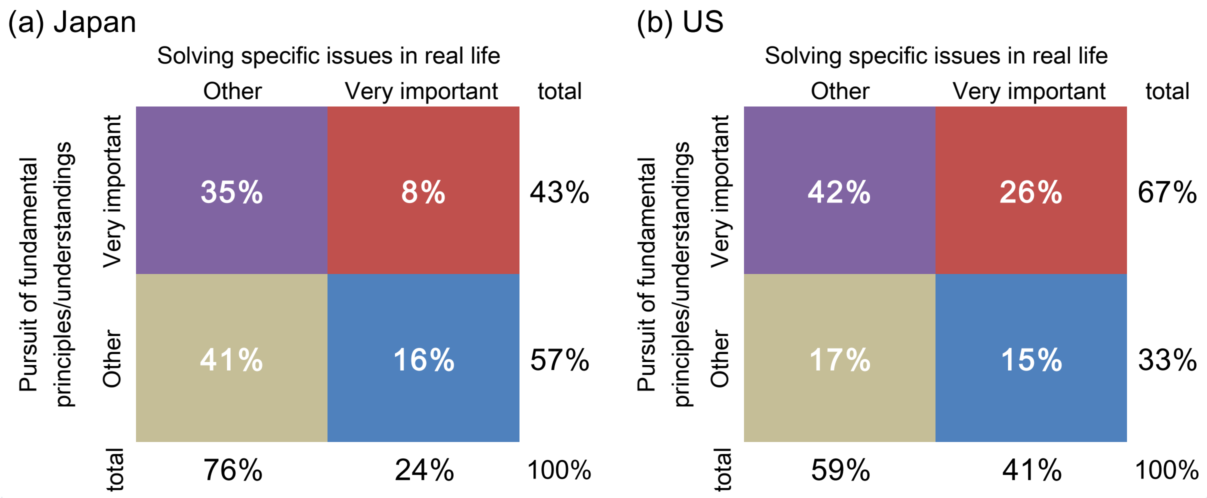
(8% in Japan). "Bohr's quadrant" is most important among the three quadrants in both countries. "Edison's quadrant" is of similar size in the two countries. The level of motivation is stronger in H projects than in N projects for the two objectives, but especially for "pursuit of fundamental principles/understandings".

Exhibit 16 Distribution of the projects by a quadrant model, H projects



Note1: The weighted result of natural sciences.

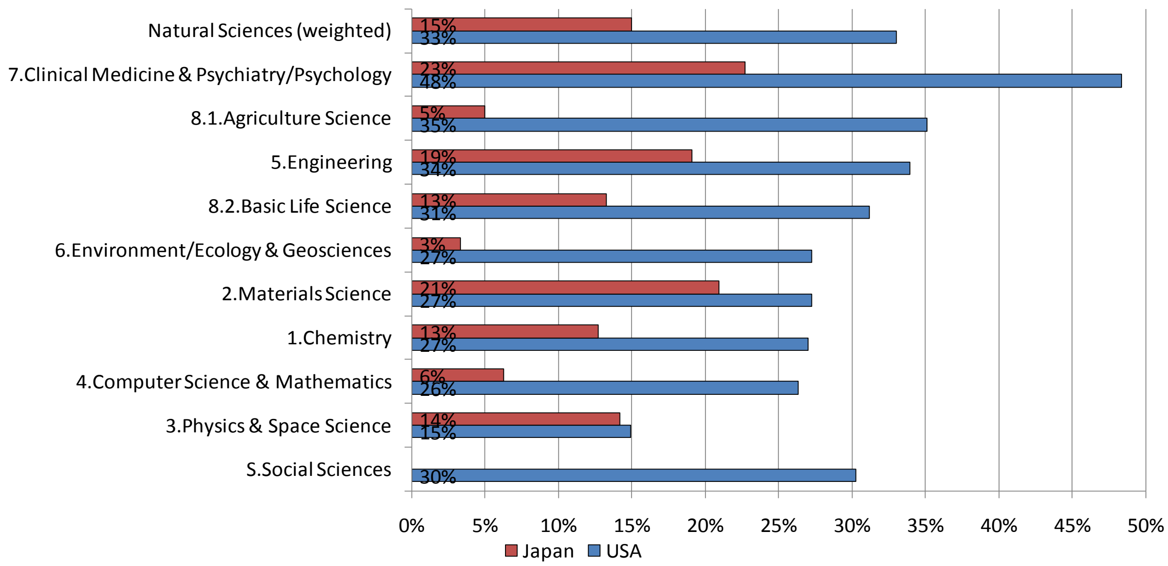
Exhibit 17 Distribution of the projects by a quadrant model, N projects



Note1: The weighted result of natural sciences.

There are significant variations in the importance of "Pasteur's quadrant" by field, as shown in Exhibit 18 for H projects. This exhibit sorts the scientific field by the share of "Pasteur's quadrant" in the US (except for social science). "Pasteur's quadrant" is especially important in clinical medicine & psychiatry/psychology in both countries. In the US, it is close to 50%. It is also relatively important in engineering in the two countries. "Pasteur's quadrant" is important in materials science only next to clinical medicine & psychiatry/psychology in Japan (but not in the US), while it is important in agricultural sciences & plant & animal science only next to clinical medicine & psychiatry/psychology in the US (but not in Japan). "Pasteur's quadrant" is significantly more important in the US than in Japan in environment/ecology & geosciences and computer science & mathematics too.

Exhibit 18 Pasteur's quadrant by field (% yes in H projects), Japan vs. US



Note1: In each field, the upper figure is for Japan and the lower figure is for the US.
Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

These results support the Stokes's view that placing the scientific research projects along one dimension from "pursuit of fundamental principles/understandings" to "solving specific issues in real life" is not adequate, since many projects are driven significantly by the two objectives. "Pasteur's quadrant" is more important in the US than in Japan.

4－2 Uncertainties in Research Process and in Research Outcome

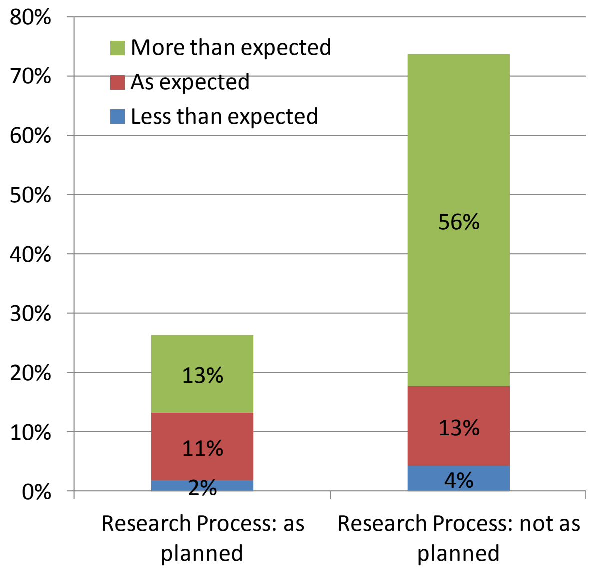
Productive research has to add something new relative to the existing stock of knowledge and uncertainty in research can be a very important part of acquiring such novelty. There can be two scenarios of acquiring such novelty: getting a novel research idea which is proven in the research process as initially expected, or novelty is acquired during the course of the research due to its uncertain process or outcome. Compared to inventions, where targeted outcome is often important (see Nagaoka and Walsh (2009a)), uncertainty can be more important in scientific research. In order to clarify this, our survey asked the researcher to evaluate the importance of uncertainty in both research process and outcome. More specifically, whether the research project that yielded the paper proceeded as initially planned (5 point Likert Scale from "largely the same as originally planned to "quite different than originally planned") and whether the main result of the focal paper is more or less significant than the initial expectations of the researchers (5 point Likert Scale from "substantially less significant than expected" to "substantially more significant than expected").

The research proceeded as initially planned for 26% of the H papers in Japan and 39% in the US, as seen in Exhibit 19. In addition, the main result of the focal paper was as initially expected for 25% of the H papers in Japan and 26% in the US. Thus, both the main result of the paper and the research process to that were as initially expected and planned only for 11% of the H papers in Japan and 14% in the US. On the other hand, 56% of the main results in Japan involved both a better than expected result as well as research process uncertainty. The corresponding number was 46% in the US. Exhibit 20 shows the results for the N papers. Both the main result of the paper and the research process to that were as initially expected and planned for 17% for both countries. On the other hand, 40% of the main results in Japan involved both a better than expected result and research process uncertainty. The corresponding number was 38% in the US. Thus, most papers involved uncertainty either in outcome or in the research process and such uncertainty is significantly higher in H papers than in N papers in both countries.

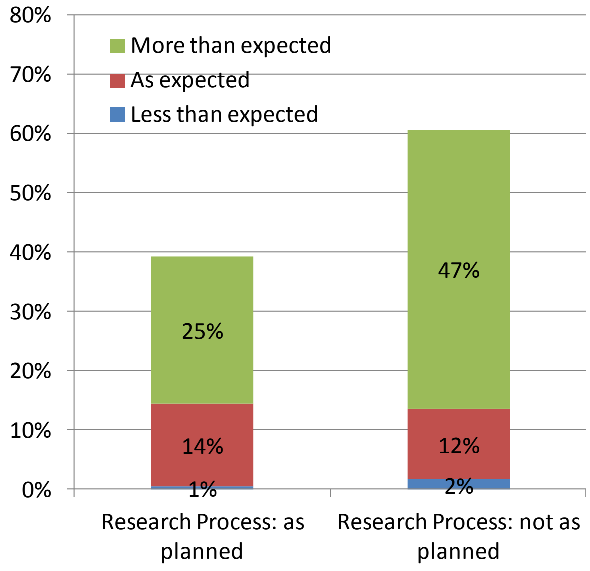
The main result of the focal paper was more than expected for 69% of the H papers and 51% of the N papers in Japan. The corresponding shares are 72% and 59% in the US. Thus, unexpected good outcome is a significant reason for H papers in both Japan and the US. Moreover, a project involving unexpected research process is more likely to generate a research output more than expected. The probability of getting a more than expected result conditional on the research process being as planned is 50 % (=13%/26%) while the probability of getting a more than expected result conditional on the research process being different from the initial planned is 76 % (=56%/74%) for H papers in Japan. The corresponding probabilities are 63% and 78% in the US. The similar relationship holds for N papers of both countries, although the difference is smaller in the US. Thus, research process uncertainty is a major factor for good research performance in both countries, indicating that uncertain research process is an importance source of novelty.

Exhibit 19 Uncertainty in process and output (distribution of the main result of the focal paper), H paper

(a) Japan



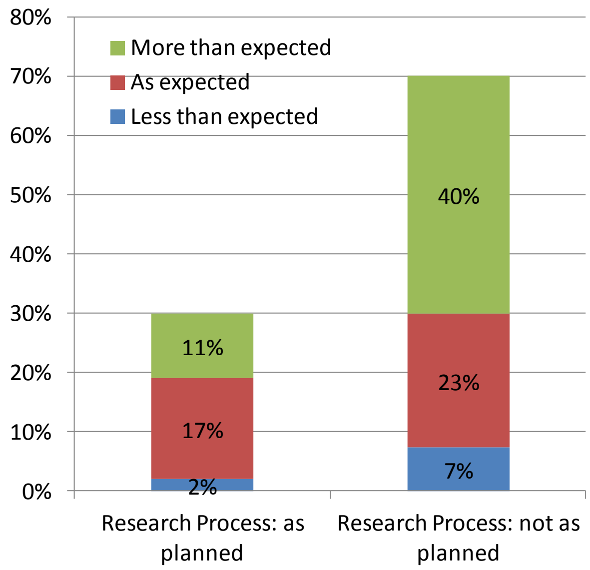
(b) US



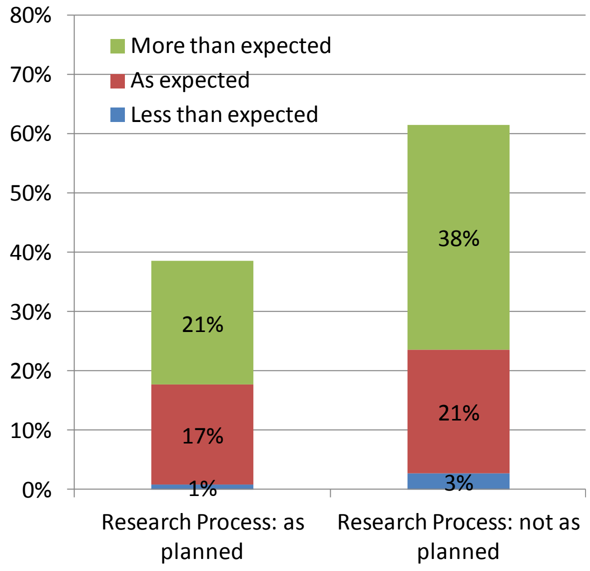
Note1: The results are not weighted by field

Exhibit 20 Uncertainty in process and output, N paper (distribution of the main result of the focal paper)

(a) Japan



(b) US

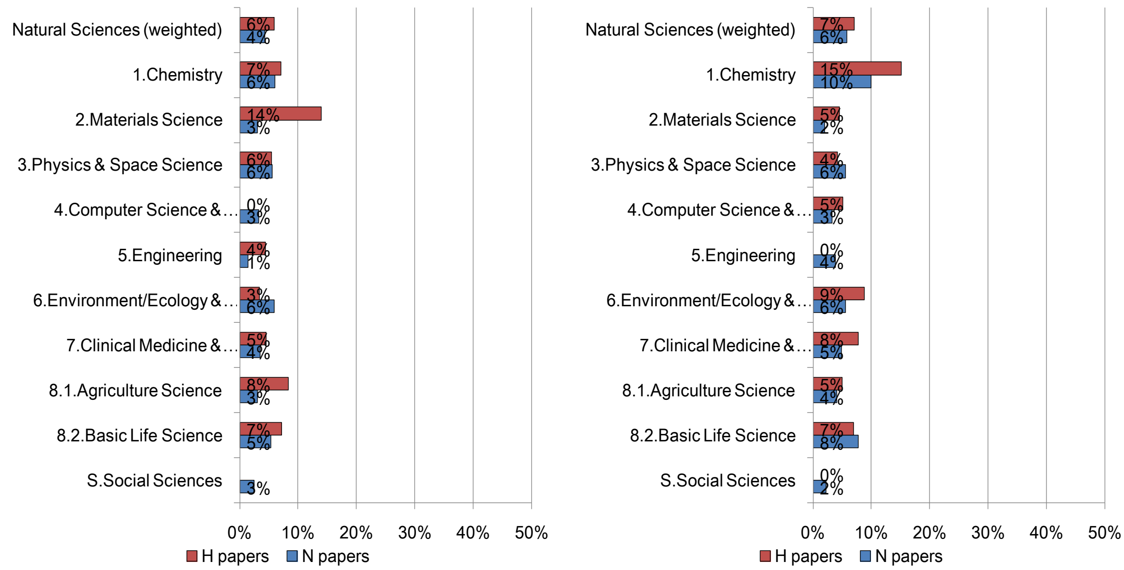


Note1: The results are not weighted by field

There are significant differences across fields in the level of uncertainty as measured by the incidence of big surprises in the research process and the outcome. Exhibit 21 shows the share of the research process being quite different from that originally planned by fields. The average share for natural sciences is 6% (7%) of the H papers and 4% (6%) of N papers in Japan (the US). In most fields, H papers involve research process uncertainty more often than N papers in the two countries. Exceptions are environment/ecology & geosciences and computer science & mathematics in Japan and physics & space science, engineering, and basic life sciences in the US. Chemistry involves most frequently large research process uncertainty in the US (15% in H papers and 10% in N papers). Chemistry is also one of those fields involving large research process uncertainty most frequently in Japan (7% in H papers and 6% in N papers). In Japan materials science involve the largest research process uncertainty for H papers (14% of the papers). Engineering involves small research process uncertainty in both countries. Although computer science & mathematics involves least uncertainty in both H and N papers in Japan, such is not the case for H papers in the US.

Exhibit 21 Uncertainty in the research process, % quite difference than originally planed

(a) Japan (b) US

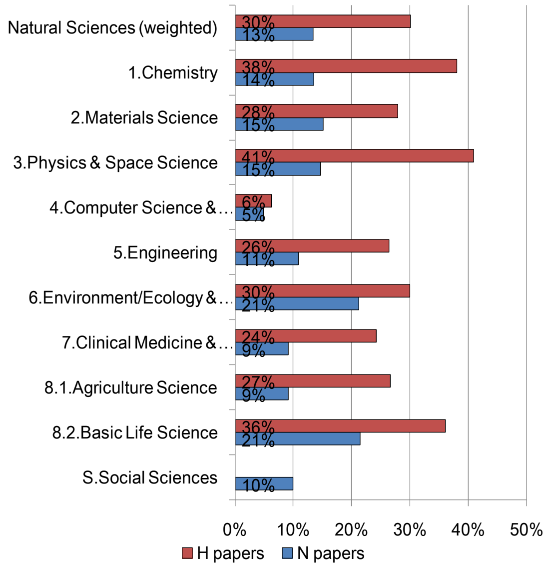


Note1: In each field, the upper figure is for the H projects and the lower figure is for the N projects.
Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

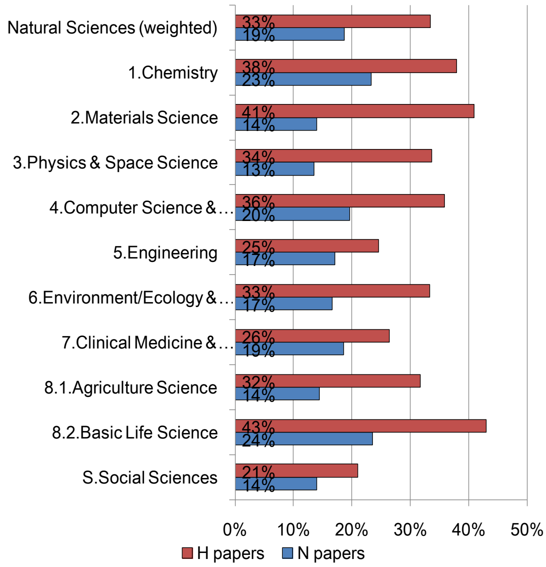
Exhibit 22 shows the probability of the main result of the focal paper being substantially more significant than expected (%). The average probability for natural sciences as a whole is 30% (33%) of the H papers and 13% (19%) of N papers in Japan (the US). Thus, it is similar across countries. In all fields, H papers involve positive surprise more often than N papers in the two countries, as expected. Top three fields which experience positive output surprise most frequently in H papers are physics & space science, chemistry, and basic life sciences in Japan, and basic life sciences, material sciences and chemistry in the US. The major difference between the two countries is computer science & mathematics, which is consistent with the above result for research process uncertainty.

Exhibit 22 Uncertainty in the main result of the focal paper, % substantially more significant than expected

(a) Japan



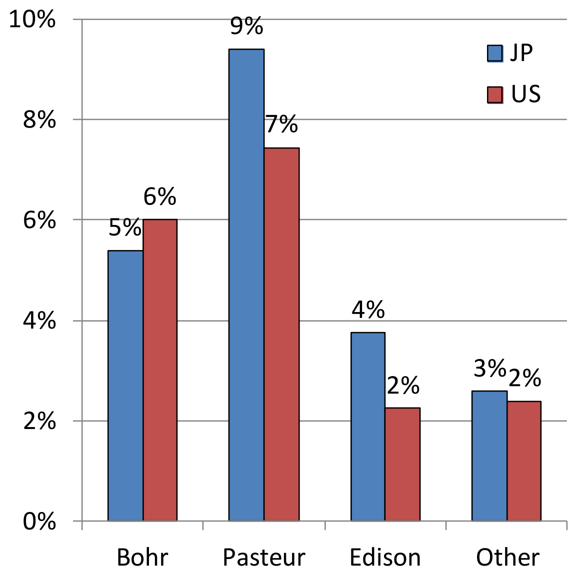
(b) US



Note1: In each field, the upper figure is for the H projects and the lower figure is for the N projects.
Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Exhibit 23 analyzes the probability of the research process being quite different by the type of the research project. In both countries, the projects in Pasteur quadrant involve research process uncertainty most frequently, followed by those in Bohr quadrant.

Exhibit 23 Quadrants of research motivations and research process uncertainty
(% quite different research process, N projects)



Note1: The results are not weighted by field

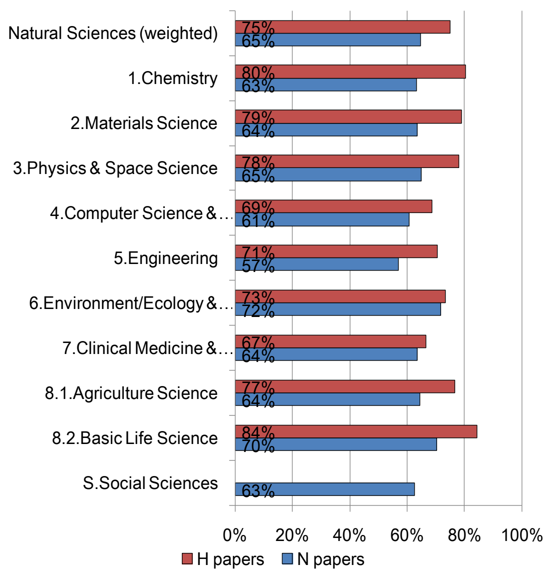
4—3 Serendipity

One important research outcome due to uncertainty is a serendipitous discovery. Our survey asked a researcher to identify whether the research output was serendipitous, that is, whether he found the answers to *the questions not originally posed*. This definition of serendipity is based on Stephan (2010) who emphasizes the importance of distinguishing "unexpected" from "accidental ". According to her, "True, Pasteur <<discovered>> bacteria while trying to solve problems that were confronting the French wine industry. But his discovery, although unexpected, was hardly <<an accident>>." The results are shown in the following Exhibit 24. In the US more than 40% of the researchers for both H papers and N papers answered in an affirmative manner (49% for H papers and 42% for N papers). This frequency is higher in Japan (75% for H papers and 65% for N papers), mainly because the US positive response for serendipity covers only the cases where the main research result of the paper was serendipitous, while the Japanese responses covers not only those cases but also the other cases where the other (not main) research result of the paper was serendipitous. According to a follow-up survey in Japan, if we cover only those cases where the main research result was a result of serendipity recognized during the research process, the probability of serendipity declines to 40 % of the papers, similar to that in the US.

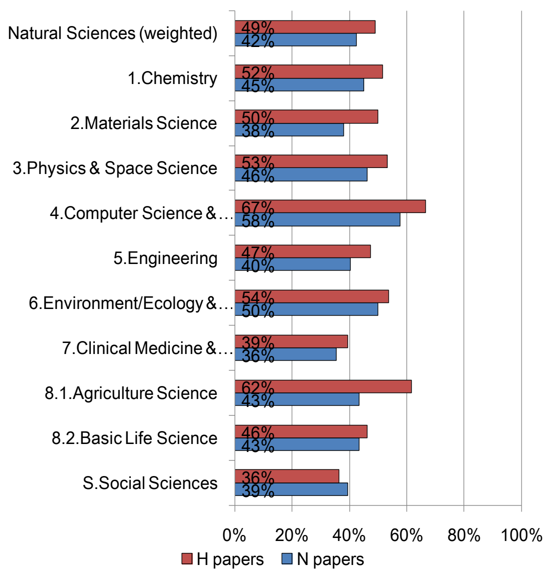
The frequency of serendipity is higher for the H paper in both countries across all fields of natural sciences. The frequency of serendipity is uniformly high across fields in Japan in H papers than in N papers. It is especially high in basic life sciences. In the US, it is high in computer science & mathematics, agriculture science and environment/ecology & geosciences.

Exhibit 24 Serendipity

(a) Japan



(b) US

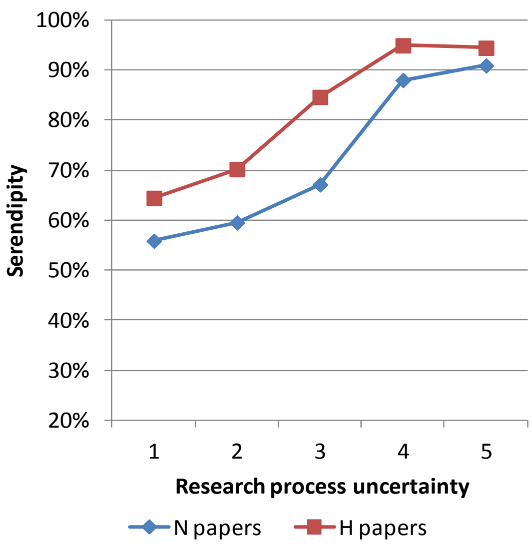


Note1: In each field, the upper figure is for the H projects and the lower figure is for the N projects.
Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.
Note3: The US positive response for serendipity covers only the cases where the main research result of the paper was serendipitous, while the Japanese responses covers not only those cases but also the other cases where the other (not main) research result of the paper was serendipitous

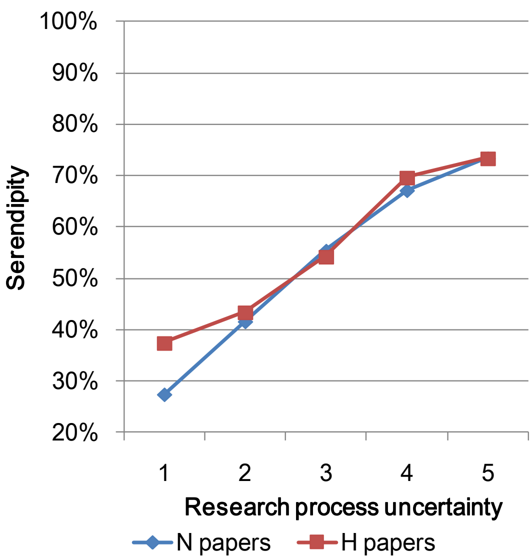
Serendipitous output is more often observed in a research project involving more process uncertainty in both countries. Exhibit 25 shows the frequency of serendipity by the level of research process uncertainty. When the level of research process increases from 1 (the same as originally planned) to 5 (quite different from originally planned), the incidence of serendipity increases by around 30% in Japan and more in the US. Thus, research process uncertainty is a major source of serendipity. Scientific research not only yields the results (often more than expected) to the original questions but also those to the questions not originally posed.

