Chapter

Sourcing Innovation in the Digital Age

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Abstract

This paper introduces a recent innovation survey, the first of its kind in the Digital Age. With coverage of 300 large firms, sampled to be representative of corporate innovation in eight countries, the survey provides a unique look at how innovation, particularly digital innovation, is being sourced by firms around the world. We find that open innovation at these companies is pervasive, but also recent. Only in the 2010s have many firms started innovating with external partners like universities, third-party experts, startups, or crowd. Overwhelmingly, firms use these new external innovation sources for digital technologies where they have internal capability shortfalls. Despite the remarkable growth in the use of external innovation sources, internal innovation sources remain more important for companies. These internal sources also produce the projects most likely to provide a competitive advantage.

Keywords: innovation sources, capabilities, digital, open innovation, competitive advantage

1. Introduction

This article presents a geographically diverse *and statistically representative* view of how firms from countries around the world are sourcing innovation in the Digital Age. To our knowledge, this is the first such survey since AI and predictive analytics have become important to firm performance, and it is certainly the one with the most complete coverage of the sources being used for digital innovation. Our results thus provide a unique view on how firms are sourcing innovation and how this relates to the digital capabilities and competitive advantage they seek.

Our data comes from a new, representatively sampled cross-country survey on corporate innovation. This 2018 survey of 300 firms was sampled to be representative of large firms in seven industries across eight countries. In each case, a validated innovation leader within the company was asked more than 100 questions about how the firm innovates. These included firm-level questions about what types of innovation the firm invests in: which innovation sources, either internal or external, the firm uses, how important these sources are, and the characteristics of their business environment. As recommended by the Oslo Manual [1], the survey also asked about specific recently completed innovation projects, gathering information on 600 projects in total. Data was gathered on which innovation source was used for each project, how that project was implemented, the match between the firm's internal capabilities and those needed for the project, and whether the project ended up providing an advantage against competitors.

We find significant changes to how firms are innovating in the Digital Age compared with what they were doing just a few years earlier, as well as to what previous surveys have found. Nearly all the firms in our sample use a mix of internal and external innovation sources, innovating internally when they have industry-leading capabilities in that area, and outsourcing innovation when they do not. Four external innovation sources (universities, third-party experts/consultants, startups, and crowd) are increasingly used by companies, as are innovation labs (internal R&D labs co-located with innovation hotspots like Silicon Valley). At the same time, there is little to no growth in the number of companies using traditional external innovation sources (suppliers, customers, and competitors) or of traditional internal innovation sources (business unit staff, central R&D).

Despite the rapid growth in the use of external sources, for 91% of firms it is internal sources that remain the most important source of innovation. Within that internal innovation, however, there is a shift away from innovating within business units to doing so centrally (at Central R&D or Innovation Labs). In addition to be more important overall, internal sources also provide 77% of the firms' most successful innovation projects. By contrast, universities and suppliers account for 17% of the most successful projects. Consistent with the importance that firms place on internal innovation sources, we find that projects that originate from inside the firm are more likely to provide competitive advantage than those coming from external sources.

We also find that digital technologies are central to firm innovation, with 97% saying that their most successful innovation of the last few years was a digital initiative. Commensurately, we see nearly all firms increasing their investment in digital innovation. There is also a strong correlation between increases in investment in digital and