Exhibit 25 Research process uncertainty and serendipity (%)

(a) Japan



(b) US



Note1: The results are not weighted by field

5 Research Competition

Scientific research is characterized as competitive process for seeking priority by Merton (1973). For such competitive process to work would require that a researcher recognizes competition *ex-ante* and is disciplined by that. While there are substantial numbers of anecdotal evidence for the importance of priority competition as a motivating force for science, including the ones described by Merton (1973) himself, the systematic evidence for this is not available. To develop a good empirical evidence for such view, our survey asked a researcher the following two questions on the number of competitors recognized *ex-ante* and on competitive threat: (1) "Approximately how many major research teams did you recognize as your potential competitors when you began the research project? Please indicate the number of potential competitors in Japan (the US)[1] and outside of Japan (the US)." and (2) "How strongly were you and your team members concerned about the possibility that your competitors would have priority over your research results?"

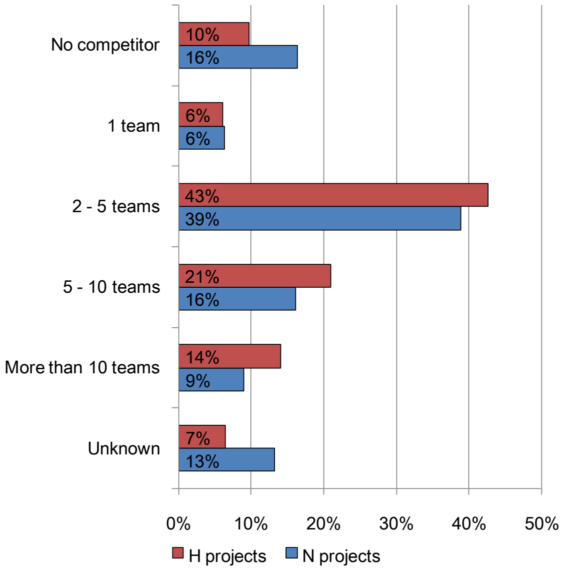
As shown in following Exhibit 26 and Exhibit 27, most of the researchers could indicate the range of the number of international (foreign) and domestic competitors (teams), even if there were a choice of "unknown". The percentage of the choice of "unknown" for the number of international competitors was only 7% (11 %) for the H projects and 13% (15%) for the N projects in Japan (the US). There were no recognized international competitors only for 10% (18%) of the H projects and for 16% (24%) of the N projects in Japan (the US). Thus, majority of scientists face clear international competitors for both H and N projects and the level of competition recognized *ex-ante* is more intense for H projects than for N projects: 84% (71%) for H projects and 71% (61%) for N projects in Japan (the US).

According to Exhibit 27, there were no recognized domestic competitors for 37% (16%) of the H projects and for 37% (23%) of the N projects in Japan (the US). That is, domestic competitors are absent for almost 40% of both H and N projects in Japan. Furthermore, there are more than 5 domestic competitors only for 8% of the H projects and 7% of N projects, while there are more than 5 international competitors for 35% of the H projects and 25% of N projects in Japan. Thus, the numbers of international competitors recognized are much larger than that of domestic competitors for scientists in Japan. Such difference does not exist in the US, which would be expected, given that the US is the largest source country of scientific research in the world. In summary, competition exists for a great majority of the projects and it is well recognized *ex-ante*. More competitors are recognized *ex-ante* in the H projects than in N projects. Domestic competition is relatively more important for US based scientists.

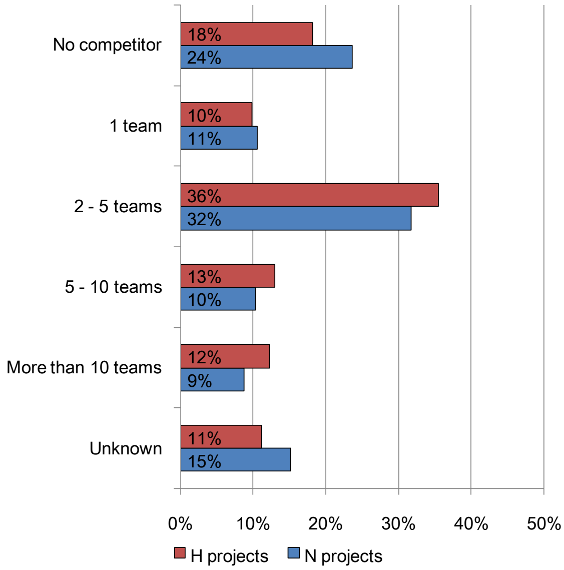
[1] The location of a research team is identified with that of its leader.

Exhibit 26 Number of potential foreign competitors recognized *ex-ante* (at the stage of project initiation)

(a) Japan



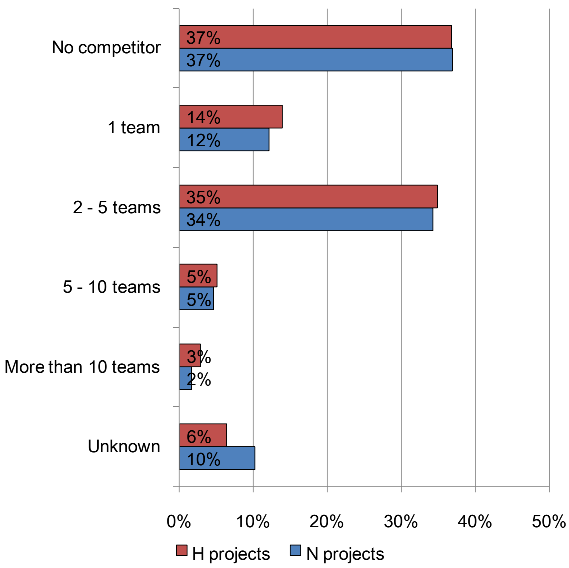
(b) US



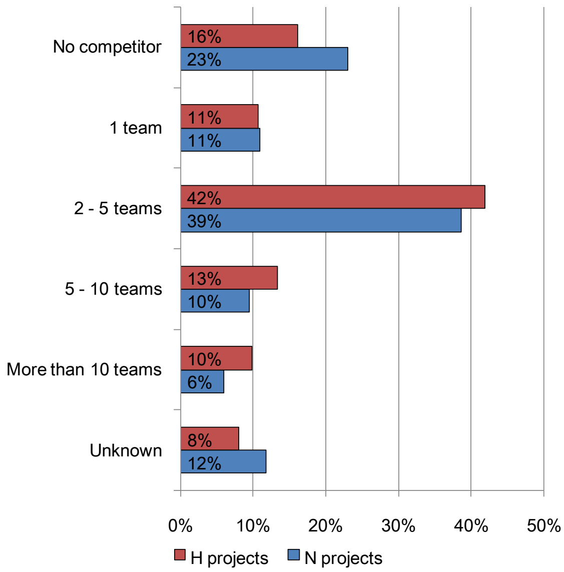
Note1: The upper figure is for the H projects and the lower figure is for the N projects.
Note2: The weighted result of natural sciences.

Exhibit 27 Number of potential domestic competitors recognized *ex-ante* (at the stage of project initiation)

(a) Japan



(b) US



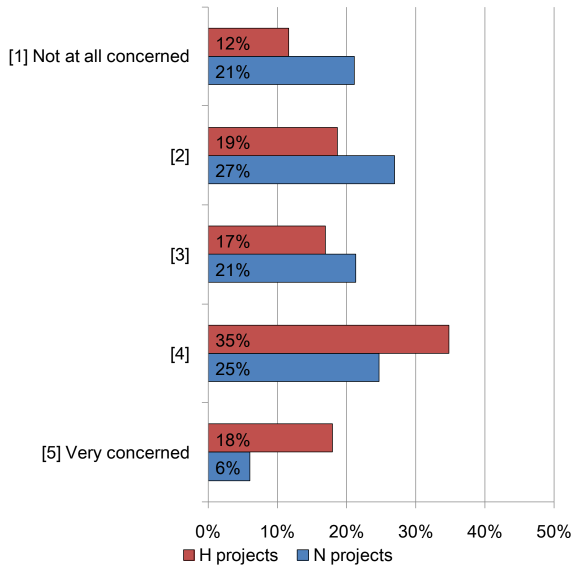
Note1: The upper figure is for the H projects and the lower figure is for the N projects.
Note2: The weighted result of natural sciences.

Researchers were concerned over priority loss in 53% (23%) of the H projects (response of 4 or 5 to the question of "How strongly were you and your team members concerned about the possibility that your competitors would have priority over your research results?") in Japan (the US) and they were very much concerned in 18% (7%) of them in the respective country (see Exhibit 28). The corresponding ratios for the N projects are 31% (6%) and 11% (4%). Thus, priority competition does seem to exert significant competitive pressure on scientists, although only a half of the researchers in Japan and only a quarter of them in the US were concerned with priority loss even in the H projects and only a minority of researchers was concerned in the N projects.

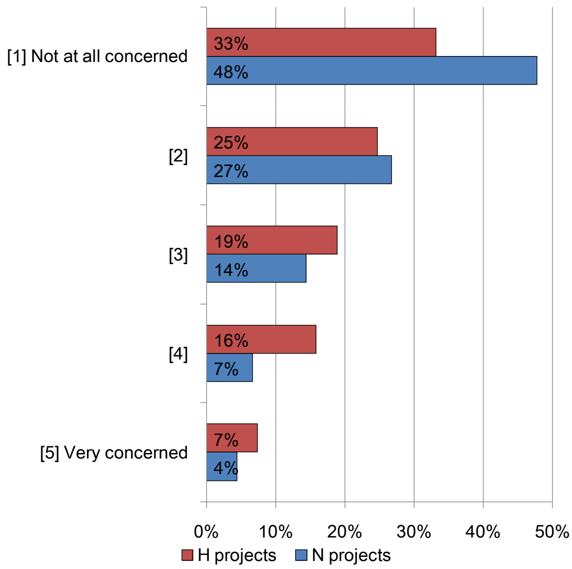
It is interesting to see that researchers for the H projects were significantly more concerned over priority loss in both countries. A potential explanation is that there are more competitors for such projects as seen in Exhibit 26 and Exhibit 27. The priority concern increases with the number of competitors recognized *ex-ante* in both countries as shown in Exhibit 29, although the slope is larger in Japan (the Japanese researchers are more responsive to perceived number of competitors).

Exhibit 28 Threat of being scooped (level of concern)

(a) Japan



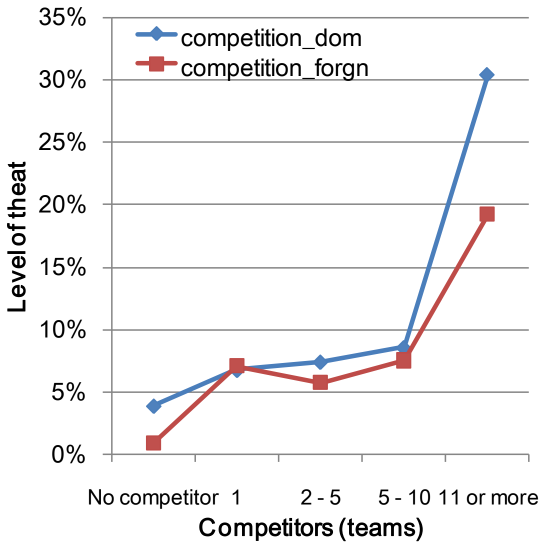
(b) US



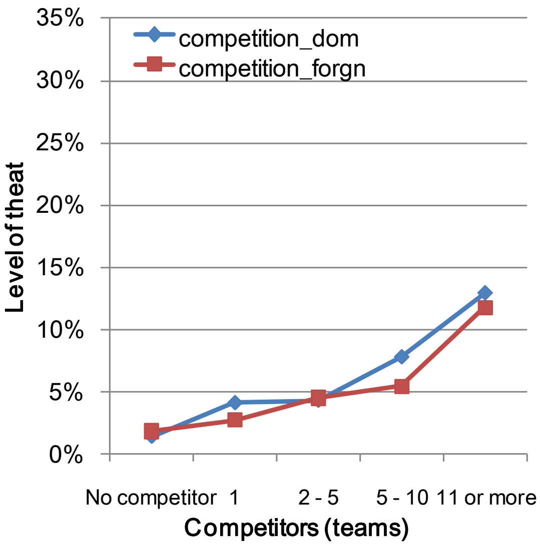
Note1: The upper figure is for the H projects and the lower figure is for the N projects.
Note2: The weighted result of natural sciences.

Exhibit 29 Percentage of very significant concern by number of competitors recognized

(a) Japan



(b) US



Note1: The results are not weighted by field

6 KNOWLEDGE SOURCES AND RESEARCH MANAGEMENT

6－1 EXTERNAL KNOWLEDGE SOURCES THAT INSPIRED THE RESEARCH PROJECT

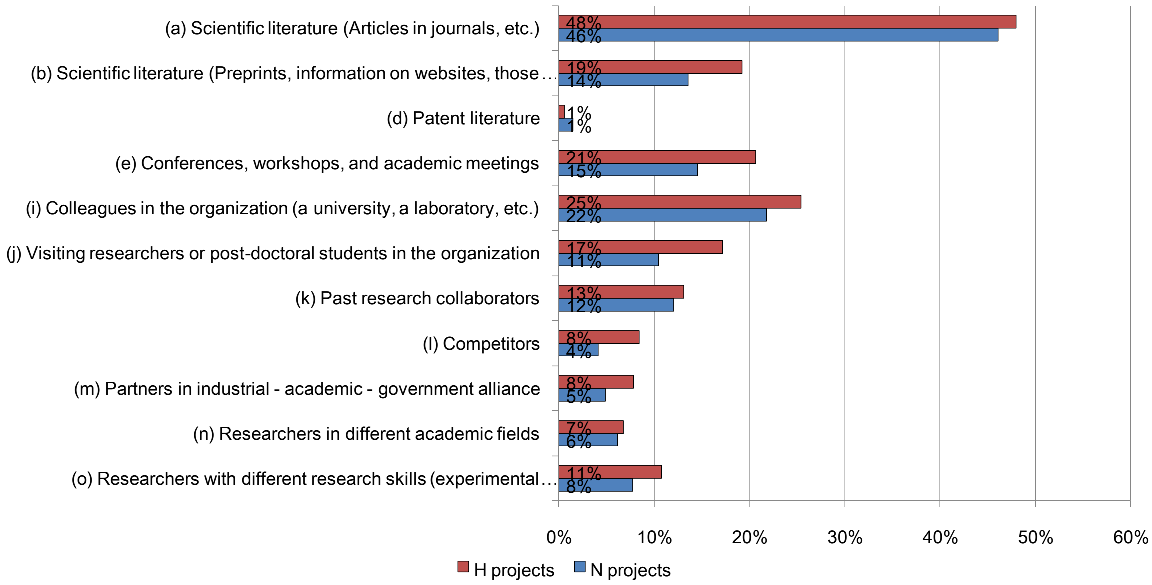
Since scientific research is a cumulative process, building on the existing stock of knowledge that is embodied in literature, experts and facilities, the scope and depth of exploiting such knowledge would affect significantly the efficiency of scientific research. It may depend on the absorptive capability of the research team as well as its management. While absorptive capability is most often used to characterize the innovation capability of industrial firms (see Cohen and Levinthal (1989)), such capability may well become relevant to the scientific research that has become more complex. Our survey identified 5 broad categories of knowledge sources based on pre-testing (one category having overlaps with the other categories): literature (open to the public and widely accessible), forums and facilities (open but less accessible for a distant researcher), internal or past collaborators (based on personal contacts within collaborative relationship), external experts (based on personal contacts) and experts in a different field or with a different skill (which have overlaps with the other categories). There are 11 subclasses of knowledge sources and a respondent was invited to evaluate each of them in terms of whether it was used or not and, when used, how important it was for suggesting the project by 5 point Likert scale.

By far, the most important knowledge source for suggesting the research project is scientific literature, as shown in following Exhibit 30 (a) and (b) for the two countries. Almost 50% of the researchers of both H and N projects say that they are very important. Colleagues in the organization (a university, a laboratory, etc.); visiting researchers or post-doctoral students in the organization; and past research collaborators follow this in both countries, exceeding 10% for each of H and N projects. In Japan, scientific literature with faster disclosures (preprints, etc.) and conferences, workshops and academic workings also exceed 10%. In the US, researchers with different research skills exceed 10%.

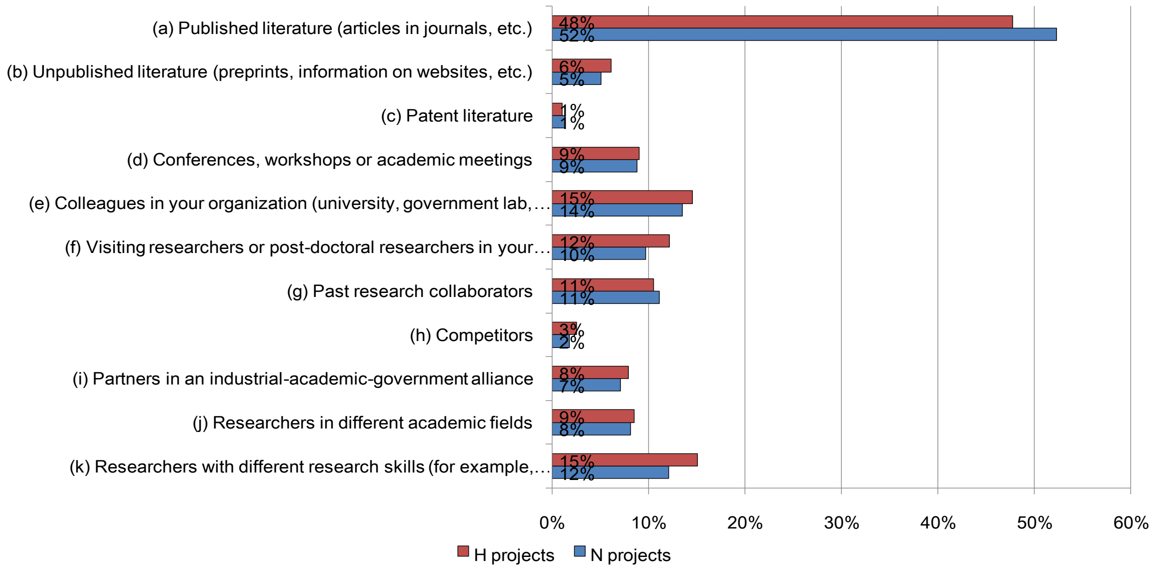
The importance attached by the researchers of H projects tends to be higher than that by the researchers of N projects for most knowledge sources (except for patent literature in the two countries and published scientific literature and past research collaborators in the US). As for Japanese survey, the difference of the incidence between these two types of projects are especially large (5% or more points) for conferences, workshops etc.; visiting researchers or post-doctoral students in the organization; scientific literature with faster disclosures. It is relatively large (2% or more points) for colleagues in the organization (a university, a laboratory, etc.) and researchers with different research skills. These differences suggest that person-to-person contact is especially important for getting an idea for initiating a good research project.

Exhibit 30 Importance of external knowledge sources for conceiving the research project (% very important)

(a) Japan



(b) US



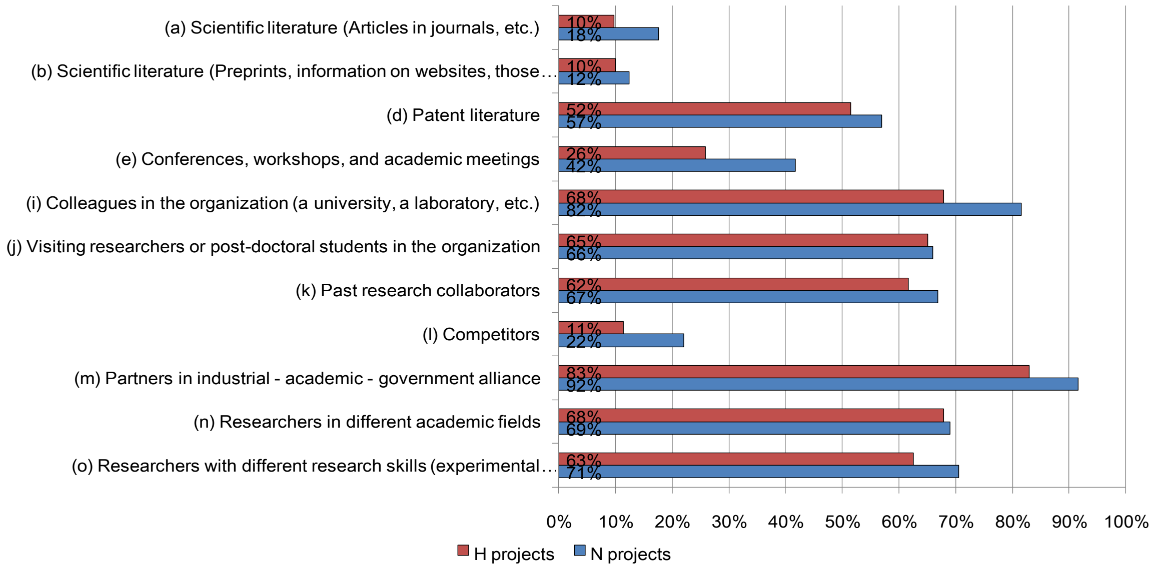
Note1: The results show the share of "very important" in the importance of knowledge sources for conceiving the research project.
Note2: The upper figure is for the H projects and the lower figure is for the N projects.
Note3: The weighted result of natural sciences.

The survey also asked the researchers to identify the country location of the most important knowledge source (such as the location of the key researcher), when the knowledge source is either "important" or "very important" for suggesting the research projects[1]. As shown in the following Exhibit 31 (a) and (b), all such most important knowledge sources are domestic (exceeding 60%) in the US. The only exception is "visiting researchers or post-doctoral researchers," for which the domestic source is most important for around 40% of the cases. On the other hand, only the sources of knowledge that are embodied in researchers tend to be domestic in Japan. Among knowledge sources for suggesting the research project, colleagues in the organization (a university, a laboratory, etc.); visiting researchers or post-doctoral students in the organization; past research collaborators are often domestic. On the other hand, the most important sources of knowledge that are embodied in literature and open forum are very often international. They include scientific literature with faster disclosures, scientific literature, and competitors. Since research competition is global (see section 5), it is not surprising that competitors as important knowledge source are also often international for researchers in Japan.

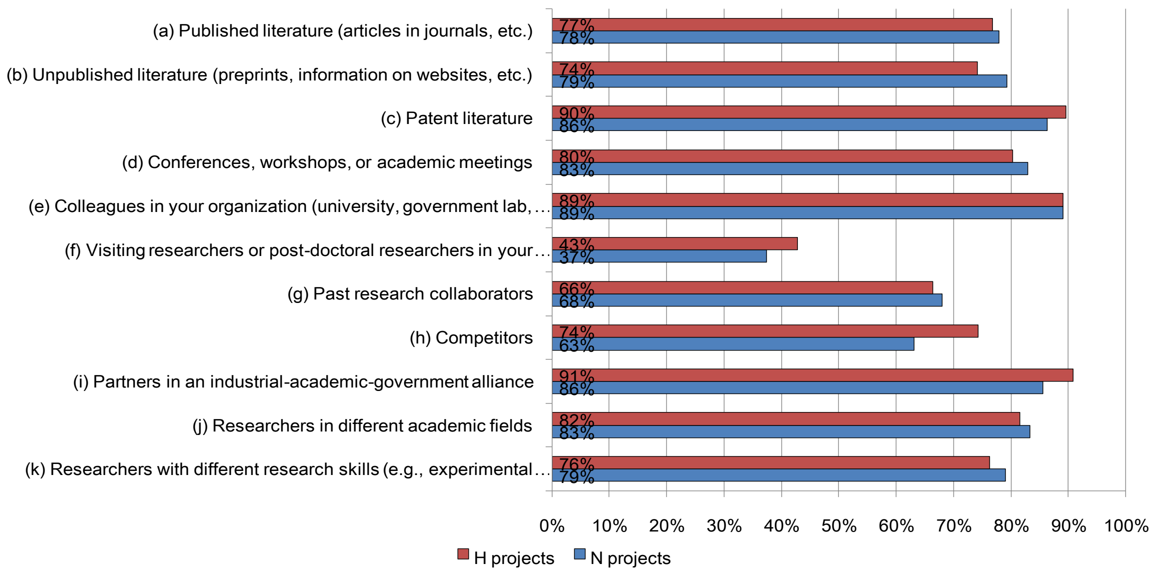
[1] The countries for a choice are Japan, the United States, Germany, the United Kingdom, France, and the other EU member countries, China and others.

Exhibit 31 Percent ranking of important knowledge sources being domestic

(a) Japan



(b) US



Note1: The upper figure is for the H projects and the lower figure is for the N projects.
Note2: The weighted result of natural sciences.

6－2 RESEARCH MANAGEMENT AND ITS POTENTIAL CONTRIBUTIONS

As pointed out earlier, most scientific researches today are teamwork. It also builds on the collaborations across organizations and across disciplines (See next section). It also faces, perhaps increasingly more, global priority competition. Therefore, we would expect that management has become increasingly important for research performance. In order to have empirical basis for evaluating the relevancy of management for a scientific research, our survey asked what management practices each research team has adopted. In this section, we focus on 7 practices which are identified commonly in the surveys of the two countries[1]. These practices cover: ambitious goal setting, information sharing and discussions in a team, division of research tasks for outsourcing of a research task, improvement of facilities and program, and development of a research community.

Exhibit 32 (a) and (b) summarizes how often each research management practice is implemented in Japan and in the US (% yes). In Japan, information sharing within a team and individual discussions between a research member and a leader are implemented for more than 70% of both H and N projects. Following this, a setting of an ambitious research project goal and continuous improvement of experiment facilities are implemented in more than 50% of the projects. In the US, a setting of an ambitious research project goal is implemented in more than 90% of the cases. Following this, development of a research community and information sharing within a research team are implemented in more than 60% of the projects.

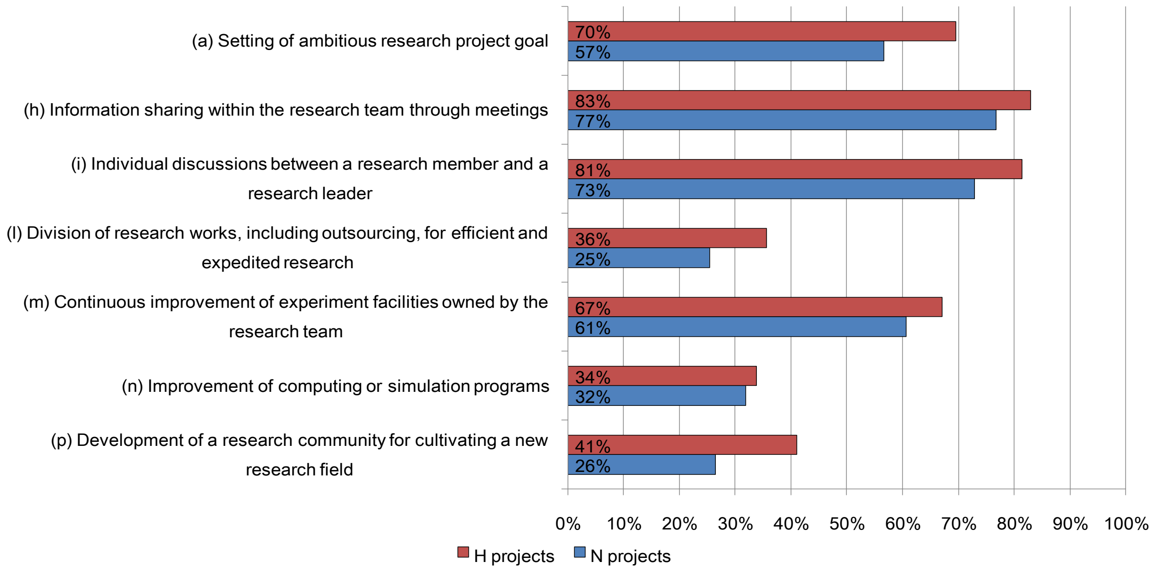
Although the patterns of implementation across management practices are similar between H projects and N projects, all management practices are implemented more in H projects. What is interesting would be the practices that are implemented in a different degree between two types of projects. The management practice with the largest difference in implementation (10% or more) in Japan are setting of ambitious research goal, division of research works, and development of a research community. It is only development of a research community in the US. This seems to suggest that the H projects are more consciously managed, taking into accounts the research environment and opportunities. The researchers in the H projects are more involved in the development of a research community for cultivating a new research field. The conscious effort of a researcher to develop a research community could help enhancing the research performance by strengthening the network externality among researchers, although it may be partially endogenous to the success of the project.

---

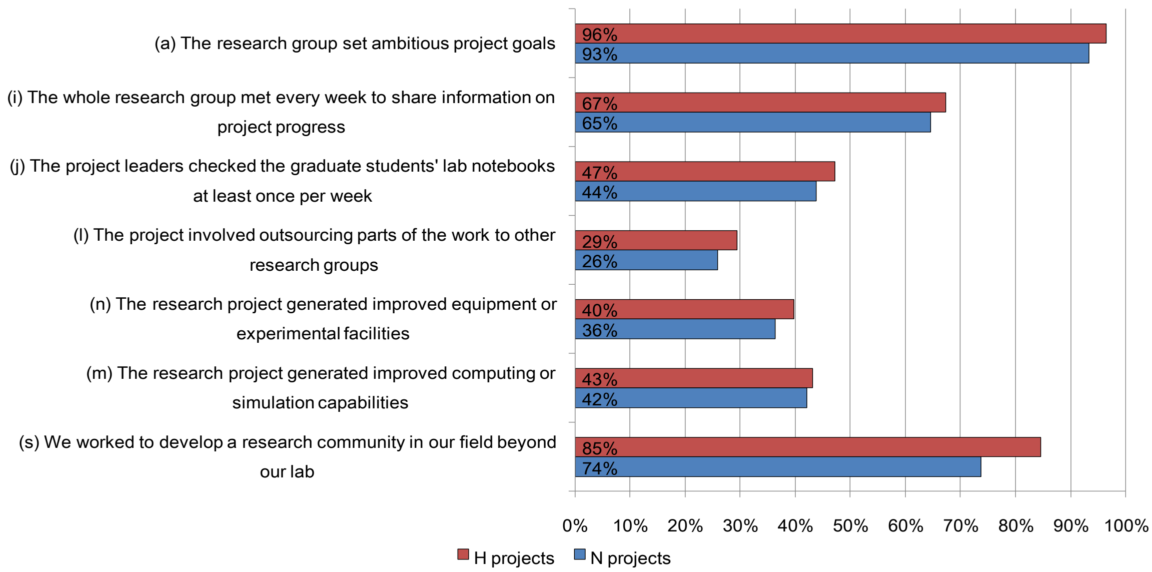
[1] The Japanese survey identified 16 management practices and asked not only whether these practices has been adopted (we identified major 16 practices based on pre-testing, excluding “the other”) but also how effective they have been (see Nagaoka, Igami, Ijichi, and Eto (2010)) .

Exhibit 32 Implementation of research management practices (% yes)

(a) Japan



(b) US



Note1: The results show the share of "yes" in the Implementation of research management practices.
Note2: The upper figure is for the H projects and the lower figure is for the N projects.
Note3: The weighted result of natural sciences.

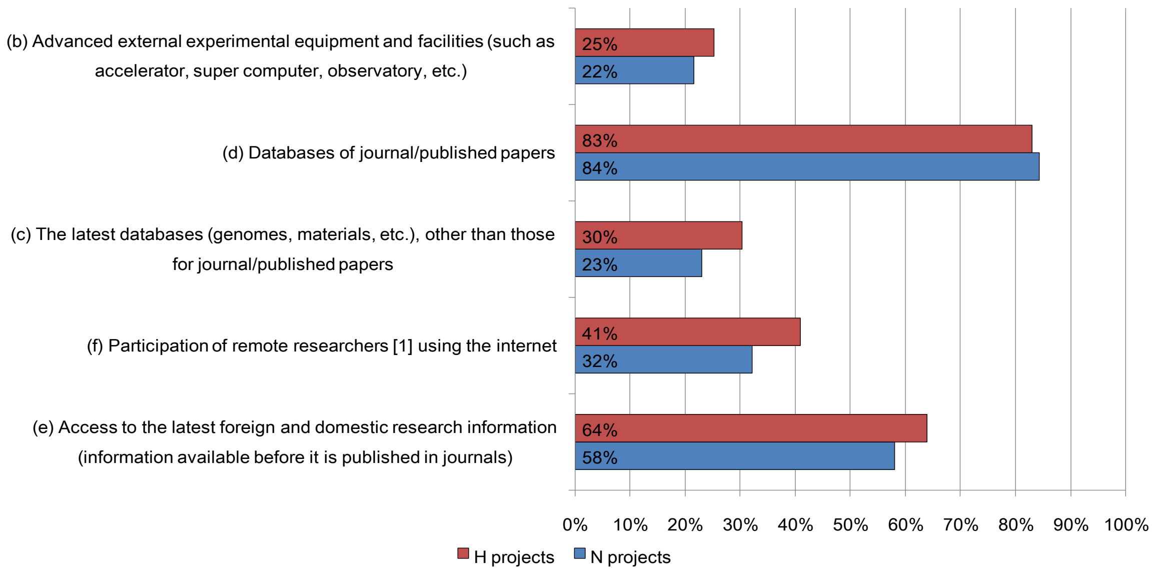
6—3 Use of Advanced Research Facilities, Databases, and the Internet for Distant Collaborators

Research equipment and database plays a very important role for scientific research (Stephan (2010)). For examples, the inventions and the progress of a particle accelerator, a scanning tunneling microscope, and a DNA sequencer have been major sources for advancing research in physics, materials science and life sciences. In addition, the availability of internet has fostered collaborative research among distant researchers and its productivity (see Agrawal and Goldfarb (2008)). Our surveys commonly identified the requirements for such facilities, including the participation of remote researchers using the internet and literature and non-literature database[1]. Exhibit 33 (a) and (b) shows the summary results for the level of the requirements of these infrastructures. Databases of journal/published papers are most frequently (more than 80%) required in both H projects and N projects in both countries. More than one quarter of the H projects required external advanced research equipment and facilities in both countries. Internet is also extensively required for facilitating the participation of remote researchers: 41% (67%) of the H projects and 32% (58%) of the N projects in Japan (US). Non-literature research tool database are also required frequently: 30% (55%) of H projects and 23 % (47%) of N projects in Japan (the US). Both participation of remote researchers using internet and non-literature research tool database seem to be substantially more used by the US researchers than Japan based researchers. All facilities and databases are more required in H projects, except for literature database by Japanese researchers.

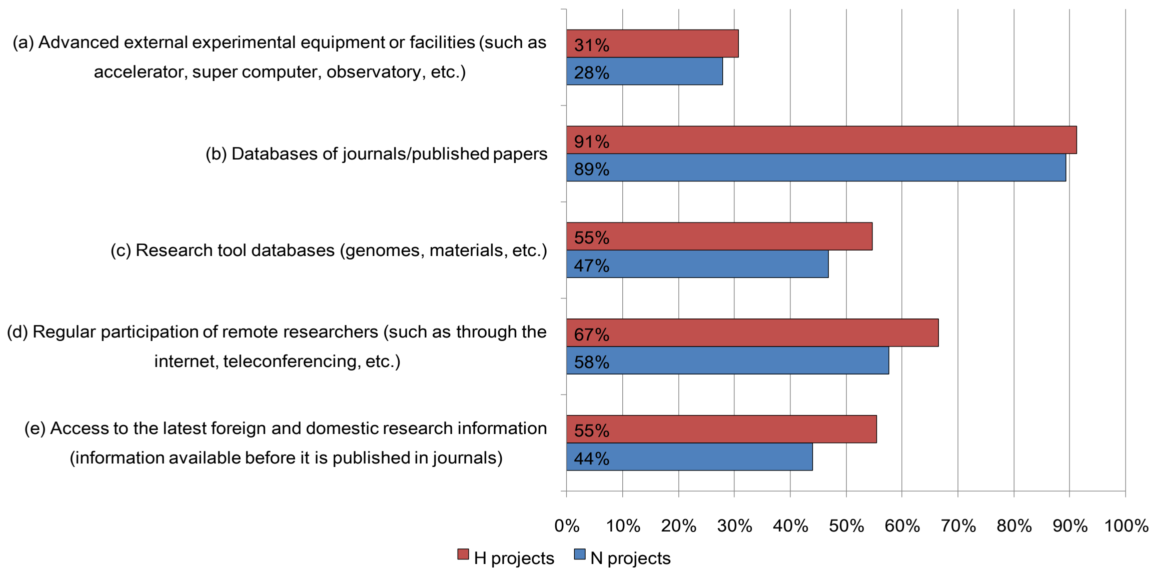
[1] The Japanese survey also asked researchers whether they used the research facilities and databases as well as how effective they were in producing the main research output, differentiating advanced research facilities owned by a research team and the external facilities.

Exhibit 33 Requirements for research facilities and equipment (% yes)

(a) Japan



(b) US



Note1: The upper figure is for the H projects and the lower figure is for the N projects.
Note2: The weighted result of natural sciences.

7 RESEARCH TEAMS AS SEEN FROM AUTHORS

The recent studies on the scientific research, based on the bibliographic information,[1] show that a unit of scientific research has increasingly shifted from an individual to a team, involving multiple organizations rather than a single organization, which is also an international rather than domestic. The recent research on science mapping[2] also suggests that interdisciplinary or cross-cutting research areas, which require combination of knowledge from different fields, have emerged broadly in science.

These developments suggest that the issue of how to design and manage a research team has become an increasingly important issue. However, the bibliographic information alone provides only limited information on who are the researchers, including their status, the role in research, disciplinary diversity and skill diversity. Furthermore, it is important to note that a significant number of researchers who contributed only research fund and materials are listed as authors, as will be shown in this section.

This survey asked a respondent to identify the authors' organizational affiliations, academic/professional positions in the organization, academic areas, areas of expertise, and the countries of birth to identify the structure of research team. This question on author profile was asked for all authors when the number of authors is 6 or less and for up to 6 authors, the first, last and corresponding authors and the randomly selected authors, when the number of authors is 7 or more. The question was also asked to respondents, when he/she was not included in the list.

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1 See Jones Wuchy and Uzzi (2008), and Saka and Kuwahara (2008)

2 See Saka, Igami and Kuwahara (2010)

7－1 Number of Authors

The share of single authored papers is 3.0% for the H papers and 6.9% for the N papers in Japanese samples; and 5.4% for the H papers and 11% for the N papers in the US samples. This indicates that most scientific research is done by a team rather than by an individual in our sample too.

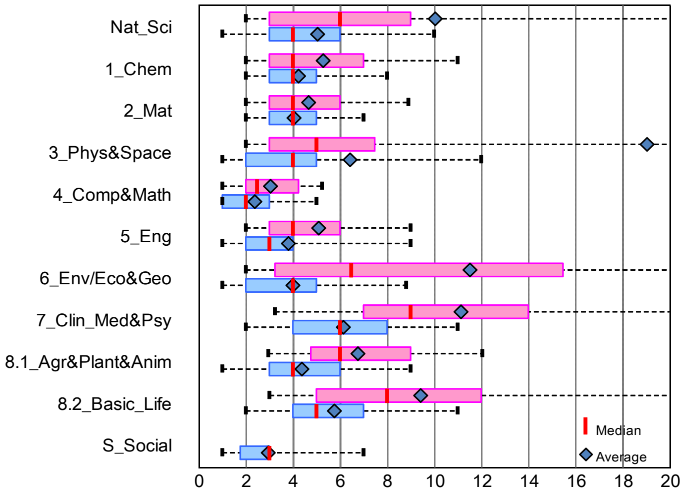
The median and average number of authors is 6 and 10 for the H projects in Japanese samples; 4 and 5.1 for N projects in Japanese samples; 5 and 7.9 for the H projects in the US samples; 4 and 4.2 for N projects in the US samples, as shown in the following exhibit. The size distribution of authors is skewed especially in the H projects.

(Number of authors by field)

The boxplots in Exhibit 34 shows the distributions of the number of authors by field. Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left ends of boxes indicate the first quartiles; and right ends of boxes the third quartiles. Left ends of whiskers indicate the 5th percentile; and right ends of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means. The bars display the range (25% to 75%) of the distribution of authors on a paper by type of the project and by field.

Exhibit 34 Distributions of number of authors by field

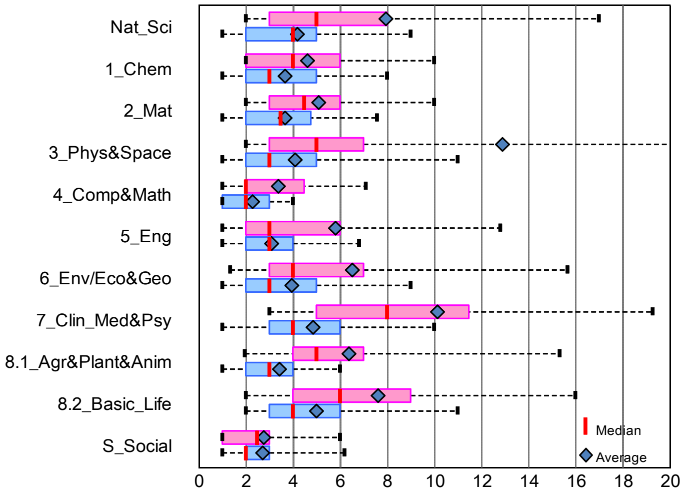
(a) Japan



unit: persons

Respondents	Minimum	Q1	Median	Q3	Maximum	Average
564	1	3	6	9	327	10.0
1473	1	3	4	6	209	5.1
71	1	3	4	7	20	5.3
186	1	3	4	5	13	4.2
43	1	3	4	6	13	4.7
99	1	3	4	5	10	4.1
127	1	3	5	8	327	19.1
253	1	2	4	5	209	6.4
16	1	2	3	4	6	3.1
61	1	1	2	3	8	2.4
68	1	3	4	6	21	5.1
138	1	2	3	4	18	3.8
30	1	3	7	16	50	11.5
85	1	2	4	5	33	4.0
66	1	7	9	14	46	11.1
198	1	4	6	8	31	6.1
60	1	5	6	9	23	6.8
132	1	3	4	6	12	4.4
83	1	5	8	12	34	9.4
321	1	4	5	7	18	5.8
-	-	-	-	-	-	-
40	1	2	3	3	8	3.0

(b) US



unit: persons

Respondents	Minimum	Q1	Median	Q3	Maximum	Average
721	1	3	5	8	375	7.9
1393	1	2	4	5	74	4.2
66	1	2	4	6	12	4.6
120	1	2	3	5	14	3.7
22	2	3	5	6	13	5.1
50	1	2	4	5	9	3.7
96	1	3	5	7	375	12.9
163	1	2	3	5	24	4.1
39	1	2	2	5	11	3.4
92	1	1	2	3	15	2.3
57	1	2	3	6	75	5.8
105	1	2	3	4	22	3.1
68	1	3	4	7	50	6.5
126	1	2	3	5	19	4.0
155	2	5	8	12	206	10.1
290	1	3	4	6	16	4.9
60	1	4	5	7	37	6.4
97	1	2	3	4	8	3.4
158	1	4	6	9	58	7.6
350	1	3	4	6	74	5.0
76	1	1	3	3	9	2.8
137	1	2	2	3	13	2.7

Note1: Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left end of boxes indicate the first quartiles; and right end of boxes the third quartiles. Left end of whiskers indicate the 5th percentile; and right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Note3: The results of natural sciences are not weighted by field

The number of authors varies significantly across scientific fields, but is quite similar between Japanese and the US samples. Since the number of authors varies significantly even in a specific scientific field, we use mainly the medians for the following comparison across fields.

The size of authors is small in computer science & mathematics and social sciences, while it is large in basic life sciences and clinical medicine & psychiatry/psychology. The range of the author size between the first and the third quartile for physics & space science is not especially large, but the gap between the median and the average is very large. This reflects the existence of the outlier, the papers with a huge number of authors (more than 300), on such subject as particle physics.

The number of authors tends to be larger for the H papers than the N papers in most fields. The variation of the number of authors is large in clinical medicine & psychiatry/psychology and basic life sciences in both Japanese and the US samples; and is large in environment/ecology & geosciences especially in Japanese samples. In these fields, the maximum size of the research team is also very large, following physics & space science.

7－2 Scope of Authors: Who Are the Authors?

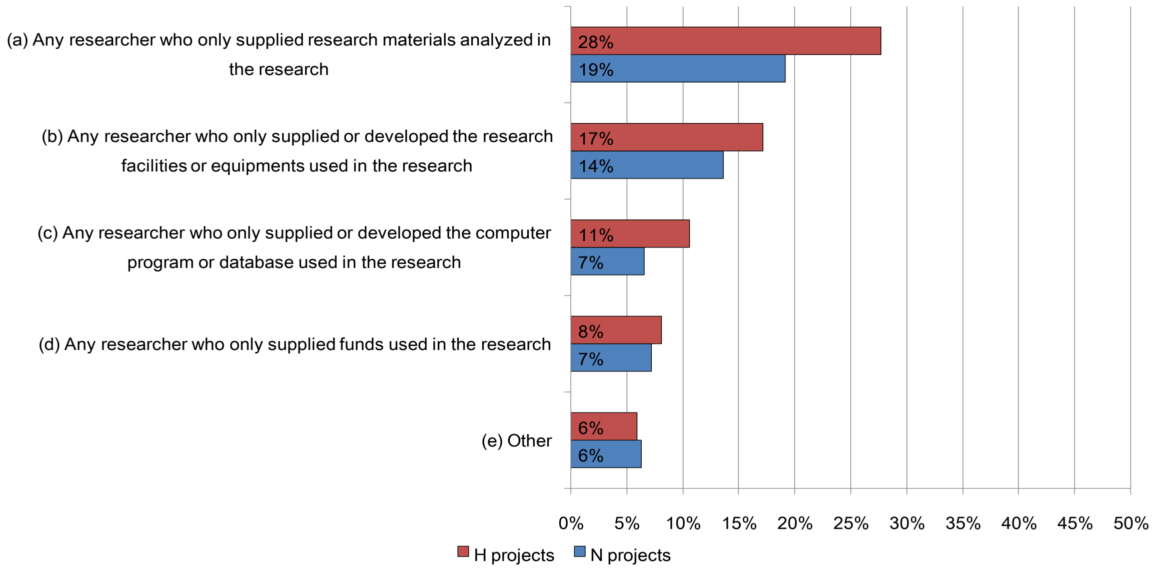
The basic question we asked in our survey is who are included among the authors, beyond those who directly contributed to the research project such as those who engaged in experiments, observations and theoretical analysis. We asked a respondent whether there are those authors who did only non-research works such as providing research materials in the project under the survey.

A large number of researchers who supplied only research materials are included as an author in both Japanese and the US samples (see Exhibit 35). The shares of such authors are 28% in the H papers and 19% in the N papers in Japanese samples; and 17% in both the H and N papers in the US samples. In addition, a researcher who supplied or developed only the research facilities or equipments is also frequently included as an author in Japanese samples (17% in the H papers and 14% in the N papers). Frequent inclusion of these researchers among the authors might have been important to provide them the incentives to provide such materials and equipments. It also indicates their importance in research.

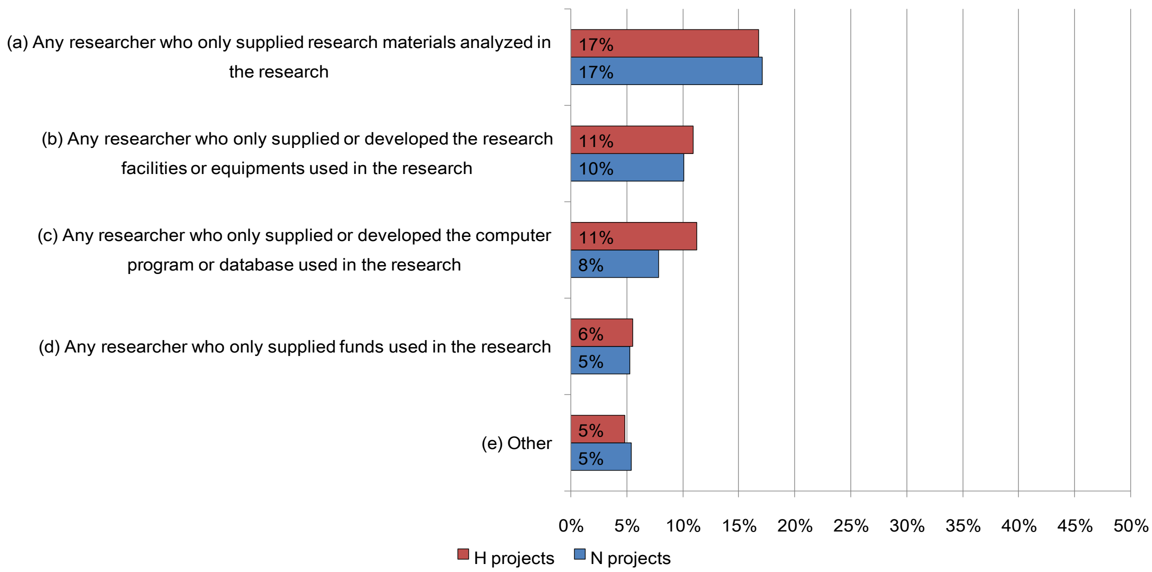
It is also noteworthy that a researcher who provided only research fund is also included as an author relatively frequently in both Japanese and the US samples. Preliminary regression analysis indicates wider scope of authors in Japanese samples is a reason why the average number of authors tends to be larger in Japanese samples compared to in the US samples.

Exhibit 35 Scope of authors

(a) Japan



(b) US



Note1: The choice is non-exclusive.
Note2: Others are those researchers who did not provide direct contribution to the research project nor any four of the listed contributions
Note3: The upper figure is for the H projects and the lower figure is for the N projects.
Note4: The weighted result of natural sciences.

7—3 Combination of Authors in Academic/Professional Position

The following analysis is limited to the samples of the focal papers written by six or less authors, so as to avoid the possible biases due to our selective sampling of the first, last and corresponding authors of the focal papers which would become important as the number of author increase to seven or more.

Exhibit 36 shows the compositions of the authors classified by academic/professional position by sector and by types of papers. Each paper has an equal weight for calculating the average. For example, in the case of a paper consisting of *n* authors, each author is given a weight of 1/*n* for the purpose of aggregation.

Exhibit 36 (a) and (b) show composition of authors, in the HEIs, in Japanese and the US samples respectively. As for Japanese samples, the share of professors is the largest, followed by associate professor and assistant professors. Professors account for around 40% in the H and N papers. On the other hand, young scholars, who are undergraduates, graduate students, or postdoctoral fellows, account for 28% of the authors of the H papers and 25% of the N papers. Students alone account for close to 20% of the authors of both types of papers.

In the US samples, professors also account for the largest share in both the H and N papers. PhD students have the second largest share in both the H and N papers. The contribution of postdoctoral fellows is as large as that of PhD students in the H papers. Young scholars account for 38% of the authors of the H papers and 32% of the N papers in the US samples, around 10% larger than those in Japanese samples. These results indicate more involvement of young scholars in the knowledge creation process in the US.

In PRIs of Japanese samples, the share of the professor level scientists is the largest, followed by associate professor level research scientists. Young scholars account for 15% of the authors of the H papers and 17% of the N papers. The share of students is small. As for the US samples, the share of the professor level scientists is the largest, followed by postdoctoral fellows and associate professor level research scientists. There is a large portion of researchers who are classified into “Other.” “Other” includes technician, the others and unknown.

In private firms, the share of the young scholars accounts for non-negligible percentage, which however is due to the fact that a research paper collaboratively done with HEIs and/or PRIs are included as the papers of the private firms[1]. This effect seems to be especially important for H papers. The share of researchers in other category is very large in the US samples, indicating the category which we used is not suitable for describing the professional position of researchers in the US firms.

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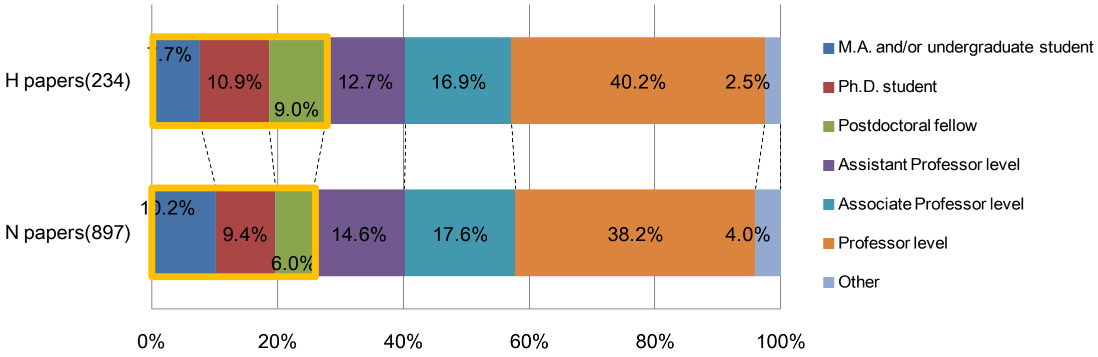
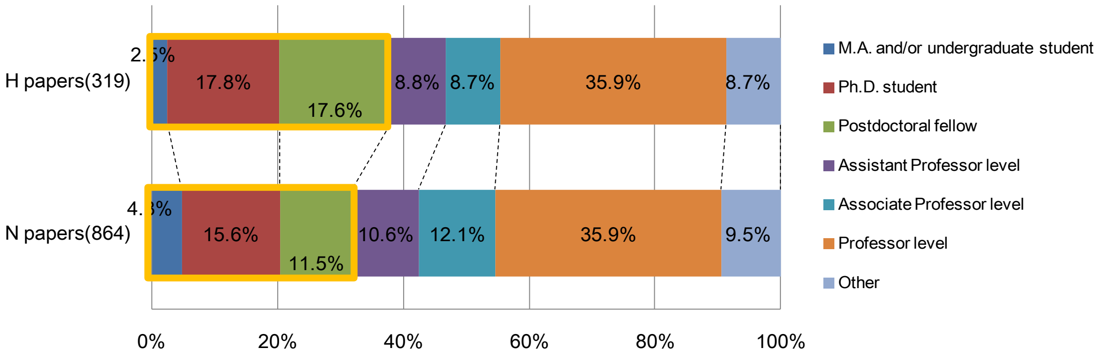
[1] The paper is assigned to the sector with which the responding author was affiliated when the focal papers were submitted.

Exhibit 36 Compositions of authors in academic/professional position (a paper basis, by sector, natural sciences)

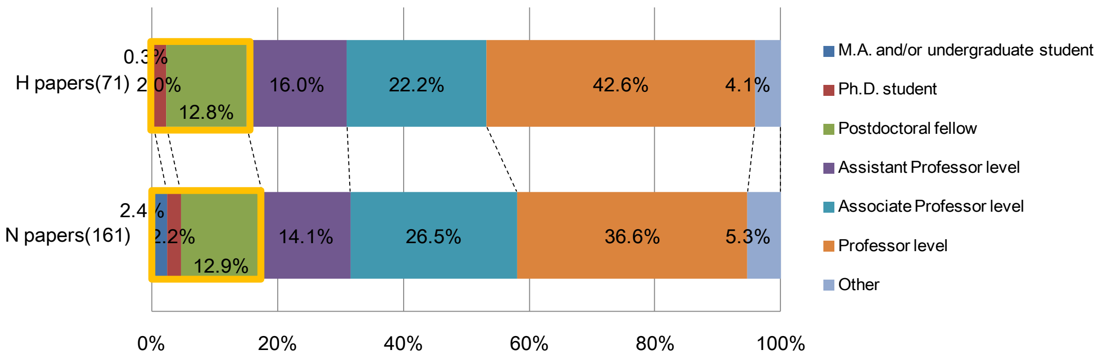
(a) Higher education institutions, Japan



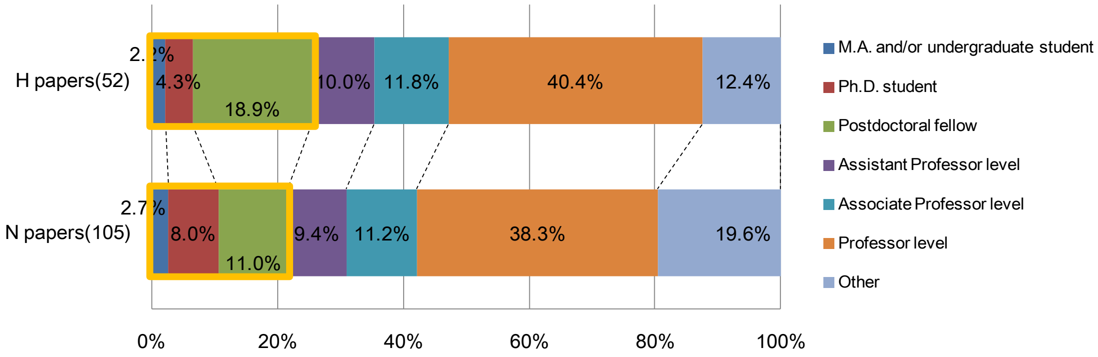
(b) Higher education institutions, US



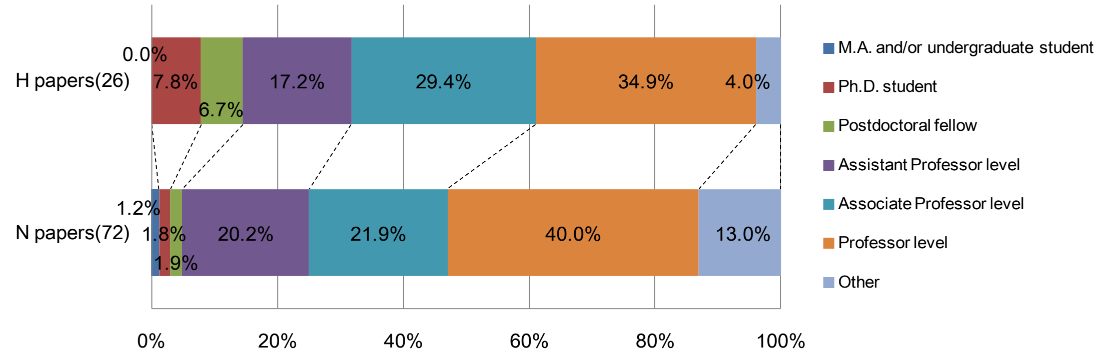
(c) Public research institutions, Japan



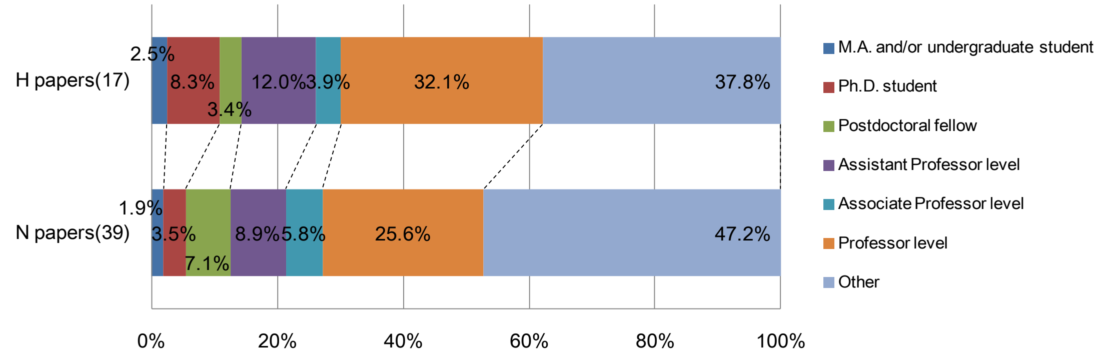
(d) Public research institutions, US



(e) Private firms, Japan



(e) Private firms, US



Note1: These exhibits cover only papers with 6 or less authors.
Note2: Each author of the paper with n authors has a weight of 1/n for aggregation
Note3: “Other” includes technician, the others and unknown.
Note4: The results are not weighted by field.

7−4 WHO ARE THE FIRST AUTHORS WHEN THE AUTHORS ARE LISTED IN ORDER OF THEIR DEGREE OF CONTRIBUTIONS

Exhibit 37 (a) shows the academic/professional positions of the first authors in the focal papers in which authors are listed in order of their degrees of contributions. It shows the shares by academic/professional position. It indicates the types of researchers who made the most contributions to the focal papers. Stephan (2010)[1] pointed out that PhD students and postdoctoral fellows appear disproportionately more as the first authors in the US articles in the journal *Science*. We extend her analysis by covering all journals and by focusing on the articles where the order of the authors is according to their contributions.

In the following discussion, we first look at the contribution of young scholars in the research team of the HEIs and whose focal paper is the N papers. As shown in Exhibit 37 (a) and (d), young scholars, i.e., undergraduates, graduate students, or postdoctoral fellows, account for 35% of the first authors in Japanese samples and for 49% of the first authors in the US samples. Contribution of young scholars is more common in the US sample, compared to Japanese samples. The percentage of young scholars in all authors of N papers is 26% and 32% in Japanese and US samples, respectively. The share of young scholars in the first authors shows remarkable increase from that in the all authors in both countries.

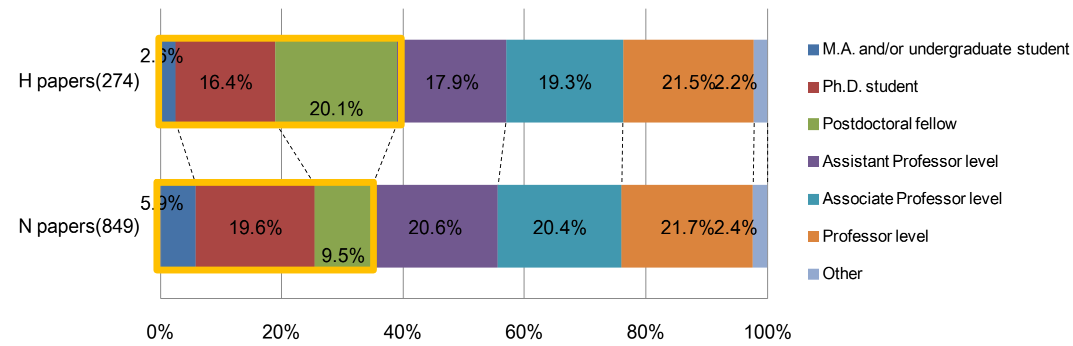
The contribution of the young scholars is especially large in life sciences in both countries. In life sciences, 45% and 61% of the first authors are young scholars in Japanese and the US samples, respectively. In physical sciences, the young scholars account for more than 50% of the first author in the US samples, while the share is around 30% in Japanese samples. In the Japanese samples, the difference in the share of the young scholars between life sciences and physical sciences is statistically significant.

Contribution of the postdoctoral fellows as the first author varies on the type of papers, i.e., H or N papers. The share of the postdoctoral fellows in the H papers is very large in both physical and life sciences in Japanese samples and in life sciences in the US samples; and the differences are statistically significant. As we can see from Exhibit 37 (a) and (d), the composition of the postdoctoral fellows and other young scholars, i.e., PhD students; master students; and undergraduate students, is different by the type of papers. The participation of other young scholars as the first author is more often in the N papers compared to the H papers. This finding indicates that one of the crucial functions of the N projects is education of students.

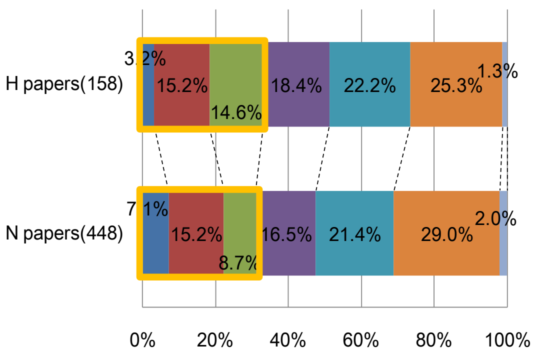
[1] Based on her seminar presentation on Economics of Science at the Research Institute of Economy, Trade and Industry (March 2010).

Exhibit 37 Academic/professional positions of the first authors in the focal papers whose authors are listed in order of their degree of contributions (by sector)

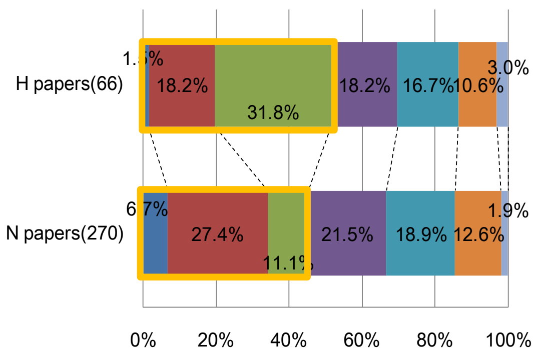
(a) Higher education institutions, Japan (natural sciences)



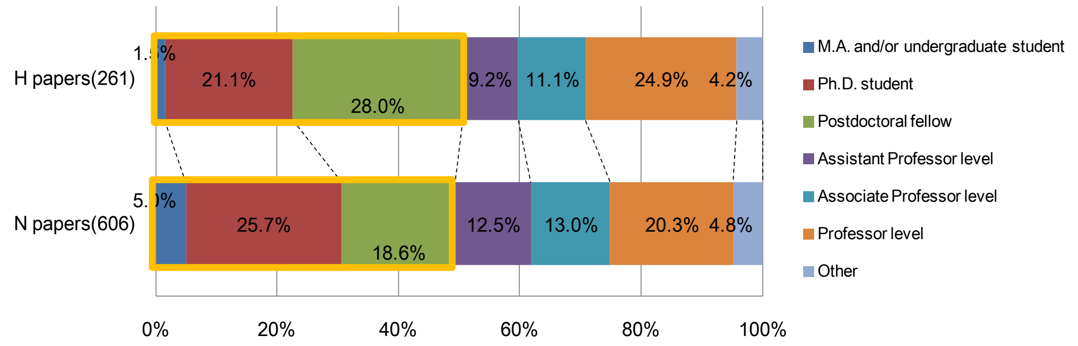
(b) HEIs, Japan (physical sciences)



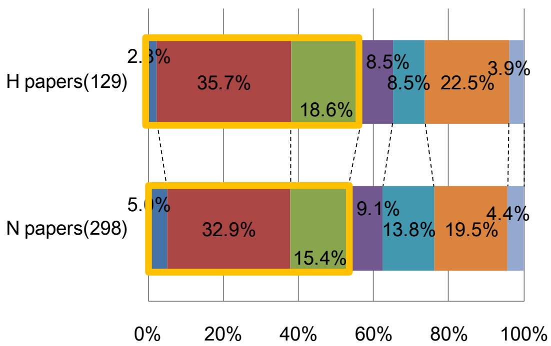
(c) HEIs, Japan (life sciences)



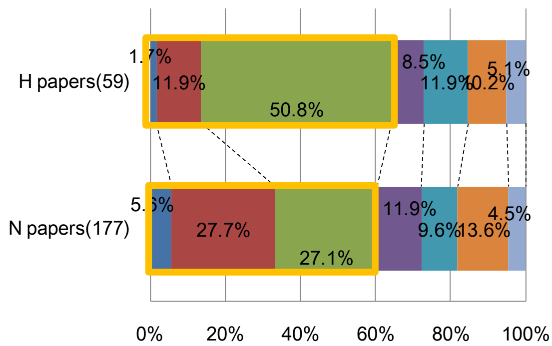
(d) Higher education institutions, US (natural sciences)



(e) HEIs, US (physical sciences)



(f) HEIs, US (life sciences)



Note1: The sample focuses on those papers the authors of which are ordered according to the contribution of the authors to the research.
Note2: "Other" includes technician, the others and unknown.

7—5 COUNTRY OF BIRTH OF THE FIRST AUTHORS

Analyses of the country of birth of researches reveal striking difference in the team formation between Japan and the US. In the following, we focus on the first authors of research teams of HEIs and investigate the differences in the origin of birth by the cohort of authors. As a proxy to measure the cohort of the authors, we used the academic position of authors. Young scholars include undergraduate students, master students, PhD students, and postdoctoral fellows. Senior authors include assistant professors, associate professors, and other academic positions.

Exhibit 38 (a) shows the country of birth of the first authors in N papers (HEIs and natural sciences). In the US samples, it was found that more than 60% of young scholars were born outside of the US and the US-born young scholars only account for 38% of the total. Among the foreign-born young scholars, China has the largest share. China-born young scholars reach to 15% of the total. European-born young scholars account for around 20% and Asia-born young scholars excluding Japan and China account for 14%. The results clearly show the US reliance on the foreign-born talents on knowledge creation process in science. The degree of reliance declines in senior scholars, the share of foreign-born researchers is around 50%.

As for Japanese samples, around 30% of young scholars and 10% of senior scholars are foreign-born. China-born and other Asia-born researchers are dominant in the foreign-born young scholars in Japanese samples.

Exhibit 38 (b) shows the country of birth of the first authors in H papers (HEIs and natural sciences). The share of foreign-born first authors increases in both young and senior scholars in Japanese samples, relative to N papers. In H papers, the share of China-born young scholars declines, while the share of European-born and US-born researchers increases remarkably. In the US samples, the share of foreign-born first authors also increases in young scholars, but it decreases in senior researchers.

Exhibit 38 Country of birth of the first authors by the type of papers (HEIs and natural sciences)

(a) N papers

HEIs		Japan	China	Other Asia	Europe	US	Other, unknown
Japan	Young scholar (297)	71.4%	10.1%	7.7%	3.4%	1.3%	6.1%
	Senior scholar (552)	89.5%	2.7%	2.4%	2.7%	1.1%	1.6%
US	Young scholar (299)	2.7%	14.7%	13.7%	20.4%	37.8%	10.7%
	Senior scholar (307)	3.3%	6.5%	13.4%	13.7%	53.7%	9.4%

(b) H papers

HEIs		Japan	China	Other Asia	Europe	US	Other, unknown
Japan	Young scholar (107)	64.5%	6.5%	8.4%	9.3%	5.6%	5.6%
	Senior scholar (167)	80.8%	3.0%	1.2%	6.0%	2.4%	6.6%
US	Young scholar (132)	2.3%	17.4%	14.4%	26.5%	27.3%	12.1%
	Senior scholar (129)	0.0%	3.9%	10.9%	13.2%	64.3%	7.8%

Note1: The sample focuses on those papers the authors of which are ordered according to the contribution of the authors to the research.
Note2: Young scholars: M.A. and/or undergraduate student, PhD student, and Postdoctoral fellow. Senior scholars: Assistant professor level, Associate professor level, Professor level, and other.
Note3: The results are not weighted by field.

7－6 DIVERSITY OF AUTHORS IN RESEARCH TEAM

This subsection looks briefly at the diversity of authors in specialized academic field, specialized skill, country of birth, and affiliating sector at the time of submitting the focal papers (Exhibit 39). It is based on the profiles of up to six authors of the focal papers, who include the first, last and corresponding authors on a preferential basis.

Exhibit 39(a) and Exhibit 40 (a) show the distribution of the number of academic fields covered by research teams, where academic fields consist of 27 fields, covering such fields as mathematics, computer science and chemistry. For both types of papers the authors are most likely to belong to one discipline. The authors of the H papers are more likely to cover more than one specialized academic field than the N papers, as shown in the exhibit. This suggests that the researches tend to be conducted by more interdisciplinary research teams in the H papers than in N papers. The feature is common in both Japanese and the US samples.

Exhibit 39(b) and Exhibit 40 (b) show the distribution of the number of skills covered by research teams, where there are 3 broad categories of skills: theory, experiment and clinical analysis. In both countries, diversities in skills are high in research teams which produced H papers.

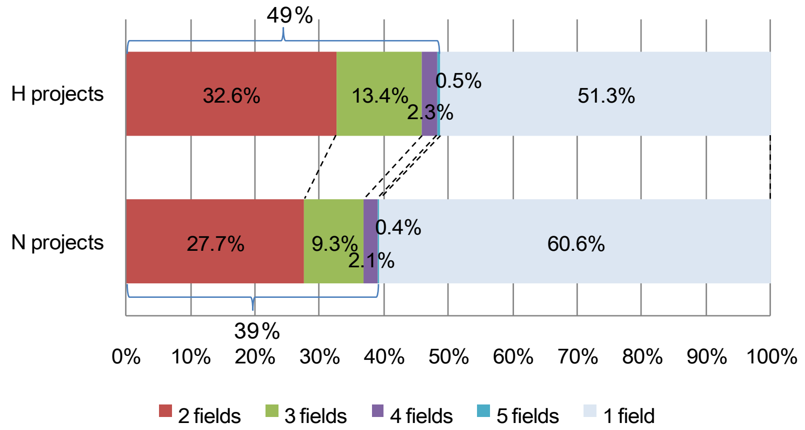
Exhibit 39(c) and Exhibit 40 (c) show the participation of foreign-born researchers in research teams. As shown in the origin of birth of the first authors, there is a striking difference between Japanese and the US samples in the combination of origins. In the N papers, foreign-born researchers are involved in around 70% of research teams in the US samples, while in around 30% of research teams in Japanese samples. Involvement of foreign researchers in research teams is more common in the H papers compared to the N papers. This characteristic is more evident in Japanese samples.

Analyses of the international co-authorship based on the organization's location shows that the average international co-authorship in 2005 – 2007 is 24% in Japan and 29% in the US. A small gap between the percentage of research teams with foreign-born researchers and the occurrence of international co-authorship in Japanese samples indicates that majority of foreign-born researchers observed in the Japanese survey were affiliated with the organizations outside of Japan. In contrast, the percentage of research teams with foreign-born researchers is much higher than the occurrence of international co-authorship in the US samples. The result means that the foreign-researchers counted here were affiliated with the organization in the US, clearly indicating "brain drain" to the US and the US's large dependence on foreign talents.

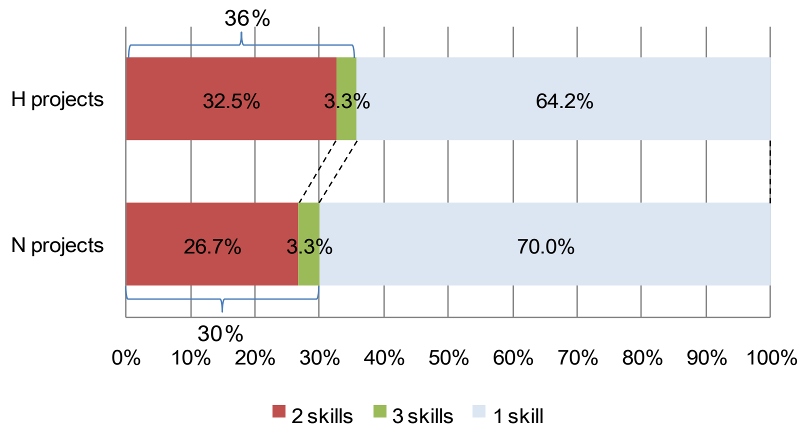
Exhibit 39(d) and Exhibit 40 (d) show the distribution of the number of sectors with which the authors of the research team is affiliated. The types of the sectors cover higher education institutions, PRIs, private firms and private non-profit research institutions. The authors of the H papers are likely to cover more than one sector than the N papers in both countries.

Exhibit 39 Diversity of authors in the research team, Japan

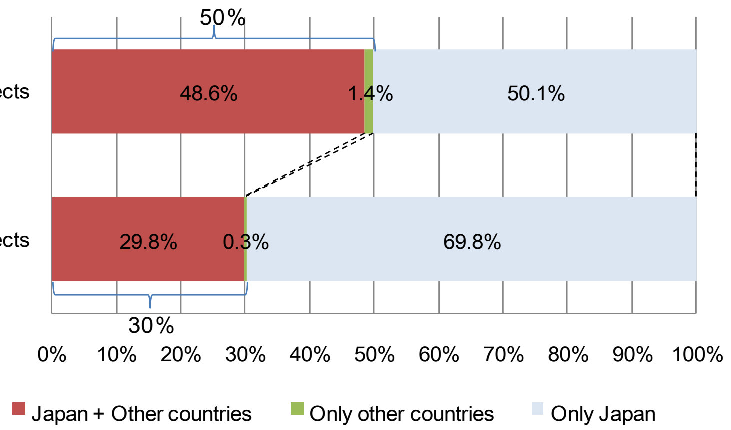
(a) Combination of specialized academic fields



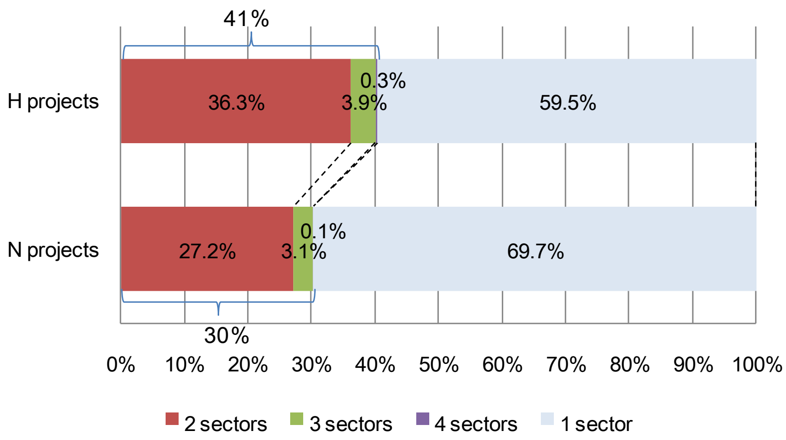
(b) Combination of specialized skills



(c) Combination of origins of birth



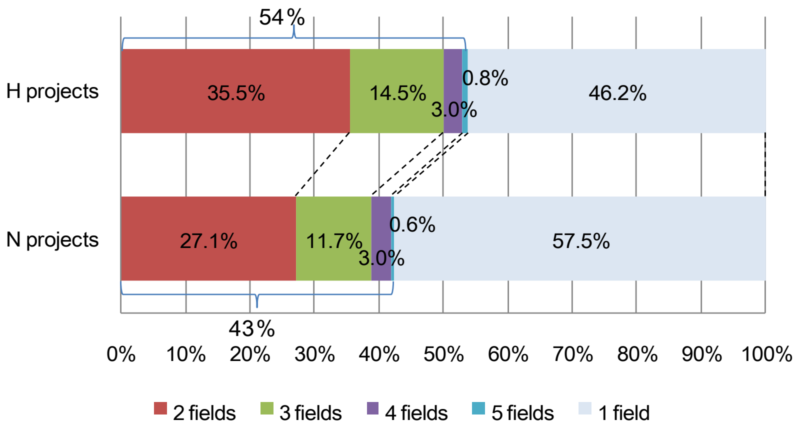
(d) Combination of sectors



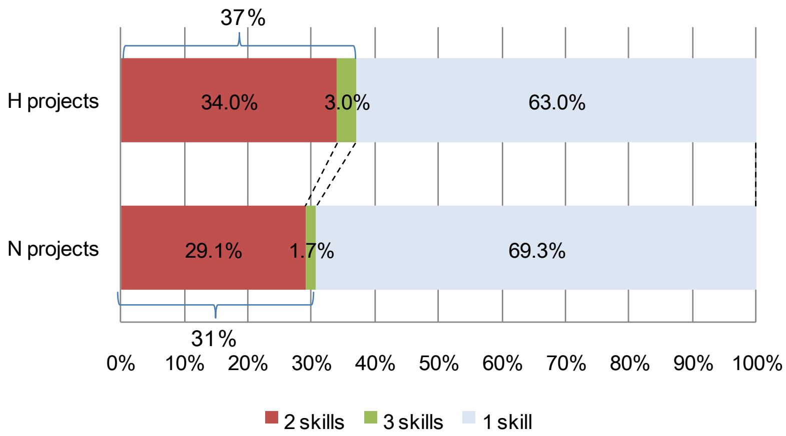
Note1: (Academic fields of specialization) One specialized field is chosen for each author among 27 fields, covering such fields as mathematics, computer science and chemistry.
Note2: (Specialized skills) One skill is chosen for each author among theory, experiment and clinical analysis
Note3: (Country of birth) Birth place chosen for each author among Japan and outside of Japan.
Note4: (Institutions) One institution is chosen for each author among university and the other higher education institutions, public research institutions, private firms and private non-profit research institutions
Note5: The weighted result of natural sciences.

Exhibit 40 Diversity of authors in the research team, US

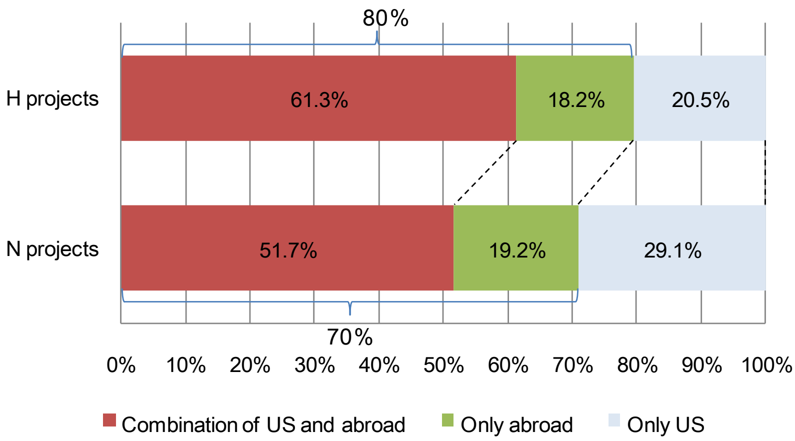
(a) Combination of specialized academic fields



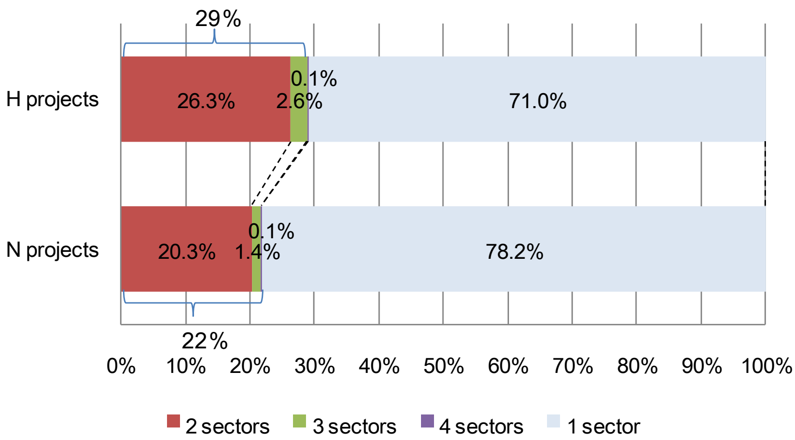
(b) Combination of specialized skills



(c) Combination of origins of birth



(d) Combination of sectors



Note1: (Academic fields of specialization) One specialized field is chosen for each author among 27 fields, covering such fields as mathematics, computer science and chemistry.

Note2: (Specialized skills) One skill is chosen for each author among theory, experiment and clinical analysis

Note3: (Country of birth) Birth place chosen for each author among Japan and outside of Japan.

Note4: (Institutions) One institution is chosen for each author among university and the other higher education institutions, public research institutions, private firms and private non-profit research institutions

Note5: The weighted result of natural sciences.

7—7 WOMEN IN RESEARCH TEAM

The ratio of female authors in research team by field of science and sector is shown in Exhibit 41. The level of participation of female scientist differs significantly across the field of science. The ratio of female scientists in life sciences is higher than that in physical sciences in both countries. Female authors account for around 30% of research team in life sciences and medicine in the US, relative to around 13% in physical sciences. In Japan they account for around 20% in life sciences and 10 % in medicine, relative to around 7% in physical sciences. Thus, the participation of female scientist in research team is more frequent in the US than in Japan. There is no major difference in the degree of participation of female scientists between H and N papers.

Exhibit 41 The ratio of female authors in research team by field of science and sector (%)

	Japan		US	
	H paper	N paper	H paper	N paper
Physical sciences (HEI)	7.5(77)	6.6(218)	13.7(193)	12.4(430)
Life sciences (HEI)	20.9(18)	17.5(93)	29.2(81)	28.5(265)
Medicine (HEI)	10.4(4)	12.1(34)	30(43)	27.5(158)
Physical sciences (PRI)	5.9(26)	5.6(39)	9.3(35)	11.4(62)
Life sciences (PRI)	15.6(11)	9.1(22)	31.2(14)	21.7(35)

Note1: These exhibits cover only papers with 6 or less authors. The number of observation is shown in parentheses.
Note2: Data of female authors in research teams in Japan was obtained by an additional survey conducted during May – July 2011.

8 INPUTS FOR RESEARCH PROJECTS

8－1 TIME BETWEEN RESEARCH PROJECT CONCEPTION AND THE FOCAL PAPER SUBMISSION

This survey clarifies how many years it takes from the conception of research project through the actual launch of research projects to the submission of the focal paper, by asking the scientists the year they conceived their research projects, the year they actually started their research projects, and the year they submitted their focal papers.

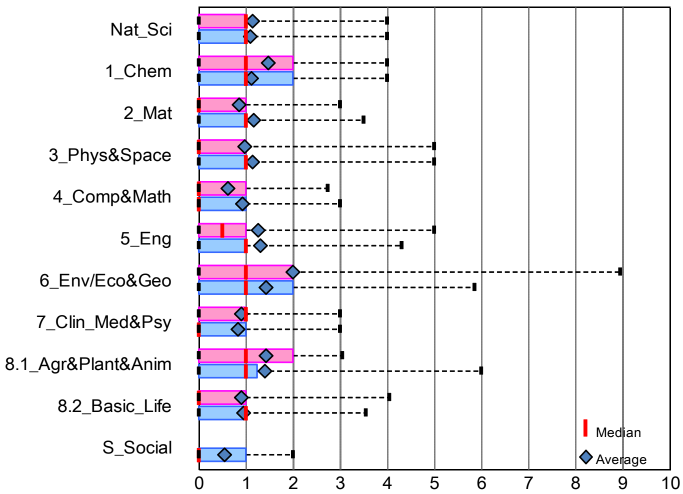
Exhibit 42 indicates the years from the conception of project to its launch by scientific field. Those show relatively small differences in the years between Japan and United States, among scientific fields, and between the H and N projects. The time-lag mostly distributes between zero and one year for the projects both in Japan and the US, although it has a longer right tail in Japan. The average time-lags in the scientific fields of chemistry; environment/ecology & geosciences; and agricultural sciences & plant & animal science in Japan, are longer than those in other scientific fields in Japan and the same filed in the US.

Exhibit 43 indicates the years from the launch of project to the submission of the focal paper by scientific field. Those show that the average and median time-lags differ among scientific fields. Also, the results show that the average and median time-lags of the projects in Japan are mostly longer than those in the Unites States even in the same scientific fields. The median time-lags are two or three years for the projects in Japan, and one or two years for those in the US. In addition, the time-lags for the H projects are likely to be shorter than those for the N projects. The average time-lag is 3.0 and 2.3 years for the H projects and 3.5 and 2.6 years for the N projects, in natural sciences as a whole, in Japan and in the US, respectively.

In summary, the time-lag between the conception of the research project and its launch is mostly a year or less in both countries but has a longer tail in Japan. Time-lag between the launch of the project and submission of the focal paper is shorter for H project than for N project and longer in Japan.

Exhibit 42 Time-lags between project conception and launch of the project

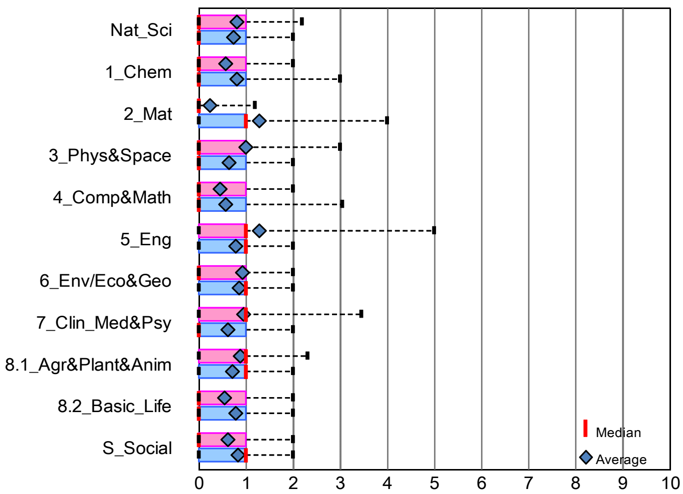
(a) Japan



unit: years

	Respondents	Minimum	Q1	Median	Q3	Maximum	Average
Nat_Sci	553	0.0	0.0	1.0	1.0	30.0	1.1
	1419	0.0	0.0	1.0	1.0	22.0	1.1
1_Chem	70	0.0	0.0	1.0	2.0	30.0	1.5
	177	0.0	0.0	1.0	2.0	10.0	1.1
2_Mat	43	0.0	0.0	0.0	1.0	5.0	0.9
	91	0.0	0.0	1.0	1.0	19.0	1.2
3_Phys&Space	123	0.0	0.0	0.0	1.0	8.0	1.0
	241	0.0	0.0	1.0	1.0	14.0	1.1
4_Comp&Math	16	0.0	0.0	0.0	1.0	5.0	0.6
	59	0.0	0.0	0.0	1.0	13.0	0.9
5_Eng	66	0.0	0.0	0.5	1.0	17.0	1.3
	135	0.0	0.0	1.0	1.0	19.0	1.3
6_Env/Eco&Geo	30	0.0	0.0	1.0	2.0	13.0	2.0
	84	0.0	0.0	1.0	2.0	11.0	1.4
7_Clin_Med&Psy	65	0.0	0.0	1.0	1.0	6.0	0.9
	194	0.0	0.0	0.0	1.0	10.0	0.8
8.1_Agr&Plant&Anim	60	0.0	0.0	1.0	2.0	15.0	1.4
	128	0.0	0.0	1.0	1.3	22.0	1.4
8.2_Basic_Life	80	0.0	0.0	0.0	1.0	12.0	0.9
	310	0.0	0.0	1.0	1.0	13.0	0.9
S_Social	-	-	-	-	-	-	-
	38	0.0	0.0	0.0	1.0	5.0	0.6

(b) US



unit: years

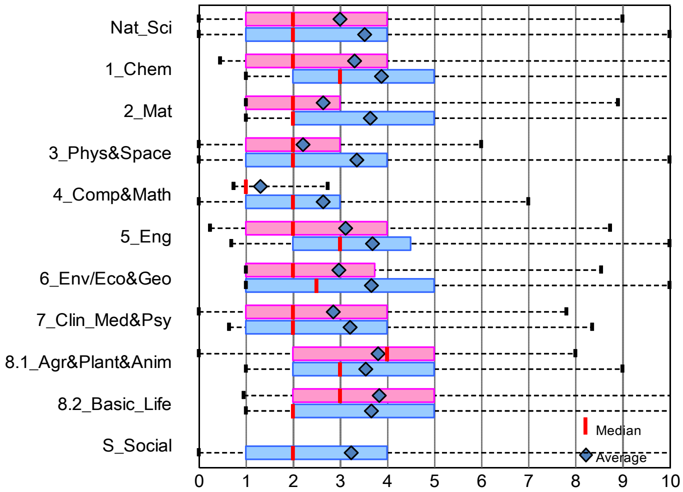
	Respondents	Minimum	Q1	Median	Q3	Maximum	Average
Nat_Sci	637	0.0	0.0	0.0	1.0	21.0	0.8
	1218	0.0	0.0	0.0	1.0	27.0	0.7
1_Chem	59	0.0	0.0	0.0	1.0	3.0	0.6
	99	0.0	0.0	0.0	1.0	7.0	0.8
2_Mat	17	0.0	0.0	0.0	0.0	2.0	0.2
	42	0.0	0.0	1.0	1.0	15.0	1.3
3_Phys&Space	94	0.0	0.0	0.0	1.0	13.0	1.0
	144	0.0	0.0	0.0	1.0	17.0	0.6
4_Comp&Math	34	0.0	0.0	0.0	1.0	2.0	0.4
	80	0.0	0.0	0.0	1.0	5.0	0.6
5_Eng	41	0.0	0.0	1.0	1.0	12.0	1.3
	89	0.0	0.0	1.0	1.0	4.0	0.8
6_Env/Eco&Geo	64	0.0	0.0	0.0	1.0	21.0	0.9
	113	0.0	0.0	1.0	1.0	12.0	0.9
7_Clin_Med&Psy	132	0.0	0.0	1.0	1.0	9.0	1.0
	244	0.0	0.0	0.0	1.0	5.0	0.6
8.1_Agr&Plant&Anim	55	0.0	0.0	1.0	1.0	5.0	0.9
	90	0.0	0.0	1.0	1.0	5.0	0.7
8.2_Basic_Life	141	0.0	0.0	0.0	1.0	14.0	0.5
	317	0.0	0.0	0.0	1.0	27.0	0.8
S_Social	62	0.0	0.0	0.0	1.0	6.0	0.6
	114	0.0	0.0	1.0	1.0	8.0	0.8

Note1: Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left end of boxes indicate the first quartiles; and right end of boxes the third quartiles. Left end of whiskers indicate the 5th percentile; and right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

Note2: The results of natural sciences are not weighted by field.

Exhibit 43 Time-lags between launch of the project and submission of the focal paper, Japan

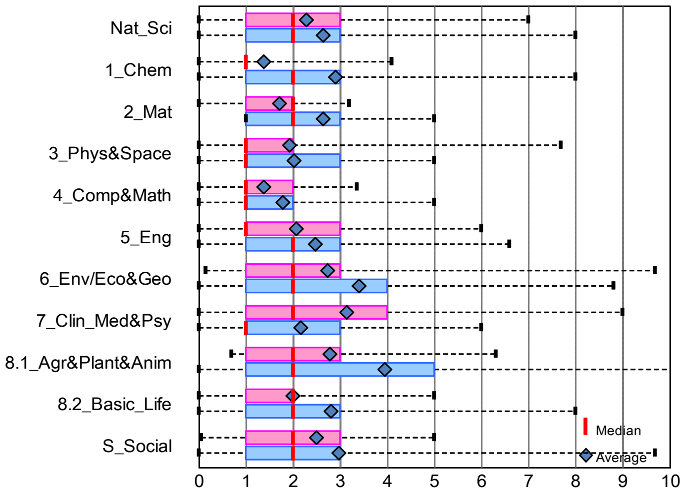
(a) Japan



unit: years

Respondents	Minimum	Q1	Median	Q3	Maximum	Average
553	0.0	1.0	2.0	4.0	31.0	3.0
1419	0.0	1.0	2.0	4.0	36.0	3.5
70	0.0	1.0	2.0	4.0	23.0	3.3
177	0.0	2.0	3.0	5.0	17.0	3.9
43	0.0	1.0	2.0	3.0	12.0	2.7
91	0.0	2.0	2.0	5.0	20.0	3.6
123	0.0	1.0	2.0	3.0	14.0	2.2
241	0.0	1.0	2.0	4.0	36.0	3.4
16	0.0	1.0	1.0	1.0	5.0	1.3
59	0.0	1.0	2.0	3.0	15.0	2.6
66	0.0	1.0	2.0	4.0	16.0	3.1
135	0.0	2.0	3.0	4.5	22.0	3.7
30	0.0	1.0	2.0	3.8	13.0	3.0
84	0.0	1.0	2.5	5.0	18.0	3.7
65	0.0	1.0	2.0	4.0	12.0	2.8
194	0.0	1.0	2.0	4.0	19.0	3.2
60	0.0	2.0	4.0	5.0	12.0	3.8
128	0.0	2.0	3.0	5.0	11.0	3.5
80	0.0	2.0	3.0	5.0	31.0	3.8
310	0.0	2.0	2.0	5.0	30.0	3.7
-	-	-	-	-	-	-
38	0.0	1.0	2.0	4.0	16.0	3.2

(b) US



unit: years

Respondents	Minimum	Q1	Median	Q3	Maximum	Average
637	0.0	1.0	2.0	3.0	18.0	2.3
1218	0.0	1.0	2.0	3.0	38.0	2.6
59	0.0	1.0	1.0	1.0	9.0	1.4
99	0.0	1.0	2.0	3.0	38.0	2.9
17	0.0	1.0	2.0	2.0	4.0	1.7
42	0.0	1.0	2.0	3.0	12.0	2.6
94	0.0	1.0	1.0	2.0	18.0	1.9
144	0.0	1.0	1.0	3.0	21.0	2.0
34	0.0	1.0	1.0	2.0	8.0	1.4
80	0.0	1.0	1.0	2.0	10.0	1.8
41	0.0	1.0	1.0	3.0	10.0	2.1
89	0.0	1.0	2.0	3.0	14.0	2.5
64	0.0	1.0	2.0	3.0	13.0	2.7
113	0.0	1.0	2.0	4.0	27.0	3.4
132	0.0	1.0	2.0	4.0	15.0	3.1
244	0.0	1.0	1.0	3.0	21.0	2.2
55	0.0	1.0	2.0	3.0	12.0	2.8
90	0.0	1.0	2.0	5.0	27.0	4.0
141	0.0	1.0	2.0	2.0	15.0	2.0
317	0.0	1.0	2.0	3.0	36.0	2.8
62	0.0	1.0	2.0	3.0	30.0	2.5
114	0.0	1.0	2.0	3.0	34.0	3.0

Note1: Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left end of boxes indicate the first quartiles; and right end of boxes the third quartiles. Left end of whiskers indicate the 5th percentile; and right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

Note2: The results of natural sciences are not weighted by field.

8－2 LABOR INPUT FOR RESEARCH PROJECTS

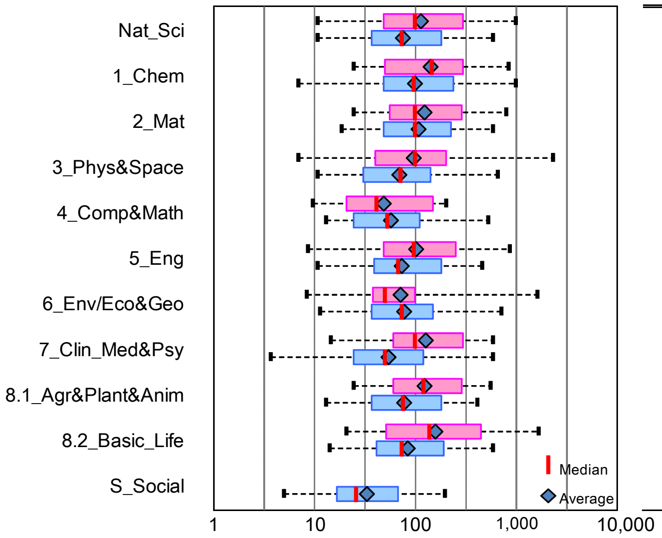
Labor input is the most basic input for a research project. We asked respondents to identify the total labor input in man-month units, which were consumed by a research team as a whole from the time of substantially initiating the research project to the time of submitting the latest paper from the research project.

Exhibit 44 shows that the total labor input in man-month units for the research project differs very substantially among scientific fields both in Japan and in the US. It shows that, in general, the H projects spend more total labor input than the N projects both in Japan and in the US, except for computer science and mathematics. The ratio of total labor input of the H projects to the N projects in natural sciences is around 1.5 (1.39 (Japan) and 1.50 (U.S.) in median; 1.50 (Japan) and 1.40 (U.S.) in average).

Also, it shows that, as a whole, the projects in Japan spend a few times as much as those in the US in each scientific field for both H and N projects. For the median of total labor input in natural sciences, the projects in Japan spend about 3 times as much as those in the US in both H and N projects. This suggests that the concept of "project" is interpreted more narrowly in the US than in Japan (the median number of papers published per project is also roughly3 times larger in Japan than in the US, see Section 9). This result may also be related to the above-mentioned result of the differences in the time-lag between the launch of project and the submission of the focal paper, which was shown in 8-1.

Exhibit 44 Total research man-months expended on the research project by field

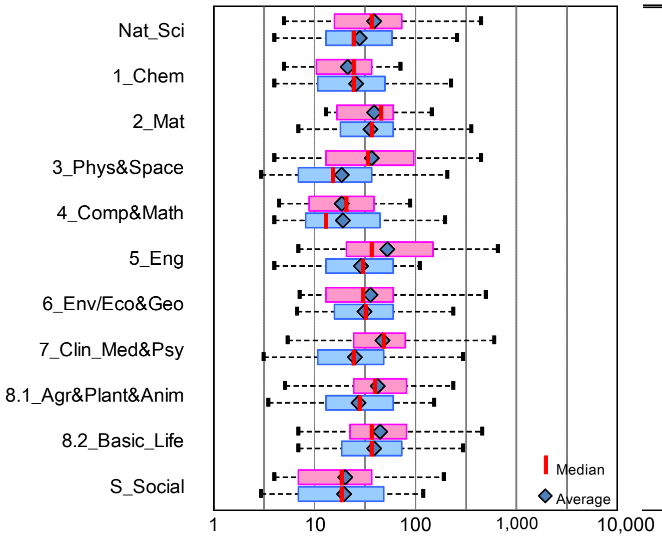
(a) Japan



unit: man-months

Field	Respondents	Minimum	Q1	Median	Q3	Maximum	Average
Nat_Sci	557	1	48	100	300	25,000	114.8
	1453	0	36	72	180	90,000	75.9
1_Chem	69	6	50	144	300	2,500	143.6
	181	2	48	96	240	3,000	98.2
2_Mat	43	4	55	100	294	2,000	125.2
	99	1	48	100	225	2,000	106.4
3_Phys&Space	124	1	39	98	204	25,000	97.5
	249	0	30	70	140	3,600	68.2
4_Comp&Math	16	6	20	41	150	420	47.5
	61	1	24	52	112	720	56.3
5_Eng	68	2	48	96	251	11,000	100.9
	135	2	38	67	180	2,268	73.7
6_Env/Eco&Geo	30	6	37	49	100	3,600	70.9
	85	5	36	72	150	90,000	77.4
7_Clin_Med&Psy	65	6	60	100	300	12,000	128.4
	196	1	24	50	120	3,360	54.0
8.1_Agr&Plant&Anim	60	1	60	120	291	1,250	123.4
	132	5	36	76	180	1,200	78.0
8.2_Basic_Life	82	3	50	136	450	3,600	158.8
	315	1	41	72	192	5,400	83.3
S_Social	-	-	-	-	-	-	-
	39	1	16	25	67	300	32.5

(b) US



unit: man-months

Field	Respondents	Minimum	Q1	Median	Q3	Maximum	Average
Nat_Sci	660	0	15	36	72	37,500	38.0
	1303	0	12	24	58	120,000	27.1
1_Chem	63	2	9	24	36	300	20.4
	114	1	10	24	50	1,000	24.9
2_Mat	22	6	16	45	60	336	38.4
	48	2	17	36	60	1,000	35.1
3_Phys&Space	94	1	12	33	96	24,000	36.1
	156	1	6	14	36	1,200	17.8
4_Comp&Math	31	3	8	20	38	100	17.8
	86	0	7	12	45	960	18.4
5_Eng	49	3	20	36	150	2,400	52.8
	99	1	12	30	60	500	27.8
6_Env/Eco&Geo	67	4	12	30	60	1,200	35.0
	120	1	15	32	60	600	30.8
7_Clin_Med&Psy	130	0	24	48	80	37,500	47.2
	264	1	10	24	48	50,000	24.1
8.1_Agr&Plant&Anim	57	0	24	40	81	1,200	41.6
	92	1	12	27	60	10,000	26.5
8.2_Basic_Life	147	4	22	36	82	3,000	44.1
	324	1	18	36	72	120,000	38.2
S_Social	62	0	6	18	36	8,568	19.5
	119	1	6	18	48	800	18.6

Note1: Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left end of boxes indicate the first quartiles; and right end of boxes the third quartiles. Left end of whiskers indicate the 5th percentile; and right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Note3: Total research man-months in the boxplots are shown in the logarithmic scale.

Note4: The results of natural sciences are not weighted by field.

8－3 AMOUNT OF MONEY SPENT FOR RESEARCH PROJECTS

The amount of money spent for research projects was also surveyed. As for the personnel expenditures, the surveyed amount includes only those for employing researchers and research assistants specifically for the research projects, which are typically defrayed by extramural funds. However, the costs that are included in this category varies by country (see below). It was evident from our interviews with faculty members in Japanese universities that they tended to exclude their own salary from the research money spent, which is usually defrayed by intramural funds. Also, the surveyed amount included only the expenditures for the facilities that were introduced specifically for the research projects, and excluded the cost of using other facilities, including those facilities that had existed. For these reasons, the surveyed amount of money spent for research projects may be significantly less than the total cost for the research projects, especially in HEIs in Japan. In addition, the respondents in the US were asked to select the most appropriate alternatives from several ranges of amount, while those in Japan were asked to fill in approximate figures. For this reason, the data of the US may be less precise than those of Japan. In the US, because of differences in the funding system, the survey also included a question on the percent of the budget spent on senior personnel (the PI and co-PI) salaries (release time, summer salary, etc.).

Exhibit 45 shows that the amount of research money spent for research projects are similarly distributed in each scientific field in both countries, although the size of the amount differs very substantially among scientific fields. It also shows that, for the H projects, there is little difference in the amount of research money spent for research projects in natural sciences as a whole between Japan (265.8 thousand dollar in average) and the US (284.5 thousand dollar in average) using 1$=100 yen conversion,. In contrast, for the N projects, the project in Japan (70.4 thousand dollar in average) spent less than those in the US (116.2 thousand dollar in average).

For the H projects, a comparison in average and median amounts shows that the projects in Japan spend more than those in the US in chemistry; agricultural sciences & plant & animal science; and basic life sciences and less in the other scientific fields.

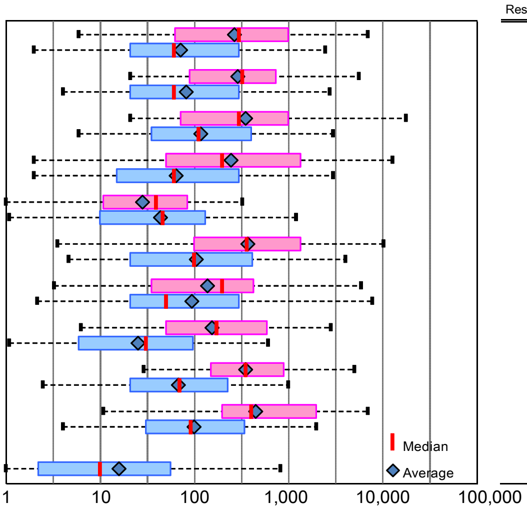
These findings (Exhibit 44 and Exhibit 45) also indicate that the US research projects are significantly more money intensive than the Japanese projects even for the H projects. . The average research budget for 12 man-months amounts to 58 thousand dollars in the US and 36 thousand dollars in Japan for H projects, which are based on the median values of man-months and budget, a 60% premium in the US.

However, it is important to put this difference in context. The research budgeting system in US and Japanese universities have several important differences that would affect such a comparison. To begin with, it is very common in the US (unlike Japan) for principal investigators to charge part of their salary to the grant, and often part of the salaries of other senior personnel. This includes salary during the summer (as most faculty have 9-month contracts), and salary for release time for teaching (which some funding agencies include as an allowable expense). In the survey, we asked what percent of the grant budget was for PI or co-PI salaries. On average, about 25% of the grant budget was dedicated to faculty salaries. Also, post-doctoral fellows are supported by the grant in the US, while in Japan, if these researchers have the position of research associate (*joshu*) they are likely to be funded out of the university's personnel budget. In addition, in the US, it is usual for PhD students, and even some master's students, to be supported by the grant. This support includes a living stipend and, often, the cost of the student's tuition. According to Stephan (2010), the cost of a PhD student is approximately the same as the cost of a post-doc. Finally, in the US, external funding generally includes a charge for the overhead expenses of the research, in addition to the direct costs of equipment, supplies, personnel, etc. The rate varies by university, but is typically about 50% of the direct costs (often higher). Thus, about one-third of the grant budget is allocated to these overhead (indirect costs recovery-ICR) expenses. One way to interpret this difference across the two countries is that US universities more explicitly budget the true costs of doing the research, including charging the grant for much of the personnel expenses (part of the PI and co-PI salaries and all of the post-doc and graduate research assistant expenses), as well as the costs to the university of maintaining the research infrastructure (buildings, computers, libraries, administrative staff, etc.).

Using the data from the survey, we can make a rough estimate of the affect of these policy differences on the average budgets. Imagine if the Japanese university was using a US-style budgeting system. If 25% of the US budget cost is for senior personnel, then we can say that this would add one-third to the Japanese budget. In addition, we find that US projects, on average, hired one more person specifically for the project (for example, a post-doc), out of a total team size of about 5 authors, or 20% of the team (adding another 25% to the Japanese budget). In addition, the average project included just under 1 graduate student, which would also likely be charged to the grant, adding another 25% to the Japanese budget. Finally, these additional personnel charges, plus the base budget (assuming costs for equipment and suppliers are similar in the two countries) would be inflated by 50% to cover the indirect costs. Thus, if the Japanese universities budgeted using the US practices, the baseline budget X would become $X(1+.33+.25+.25)(1.5)=2.75X$, i.e., the base budget plus 33% for PI salaries, 25% for post-doc, 25% for graduate research assistant, all of which is multiplied by 50% for ICR. Given these differences, it is not surprising that there is a substantial premium per man-month in the US budgets. Thus, we should be careful when comparing budget numbers across countries, especially for university-based projects.

Exhibit 45 Amount of money spent directly used for the research project by field

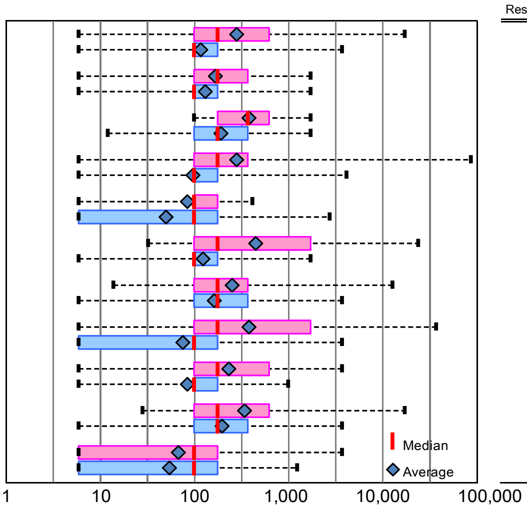
(a) Japan



unit: $1K

Field	Respondents	Minimum	Q1	Median	Q3	Maximum	Average
Nat_Sci	554	0	62	300	997	200,000	265.8
	1448	0	20	60	300	300,000	70.4
1_Chem	71	4	89	320	748	30,000	289.5
	176	0	20	60	300	50,000	82.1
2_Mat	41	1	70	300	1,000	50,000	352.3
	99	0	35	110	400	30,000	117.9
3_Phys&Space	123	0	50	200	1,342	200,000	243.6
	248	0	14	60	300	50,000	64.0
4_Comp&Math	16	0	10	39	85	400	27.3
	61	0	9	45	130	20,000	42.7
5_Eng	68	1	100	358	1,347	60,000	367.4
	133	0	20	100	410	40,000	103.8
6_Env/Eco&Geo	30	0	34	200	422	8,000	139.5
	85	0	20	50	300	300,000	94.0
7_Clin_Med&Psy	64	0	50	173	600	6,000	154.4
	196	0	5	30	96	10,000	24.4
8.1_Agr&Plant&Anim	60	8	150	350	900	5,000	356.7
	132	0	20	69	230	4,000	66.8
8.2_Basic_Life	81	0	200	400	2,000	56,000	454.2
	318	0	30	90	340	20,000	99.8
S_Social	-	-	-	-	-	-	-
	39	0	1	9	55	3,000	15.0

(b) US



unit: $1K

Field	Respondents	Minimum	Q1	Median	Q3	Maximum	Average
Nat_Sci	693	5	100	175	625	100,000	284.5
	1349	5	100	100	175	100,000	116.2
1_Chem	65	5	100	175	375	62,500	165.7
	119	5	100	100	175	100,000	130.2
2_Mat	22	100	175	375	625	6,250	380.2
	46	5	100	175	375	8,750	191.4
3_Phys&Space	95	5	100	175	375	100,000	281.0
	157	5	100	100	175	100,000	97.3
4_Comp&Math	37	5	100	100	175	875	83.0
	89	5	5	100	175	62,500	49.8
5_Eng	53	5	100	175	1,750	100,000	452.6
	101	5	100	100	175	100,000	122.2
6_Env/Eco&Geo	67	5	100	175	375	100,000	252.1
	119	5	100	175	375	87,500	164.2
7_Clin_Med&Psy	144	5	100	175	1,750	100,000	379.0
	283	5	5	100	175	100,000	74.3
8.1_Agr&Plant&Anim	58	5	100	175	625	6,250	235.3
	97	5	100	100	175	87,500	84.2
8.2_Basic_Life	152	5	100	175	625	100,000	343.1
	338	5	100	175	375	100,000	195.8
S_Social	70	5	5	100	175	100,000	67.5
	131	5	5	100	175	37,500	54.2

Note1: Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left end of boxes indicate the first quartiles; and right end of boxes the third quartiles. Left end of whiskers indicate the 5th percentile; and right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Note3: Amounts of research money spent in the boxplots are shown in the logarithmic scale.

Note4: 1$=100 yen conversion,

Note5: The results of natural sciences are not weighted by field.

8－4 Sources of Funds for Research Projects

8－4－1 Combination of Multiple Sources of Funds

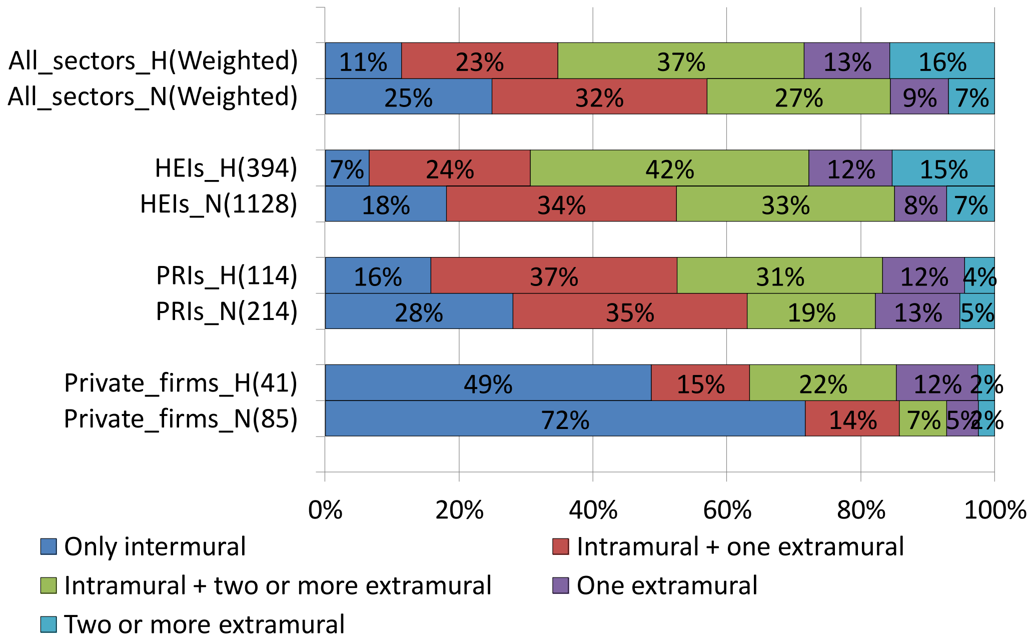
Research projects are conducted by using various kinds of sources of funds. Exhibit 46 shows the combinations of sources of funds and, if any, number of extramural funds for research projects by sector. It shows that the nature of the combinations differs among sectors both in Japan and in the US. In private firms, about a half to three-fourths of research projects are conducted by using only intramural fund. In PRIs, about a half of research projects in the US are conducted by using only intramural fund, while only about one-sixth to a quarter of research projects in Japan are done so. In contrast, in HEIs, about 82 to 95% of research projects are conducted by using extramural funds. In HEIs and PRIs, the H projects are more likely to be conducted by using extramural funds than the N projects in both countries.

There is a difference in the combinations of sources of funds between Japan and the US. For HEIs, in Japan, two-thirds of the research projects are conducted by using both intramural and extramural funds. In particular, 42% of the H projects are conducted by using intramural and two or more extramural funds. Only 27% of the H projects are conducted by using only extramural funds. On the other hand, in the US, 59% of the H projects are conducted by using only extramural funds. Also, 36% of the H projects and 37% of the N projects are conducted by using only one extramural fund.

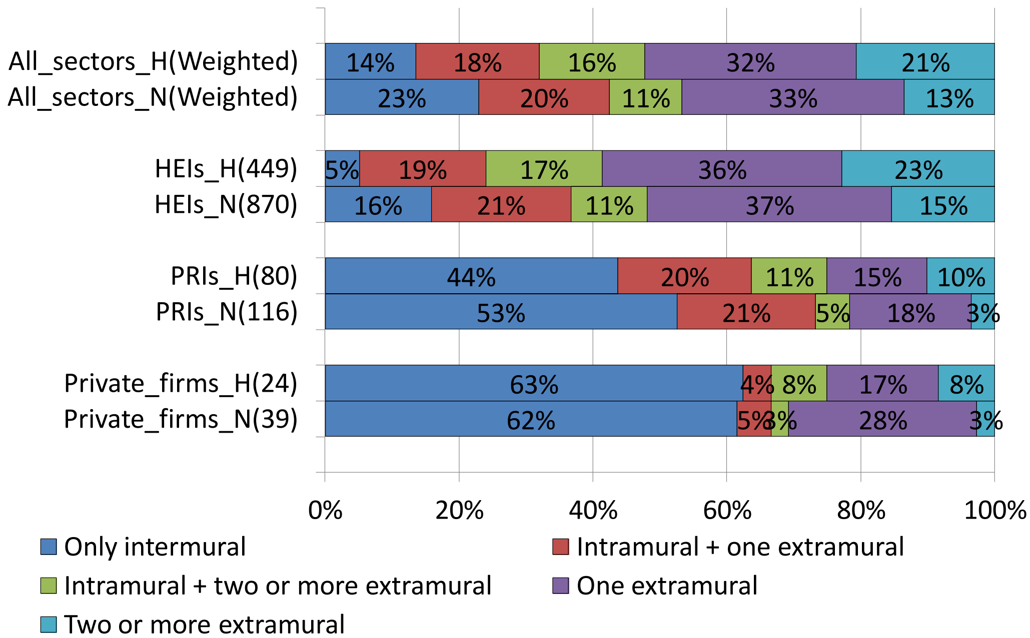
Those findings indicate that major sources of funds for supporting research projects are different between Japan and the US. The research projects, in Japan, use both intramural and extramural funds in both HEIs and PRIs, while, in the US, those in HEIs use mainly extramural funds; and those in PRIs use significantly intramural fund.

Exhibit 46 Combination of sources of funds

(a) Japan, natural sciences



(b) US, natural sciences



Note1: In each sector, the upper figure shows the result of the H projects and the lower figure shows the result of the N projects

Note2: The "intramural fund" indicates fund of the institutions that the research team members belong to, based on the government grants for operative expenses *etc.* for the HEIs, and the internal fund for private firms.

Note3: The "extramural" covers both the fund from the institution-base as well as the funds from the project-base programs.

8－4－2 Disaggregated sources of funds

Exhibit 47 shows the combinations of sources of fund by type of fund.

In terms of simple average of the combinations of sources of funds in a country as a whole both for the H projects and for the N ones, more than half of the fund of a research project is supported by Grant-in-Aid for Scientific Research (e.g. KAKEN), the funds for academic fundamental research, and intramural funds in Japan, while two-thirds of the fund of a research project is supported by mission-oriented public funds and intramural funds in the US.

In terms of weighted average of the combinations of sources of funds in a country for the H projects, mission-oriented public funds become significantly more important (38% in Japan, and 50% in the US). Still, in Japan, KAKEN accounts for 27% of the total fund, and plays an important role for supporting research projects.

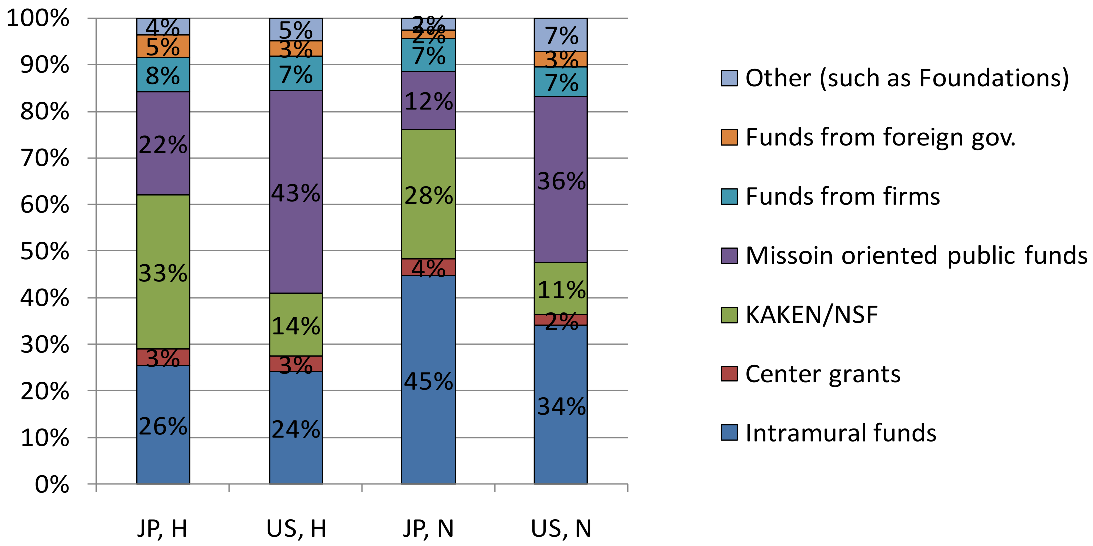
Exhibit 48 shows the combinations of sources of fund by type of sector and by broad scientific fields.

For HEIs, in Japan, in any of three broad scientific fields, KAKEN accounts for around one-third to a half of the total fund. In contrast, in the US, NSF fund accounts for around one-fourth in physical sciences, and mission-oriented public funds from NIH accounts for one-third to a half in life sciences and medicines.

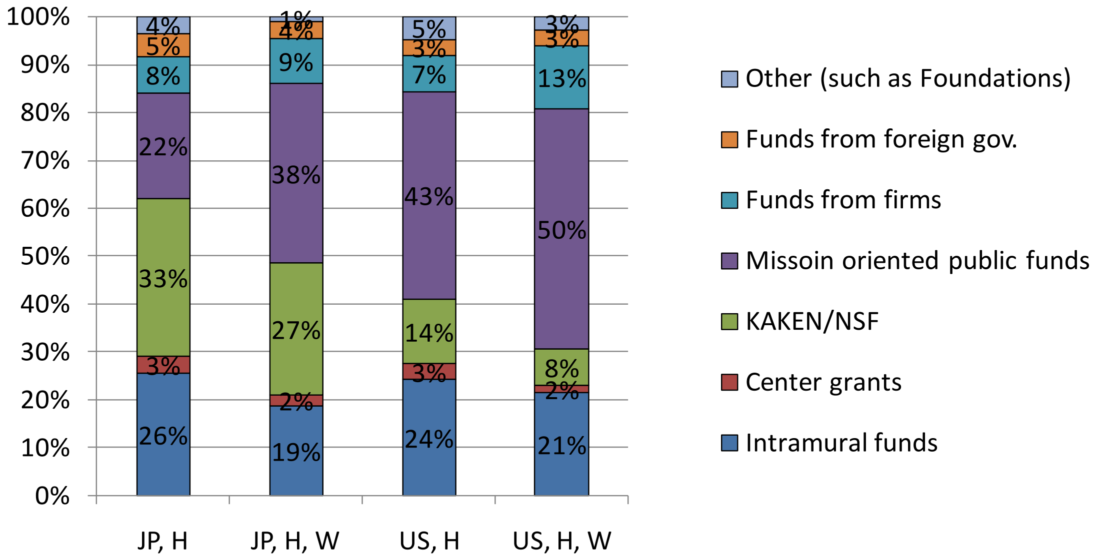
Those differences in the combinations of sources of funds between Japan and the US are likely to reflect the differences in systems of public research funding and functions of higher education institutions (HEIs) and public research institutions (PRIs). In Japan, fundamental research is mainly supported by KAKEN as well as major mission-oriented research funds, such as research programs of JST under the auspices of MEXT, ones of NEDO under the auspices of METI, and the Health and Labor Sciences Research Grants. On the other hand, in the US, there are many governmental organizations, such as NIH, DOD, and DOE, for providing mission-oriented public funds to support fundamental research. In addition, the compositions of sources of extramural funds are much less different in Japan than in the US among scientific fields.

Exhibit 47 Sources of funding

(a) Simple average



(b) Weighted average

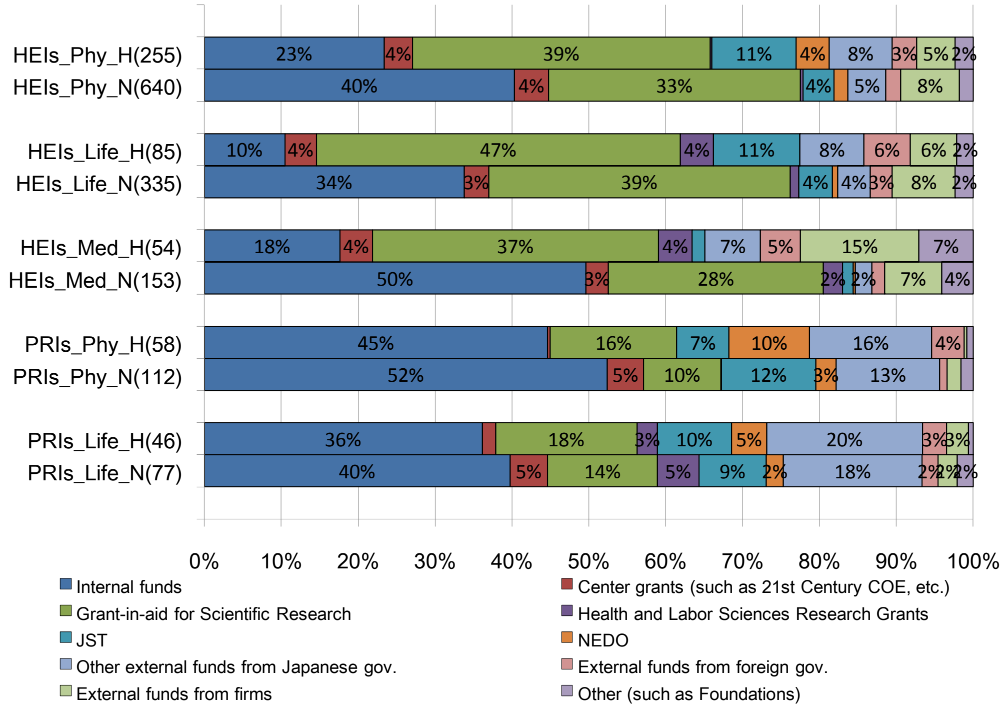


Note1: Mission-oriented public funds in Japan includes funds from JST and NEDO; Health and Labor Sciences Research Grants; other competitive grants; and non-competitive grants from government. Mission-oriented public funds in US includes funds from NIH, DOD and DOE; other competitive grants; and non-competitive grants from government.

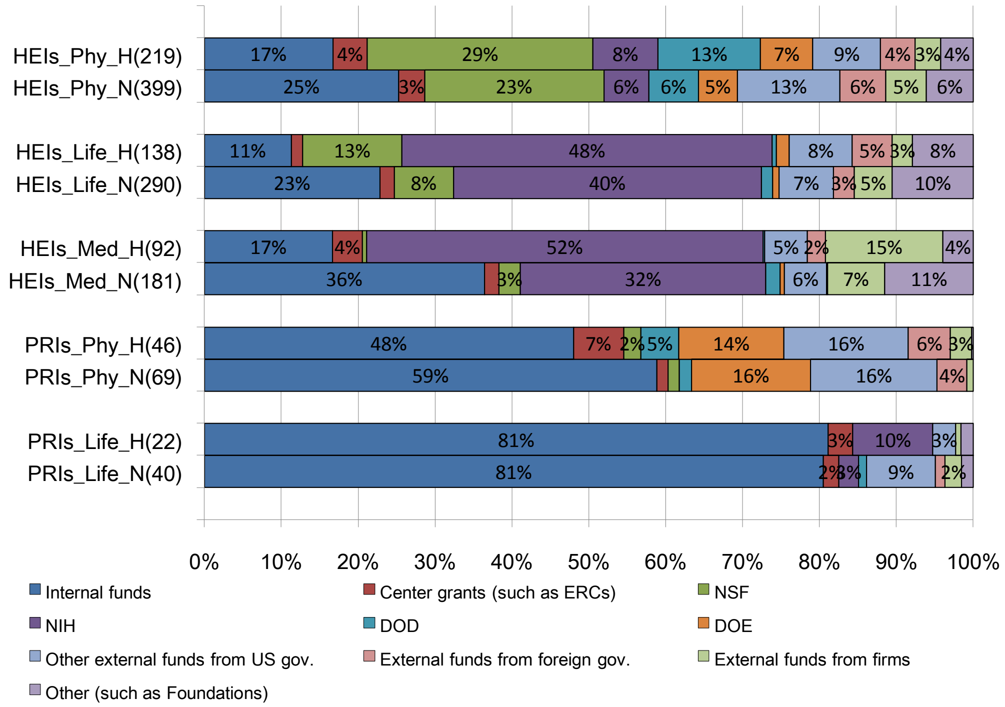
Note2: Extremely large projects (top1%) are excluded from the weighted average.

Exhibit 48 Composition of Sources of Funds by Field and Sector (a research project base)

(a) Japan



(b) US



Note1: The "intramural fund" covers the fund of the institutions that the research team members belong to, based on the government grant for operative expenses *etc*. for the HEIs, and its own fund for private firms.

9 OUTPUTS AND IMPACTS OF THE RESEARCH PROJECTS

9－1 NUMBER OF REFEREED PAPERS FROM RESEARCH PROJECTS

Exhibit 49 shows the distribution of the refereed papers by field (including both papers written in English and in Japanese or other languages). In Exhibit 49, red boxplots indicate the distributions for the H projects; and blue ones for the N projects. The left end of boxes indicates the first quartile; and the right end of boxes the third quartile. The left end of whiskers indicates the 5th percentile; and the right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

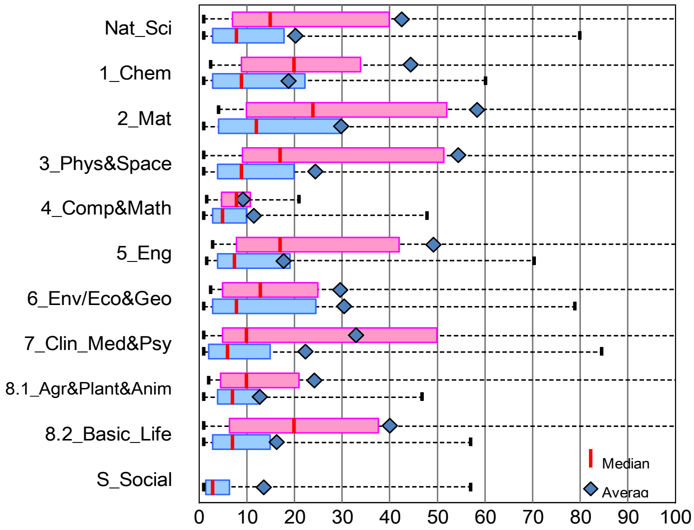
In all fields combined, H projects in Japan produced 15 papers for the median and 43 papers on average. N projects produced 8 for its median and 20 on average. In the US, the number of papers produced is smaller, with an average of 16 and median of 5 for H projects and an average of 7 (and median of 3) for N projects. This (along with the data on man-months) suggests that projects are smaller (or the concept of "project" is interpreted more narrowly) in the US than in Japan. In almost all fields the averages are larger than the medians, due to a small number of very productive projects, and many with modest productivity (with the first quartile often being 3 or less, especially for the US and for N projects in Japan). In addition to very large project effects, this skew in the distribution likely reflects the uncertainties (and cumulative nature) of the discovery process in scientific research[1]. The following discussion uses mainly the medians of the number of papers from a project.

We can see that H projects produce substantially more papers than N projects in all fields. In all fields aggregated, for Japan, the ratio of the median number of papers across H and N projects (15/8=1.9) is larger than the ratio of research's man-months (100/72=1.4), although it is smaller than the ratio of research fund ($300K/$60K=5.0). In the US, we see the same pattern, although the three ratios are more similar: 1.7 for papers, 1.5 for researcher months, and 1.8 for budget. In both countries, the inter-quartile range (the distance between the first quartile and the third quartile) is much larger in H projects, compared to N projects. This indicates that a relatively large share of H projects generate a large number of the refereed papers.

[1] The number of papers may follow a power law distribution than a log normal distribution. Newman M. E. J. (2006), "Power laws, Pareto distributions and Zipf's law," *Contemporary Physics*, 46 ; 323 – 351.

Exhibit 49 Distributions of the number of refereed papers yielded from research project by field

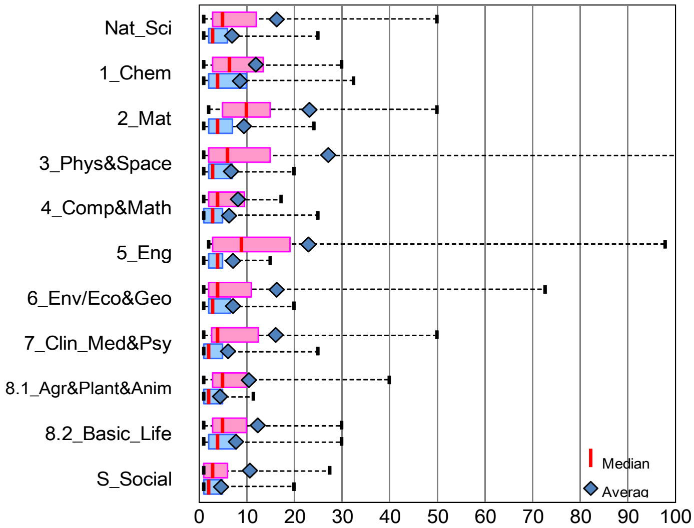
(a) Japan



unit: papers

Respondents	Minimum	Q1	Median	Q3	Maximum	Average
554	1.0	7.0	15.0	40.0	610.0	42.6
1434	1.0	3.0	8.0	18.0	950.0	20.2
71	1.0	9.0	20.0	34.0	374.0	44.4
180	1.0	3.0	9.0	22.3	302.0	18.8
43	1.0	10.0	24.0	52.0	500.0	58.5
98	1.0	4.3	12.0	30.0	365.0	29.8
126	1.0	9.3	17.0	51.5	500.0	54.5
250	1.0	4.0	9.0	20.0	400.0	24.5
16	1.0	4.8	8.0	10.8	24.0	9.3
59	1.0	3.0	5.0	10.0	120.0	11.5
67	1.0	8.0	17.0	42.0	610.0	49.2
136	1.0	4.0	7.5	19.3	188.0	17.8
29	1.0	5.0	13.0	25.0	140.0	29.6
83	1.0	3.0	8.0	24.5	950.0	30.5
61	1.0	5.0	10.0	50.0	140.0	33.1
187	1.0	2.0	6.0	15.0	708.0	22.3
59	1.0	4.5	10.0	21.0	190.0	24.3
130	1.0	4.0	7.0	13.0	124.0	12.8
82	1.0	6.5	20.0	37.8	419.0	40.1
311	1.0	3.0	7.0	15.0	408.0	16.3
-	-	-	-	-	-	-
39	1.0	1.5	3.0	6.5	160.0	13.6

(b) US



unit: papers

Respondents	Minimum	Q1	Median	Q3	Maximum	Average
708	1.0	3.0	5.0	12.0	530.0	16.3
1354	1.0	2.0	3.0	6.0	300.0	7.0
64	1.0	3.0	6.5	13.5	100.0	12.0
118	1.0	2.0	4.0	10.0	130.0	8.6
21	1.0	5.0	10.0	15.0	250.0	23.3
47	1.0	2.0	4.0	7.0	147.0	9.6
96	1.0	2.0	6.0	15.0	500.0	27.1
156	1.0	2.0	3.0	7.0	85.0	6.7
38	1.0	2.0	4.0	9.5	100.0	8.2
91	1.0	1.0	3.0	5.0	100.0	6.4
54	1.0	3.0	9.0	19.3	250.0	23.1
100	1.0	2.0	4.0	5.0	150.0	7.1
67	1.0	2.0	4.0	11.0	300.0	16.3
126	1.0	2.0	3.0	6.8	220.0	7.2
152	1.0	2.8	4.0	12.5	530.0	16.2
280	1.0	1.0	2.0	5.0	300.0	6.2
60	1.0	3.0	5.0	10.0	100.0	10.5
96	1.0	1.0	2.0	5.0	71.0	4.4
156	1.0	3.0	5.0	10.0	300.0	12.4
340	1.0	2.0	4.0	8.0	165.0	7.9
74	1.0	1.0	3.0	6.0	200.0	10.8
130	1.0	1.0	2.0	5.0	75.0	4.8

Note1: Red boxplots indicate the distributions for the H projects; and blue ones for the N projects. Left end of boxes indicate the first quartiles; and right end of boxes the third quartiles. Left end of whiskers indicate the 5th percentile; and right end of whiskers the 95th percentile. The red bands in bars indicate the medians; and rhombi in bars the means.

Note2: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Note3: Results show the summation of refereed papers written in Japanese, English, and other language. The responses saying the number of refereed paper from the projects was 0 were excluded from the results.

Note4: The results of natural sciences are not weighted by field.

9－2 Graduate Education through the Research Project

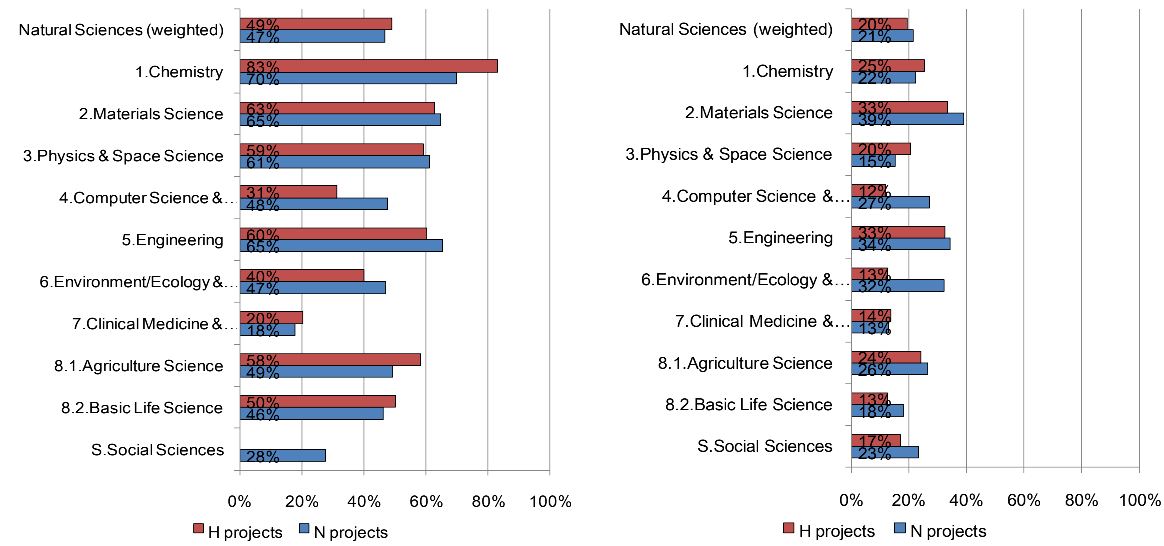
In addition to research papers, an important outcome of research is educated students. Exhibit 50 and Exhibit 51 show the share of research projects that produced a master's degree and a doctoral degree. In Japan, across all fields combined, almost a half of research projects produced a master's degree, and about 70% of them produced doctoral degrees. In the US, we see somewhat fewer projects producing PhDs (although, as noted above, projects may be defined more narrowly), and many fewer projects producing master’s degrees. In both countries, a research project is more likely to produce doctoral degrees more often than master’s degrees.

As we showed above, doctoral students are often the first authors of the papers when the order of the authors is according to their contribution to the research, while it is rare that master or undergraduate students are the first authors. This is consistent with a larger incidence of doctoral degrees from research projects. H projects tend to produce more PhD degrees than do N projects.

Exhibit 52 shows the percent of projects that trained post-doctoral fellows. Post-doctoral fellows are becoming a key part of the science system (Stephan, 2010). We find that about 60% of H projects in both countries included a post-doctoral fellow, while the rate is substantially lower for N projects (around 40%).

Exhibit 50 Share of research projects that produced master's degree recipients

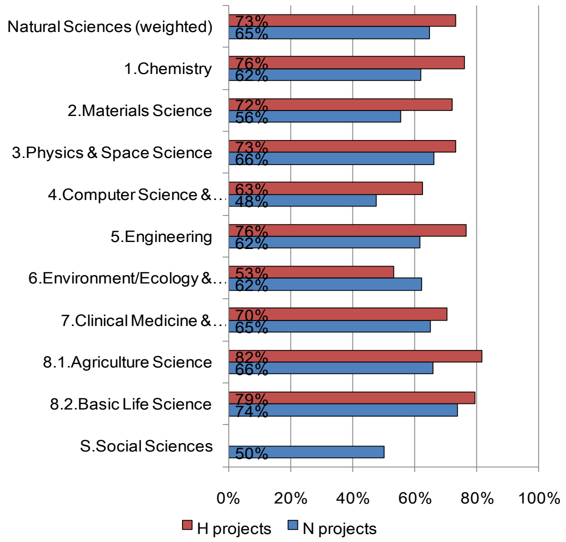
(a) Japan (b) US



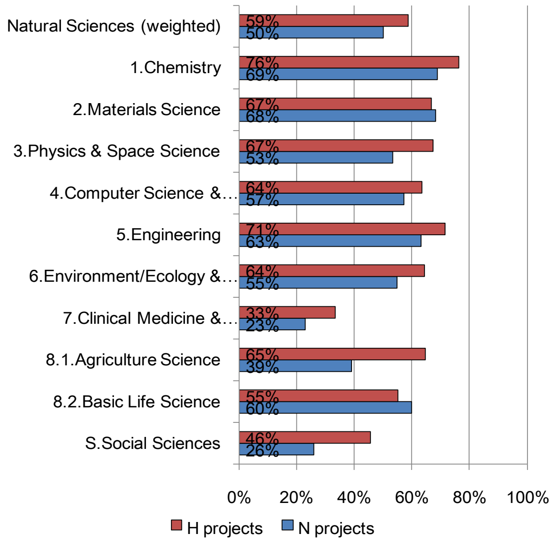
Note1: Both domestic and foreign born students.
Note2: In each field, the upper figure is for the H projects and the lower figure is for the N projects.
Note3: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Exhibit 51 Share of research projects that produced PhD recipients

(a) Japan



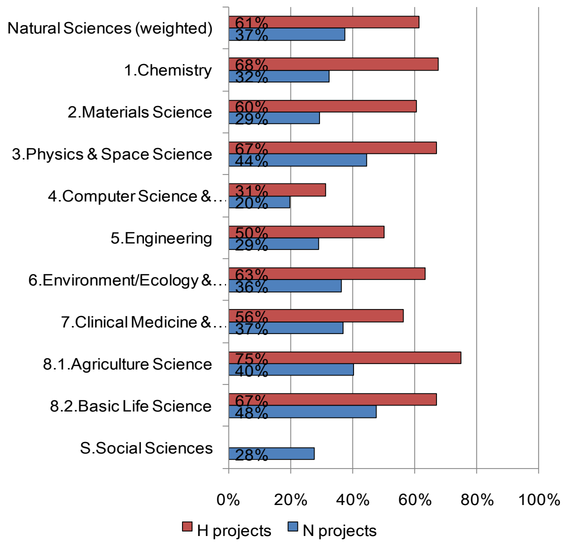
(b) US



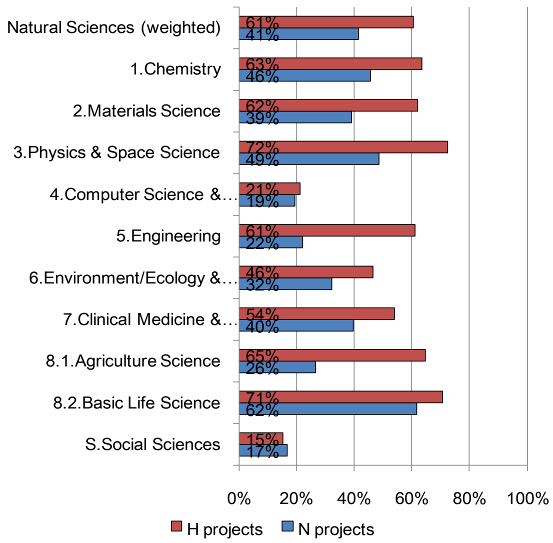
Note1: Both domestic and foreign born students.
Note2: In each field, the upper figure is for the H projects and the lower figure is for the N projects.
Note3: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

Exhibit 52 Share of research projects that trained postdoctoral fellows

(a) Japan



(b) US



Note1: Both domestic and foreign born students.
Note2: In each field, the upper figure is for the H projects and the lower figure is for the N projects.
Note3: Result of social sciences in Japanese H projects was not shown due to the small number of responses.

9—3 PATENT APPLICATION, LICENSE AGREEMENT OR PATENT ASSIGNMENT

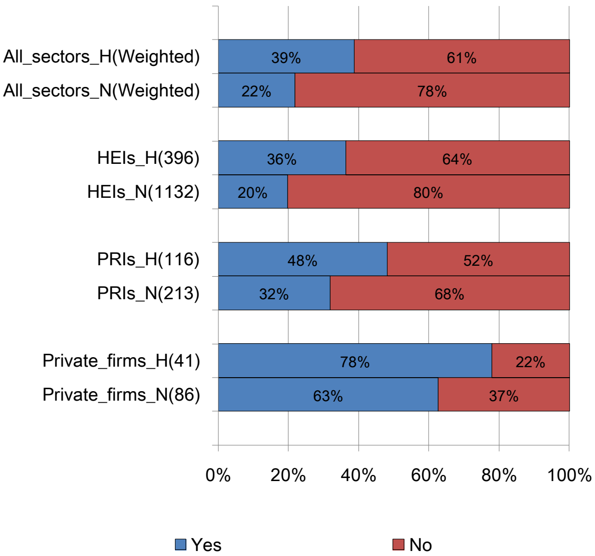
Exhibit 53 shows the incidence of patent applications (domestic and/or foreign application) and of license agreements (or patent assignment). In Japan 39% of the H projects and 22% of the N projects led to at least one patent application on average. In addition, the incidence of a foreign patent application conditional on a patent application is 63% in the H projects and 50% in the N projects. For the US, the patenting rates are lower: 17% for H projects and under 10% for N projects, and only about 25% of H patents and 18% of N patents were also applied for overseas. Thus, patenting rates, and especially international patenting, appears to be greater in Japan. However, it is important to note that the projects are more broadly defined in Japan (roughly 3 times more man-months and published papers), although patenting probability is still higher in Japan, controlling for the size of projects (man-years), as seen Exhibit 54).

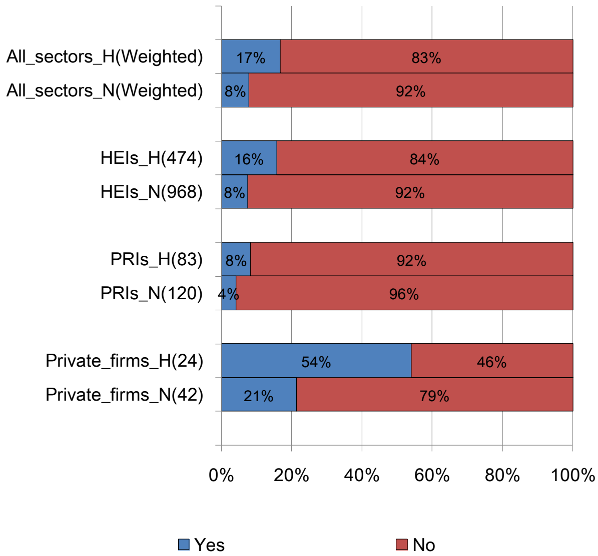
If we focus on sectors, the majority of Japanese research projects of private firm led to patent application: 78% from the H projects and 63% from the N projects. Among US industry respondents, over half of H projects, but only 21% of N projects led to a patent. In Japan, we see somewhat higher rates of patenting in public research institutes than in universities, with the opposite ranking in the US.

Exhibit 53 Patent applications arising from the findings of a research project

(a) Japan

(b) US



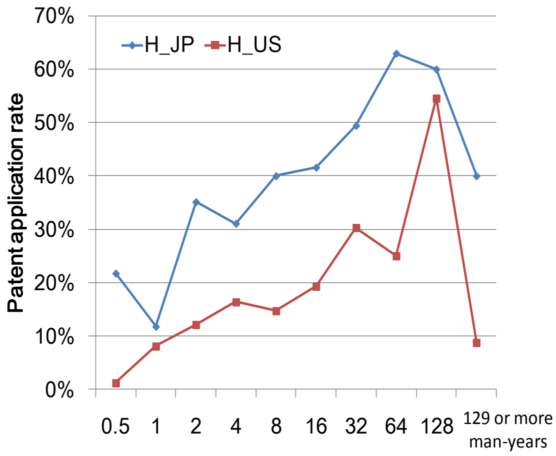


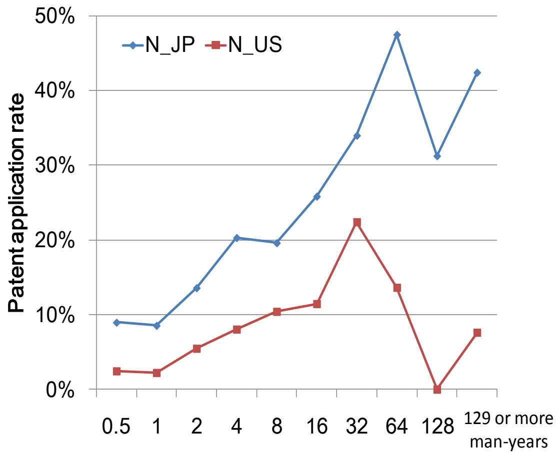
Note1: In each sector, the upper figure shows the result of the H projects and the lower figure shows the result of the N projects

Exhibit 54 Patent applications by project size

(a) H projects

(b) N projects





Note 1: Horizontal axis represents a number of research man-years of a project and the vertical axis represents the average incidence of domestic patenting from a project.

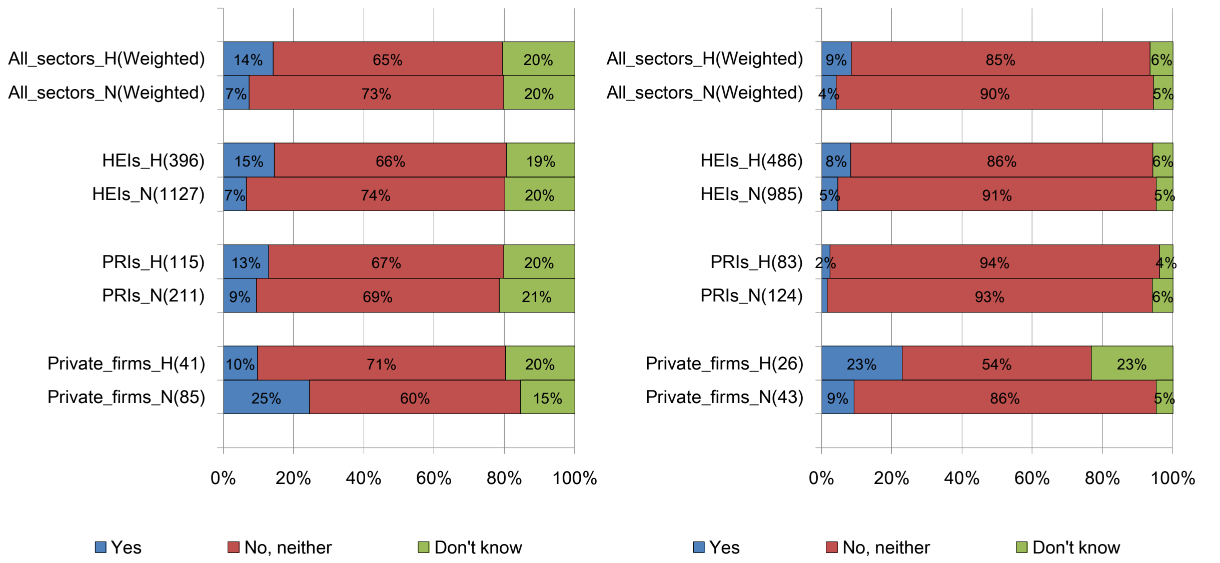
Note2: The results are not weighted by field.

As for a license agreement and the assignment of patents[1], in both countries, licensing or assignment are significantly more frequent for the H projects on average (Exhibit 55). We also see that licensing or assignment is more common in Japan than in the US, for both H and N projects, suggesting that commercialization rates (measured by patents or by licensing) are higher, per project, in Japan than in the US. Since higher quality patent is more likely to be licensed, these results suggest that there is a positive correlation between the quality of academic publication and the quality of a patent at project level, consistent with the patterns observed across individuals (See Stephan (2010) for a review). However, interestingly, for private firms, in Japan there are more license agreements and assignments in the N projects than in the H projects, but not in the US. These results suggest that technology markets operate differently in the two countries.

As Exhibit 56 indicates, know-how is supplied for most cases when patent license agreement and assignments occur, in both countries. As Jensen and Thursby (2001) suggest, many technologies are still very nascent when first patented, and require the know-how of the inventor in order to move the technology toward commercialization.

Exhibit 55 Licensing or assignments of any research results

(a) Japan (b) US

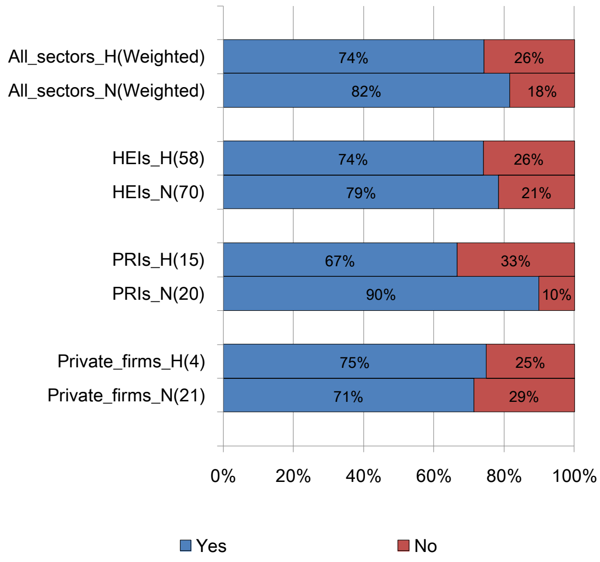


Note1: In each sector, the upper figure shows the result of the H projects and the lower figure shows the result of the N projects

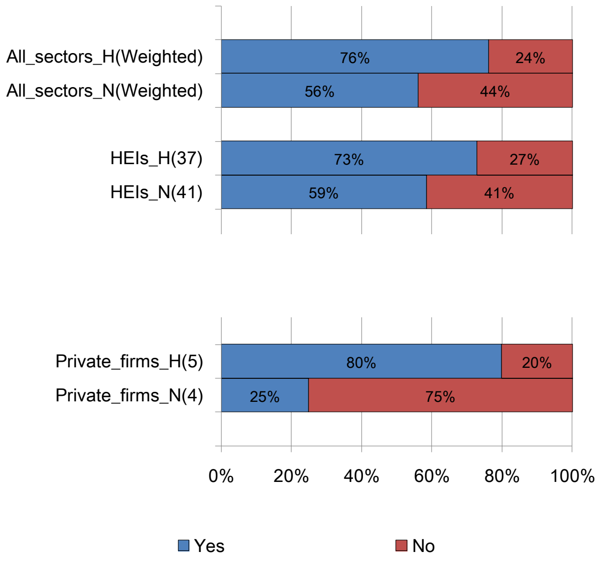
[1] It is important to note that an assignment of a patent can take place without a patent application, since the legal right to apply for a patent can be transferred.

Exhibit 56 Provision of know-how

(a) Japan



(b) US



Note1: In each sector, the upper figure shows the result of the H projects and the lower figure shows the result of the N projects

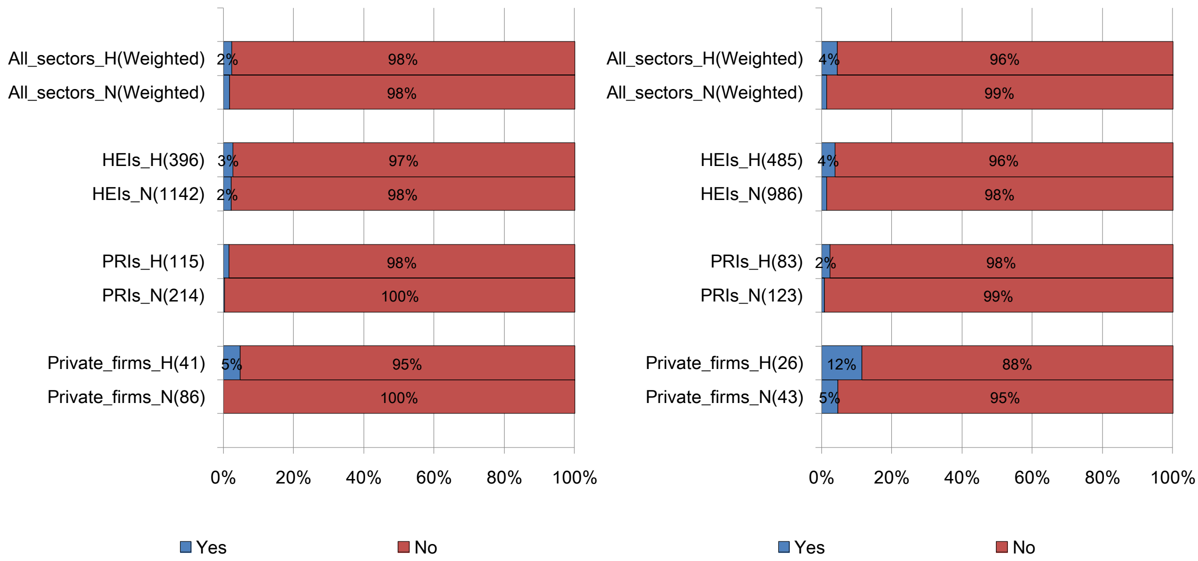
9－4 Establishment of Start-up Company and Contribution to the Standardization

Exhibit 57 and Exhibit 58 show the rates of start-ups by organization type and by field. In both countries, the share of the research projects that led to a new start-up company is only a few percents (less than 5%, even for H projects). The survey also asked if the members of the project considered starting a firm based on the project. If we include those who seriously considered starting a firm, the average increases to about 10% in total, suggesting that the possibility of a start-up company is considered as a real option. Among H projects in the US, start-ups were most common (more than 5% of projects in a field) in chemistry, materials science, engineering and basic life sciences. For H projects in Japan, only materials science and engineering were above 5% of projects.

In Japan, the survey also asked if the project contributed to a standard. About 10% of projects reported contributing to a standard or that such a standard was under serious consideration.

Exhibit 57 Start-up companies established based on the findings

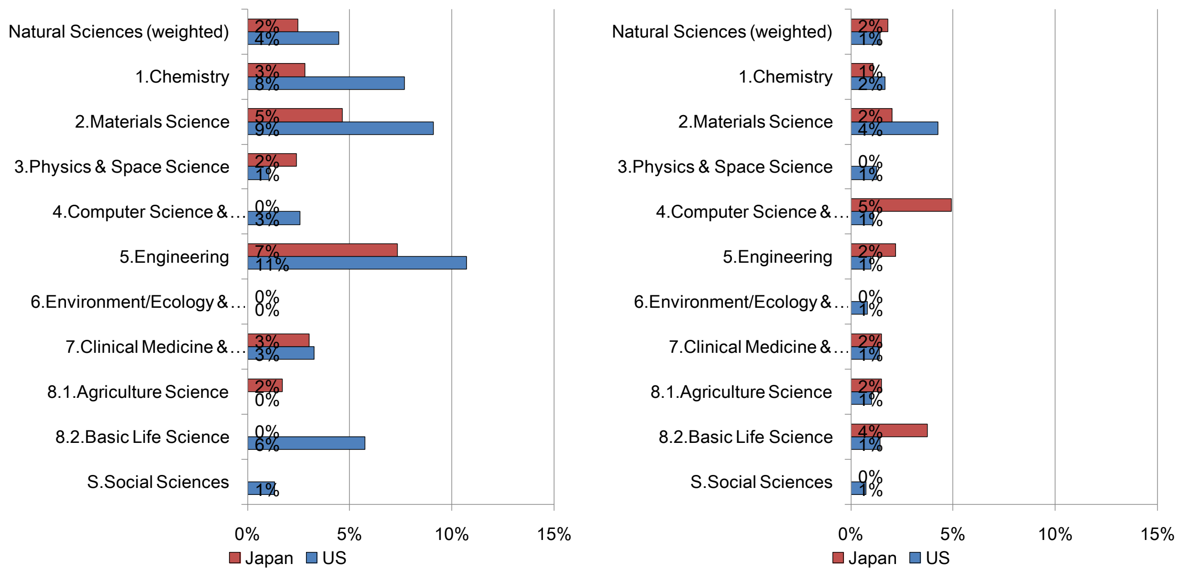
(a) Japan (b) US



Note1: In each sector, the upper figure shows the result of the H projects and the lower figure shows the result of the N projects

Exhibit 58 Start-up companies established based on the findings by field

(a) H projects (b) N projects



Note1: In each field, the upper figure is for Japan and the lower figure is for the US.

9—5 SUMMARY OF THE OUTPUT OF RESEARCH PROJECTS

Finally, Exhibit 59 provides a summary of the outputs from a research project. First, we can see that H projects are almost always more productive than N projects, on nearly every dimension, with MS degrees in the US and the training of US born post doctoral fellows being the only exception. We can also see that training researchers is the major output of the research (besides the publication itself). We also see that foreign-born personnel are widely participating in US science. In particular, projects are especially likely to train foreign-born (compared to US born) post-doctoral fellows, and that this is even more true for the H projects. A half of H projects engaged a foreign-born post-doctoral fellow. The US projects were also more likely to educate foreign-born PhD students than US born. However, US born master's students are more common than are foreign-born.

The gap between H and N projects is especially sharp for commercialization, with H projects producing patents, licenses and start-ups at much higher rates than N projects.

Exhibit 59 Summary of the outputs from a research project

		Japan			US		
		H project (a)	N project (b)	(a)/(b)	H project (a)	N project (b)	(a)/(b)
Total research man-months (Median)		100	72	1.4	36	24	1.5
Refereed papers (Median)		15	8	1.9	5	3	1.7
Training of Post Doctoral fellows	All	61%	37%	1.6	61%	41%	1.5
	Domestic born	50%	28%	1.8	15%	19%	0.8
	Foreign born	36%	20%	1.8	46%	30%	1.5
Ph. D recipients	All	73%	65%	1.1	59%	50%	1.2
	Domestic born	66%	58%	1.1	36%	27%	1.3
	Foreign born	32%	21%	1.6	37%	31%	1.2
Master's degree recipients	All	49%	47%	1.0	20%	21%	0.9
	Domestic born	47%	45%	1.0	13%	15%	0.9
	Foreign born	11%	8%	1.4	8%	9%	0.9
Patent applications		39%	22%	1.8	17%	8%	2.1
Start up		2%	2%	1.4	4%	1%	3.1
Licensing		14%	7%	1.9	9%	4%	2.0
Standard		13%	8%	1.6			
Commissioned research and joint research		78%	60%	1.3			
Technical guidance		39%	27%	1.4			
Research tools		50%	41%	1.2			
Follow-up research		90%	75%	1.2			

Note1: The weighted result of natural sciences.
Note2: Project size (man-months and the number of papers) is significantly smaller in the US than in Japan, as shown in the above Table..
Note3: In getting the incidence of outputs we count "don't know" responses as negative responses.

10 CONCLUSIONS

This paper has reported the initial findings from a large-scale survey of Japanese and US researchers on the knowledge creation process in science from a comparative perspective. One-third of the samples are from highly cited papers in each scientific field by year (top 1% in the world, H papers) and the rest are from randomly selected papers (N papers). We call the research projects that yielded H (N) papers H projects (N projects). More than 80% of the respondents executed the central part (or a part of the central part) of the projects and around 80% of the respondents played either the leading role or at least some role in the management of the projects.

The survey characterized the motivations of the research projects; the knowledge sources which inspired the projects; uncertainty in the knowledge creation process; research competition; composition of the research team; sources of research money; and the research outputs, including papers, patents, license/assignment and start-ups.

Major findings are as follow:

1. More than 70% of the responding scientists belong to higher education institutions in both countries (73% of the H papers in Japan and 76% of the H papers in the US); 10% to 20% of the respondents belong to pubic research organizations (higher in Japan); and around 5% of the respondents belong to private firms in both countries.
2. Japanese respondents are younger: as for submission age, the average ages of respondents in the natural sciences are 42.8 (H papers) and 43.7 (N papers) in the Japanese sample; and 45.6 (H papers) and 46.7 (N papers) in the US sample. Around 90% of respondents (89% in Japan and 92% in the US) had doctoral degrees when the research was launched. Japanese respondents are as mobile across organizations as US respondents, controlling for age.
3. Pasteur's quadrant (both "Pursuit of fundamental principles/understandings" and "Solving specific issues in real life" are very important motivations) occupies a significant part of scientific research in both countries. Among H projects, the share in Pasteur's quadrant is more than twice as high in the US than in Japan (33% vs. 15%).
4. Bohr's quadrant (only "Pursuit of fundamental principles/understandings" is very important) accounts for the largest share of research projects (45% (35%) of the H (N) projects in Japan and 46% (42%) of H (N) projects in the US. Edison's quadrant (only "Solving specific issues in real life" is very important) accounts for 15% (16%) of the H (N) projects in Japan and 11% (15%) of the H (N) projects in the US.
5. Research involves very substantial uncertainty in both countries. Both the main result of the paper and the research process were as initially expected or planned only for 11% of the H papers in Japan and 14% in the US (17% of the N papers in both countries). Research process uncertainty is high in Pasteur's and Bohr's quadrants in both countries.
6. In both countries, the research output of the paper often found answers to questions not originally posed, that is, serendipity in the sense of (Stephan (2010)) occurred. H papers involve more serendipity and a serendipitous output is more often observed in a research project involving more process uncertainty in both countries. Thus, scientific research not

only yields the results (sometimes more than expected) to the original questions but also those to the questions not originally posed. Appreciating such option value would be important for scientific research funding.

7. In both countries, most researchers recognize the extent of research competition *ex-ante* (only a minority chose "don't know"). A significant number of researchers were concerned with priority loss (more than 50% of the researchers in Japan and 23% of them in the US for H papers). Such concern is stronger in H projects than in N projects. It increases with the number of competitors recognized *ex-ante*. Priority threat is seen as greater in Japan than in the US.
8. By far, the most important knowledge source for suggesting the research project is scientific literature in both countries. Colleagues in the organization (a university, a laboratory, etc.), visiting researchers or post-doctoral students in the organization and past research collaborators follow scientific literature in both countries. The locations of the important knowledge sources are often domestic (exceeding 60%) for the US scientists, while they are often abroad for Japanese scientists, except for the knowledge sources embodied in researchers and facilities.
9. Research is more actively managed in H projects than in N projects in both countries: ambitious goal setting, information sharing and discussions in a team, division of research tasks for outsourcing of a research task, improvement of facilities and program, and development of a research community
10. US scientists seem to make more use of research tool databases, and to engage remote researchers, using the internet, in their research projects.
11. Most scientific research is done by a team in both countries. The share of single authored papers is 3.0% in Japan and 5.4% in the US for H papers. The median author size is 6 in Japan and 5 in the US for the H papers (4 for N papers in both countries). A researcher who provides only materials or research facilities is often added as an author in both countries, and authorship is more expansive in Japan, which is consistent with a larger size of authors per paper in Japan.
12. Young scholars (students and postdoctoral fellows) are important contributors for research efforts in both countries. Post-doctoral students and doctoral students are often the first authors of H papers when the order of the authors is according to their contributions in both countries (young scholars account for 40% in Japan and 50% in the US in the case of higher educational institutions).
13. The involvement of young foreign-born scholars is important in both countries. It accounts for more than 70% of the first authors of H papers in the US and around one-third in Japan.
14. Research teams have more diversified memberships in terms of specialized academic fields, specialized skills, origins of birth and types of sectors in H papers than in N papers in both countries. The US teams are significantly more diversified in the origins of birth than the Japanese teams (80% of teams in the US involve researchers from more than one country vs. 50% in Japan for H papers). Given that international co-authorship in terms of the locations of affiliated organizations of the US is only modestly larger than that of Japan (24% in Japan and 29% in the US in 2005 – 2007), the above difference largely reflects the inflow of foreign-born scholars in the US.
15. The time-lag between the conception of the research project and its launch is mostly a year

or less in both countries but has a longer tail in Japan. Time-lag between the launch of the project and the submission of the focal paper is shorter for H project than for N project and shorter in the US.

16. In terms of the median of the total labor input per project in natural sciences, the projects in Japan spend about 3 times as much as those in the US in both H and N projects. The median number of papers published per project is also roughly 3 times larger in Japan than in the US, suggesting that the concept of "project" is interpreted or defined more narrowly in the US than in Japan. In addition, the research projects in the US are significantly more money intensive than those in Japan. However, some of this difference is due to accounting practices in the two countries (e.g., the extent to which the grant includes all the direct and indirect costs of research).
17. H projects are not only large but significantly more money intensive (higher expenses relative to man-months) than N project in Japan. The median budget of H projects is 5.0 (1.8) times more than that of N projects, while the median size of man-months is only 1.4 (1.5) times larger in Japan (the US).
18. The majority of research projects of higher education institutions in Japan were funded by a combination of intramural and extramural sources. In contrast, more than 50% of research projects of US universities were funded only by external sources. On the other hand, in public research institutions, about a half of research projects in the US are conducted using only intramural fund, while only about one-sixth to a quarter of research projects in Japan are.
19. Mission-oriented programs account for a significantly larger share of the research funding in the US than in Japan (43% (22%) of the H projects on the simple average and 50% (38%) on the weighted average in the US (Japan)). Industry accounts for a relatively small and similar shares of funding in both countries (8% of the H projects in Japan vs. 7% of the H projects in the US in the simple average). Surprisingly, industry funds a greater share of the projects of higher educational institutions in Japan than in the US (5% of the H projects and 8% of the N projects in Japan vs. 3% of the H projects and 5% of the N projects in the US). If we measure industry funding by the percent of projects with at least some industry funding, this contrast is even greater (As for H projects, 24% of Japanese projects have at least some industry funding, compared to 12% of US projects).
20. The median number of refereed papers produced by H projects is 1.9 (1.7) times larger than that of N projects in Japan (the US), which is larger than the research labor input ratio but smaller than the research money ratio between H and N projects. The distribution of the number of refereed papers produced from a project is highly skewed (it has a long right tail).
21. Educational outputs of the research projects are also important, especially training of PhDs and postdoctoral fellows. More than 73% (59%) of H projects produced a PhD in Japan (the US). Educational outputs are larger in H projects than in N projects in both countries. The research projects also often produced materials and other research tools.
22. Research projects resulted in more patent applications in Japan than in the US (39% of the H projects and 22% in N projects in Japan. The corresponding shares are 17% and 8% in the US). They also resulted in more licensing or assignments of a research result in Japan (14% of the H projects and 7% of the N projects. The corresponding shares are 9% and 4%). Note,

however, that the projects are more broadly defined in Japan (roughly 3 times more man-months and published papers). H papers are more often commercialized in both countries. There exist significant variations across scientific fields: materials science, chemistry, and engineering are the most commercially active fields in both countries, while basic life sciences and clinical medicines are only moderately commercially active

23. A majority of licensing and assignment (70 to 80%) were associated with the provision of know-how in both countries, indicating the importance of technology transfer effort on the part of universities.
24. Only a relatively few research projects resulted in start-ups in both countries (2% of the H projects in Japan and 4% of the H projects in the US).

There are some important implications of our initial findings upon "research on research" and upon science policy, although many of them are preliminary observations. First, Pasteur's quadrant is quantitatively important in both countries. This implies that complementarity may exist between science and innovation even at the project level for a significant share of science. In such areas, a university and industry collaboration would be particularly important.

Second, uncertainty is important in the scientific discovery process, in the sense that scientific research not only yields sometimes more than expected results to the original questions but also those to questions not originally posed. It is important to ensure *ex-post* flexibility in research scope to capture unexpected opportunities as well as to appreciate such option value *ex-ante* for scientific research funding. It will be an important research issue to assess how the funding system as whole, including intramural funds, function to support the exploitation of uncertainty and serendipity.

Third, scientists clearly perceive competition *ex-ante* in both countries, and this priority threat is perceived as greater by the scientist of H projects than those of N projects. However, scientists in the US generally perceive this priority threat as smaller than in Japan, while the lag between the conception, launch and submission is smaller in the US than in Japan. It will be an important research issue to provide a consistent explanation of these patterns as well as the relationship between the impacts of priority competition on research performance.

Fourth, H projects are not only large but are significantly more money intensive (higher expenses relative to man-months) than N projects, and especially in Japan. It will be important to understand why such is the case.

Fifth, our study shows that the linkage between higher educational institutions and industry is stronger in Japan than in the US, in terms of industry funding, contrary to prevailing views. Exploration of the reasons for such gap will be important.

Sixth, 70% or more of licensing and assignment were associated with the provision of know-how, indicating the importance of technology transfer effort on the part of universities.

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(Knowledge creation process in science:
Key comparative findings from the Hitotsubashi-NISTEP-Georgia Tech scientists' survey in Japan and the US)

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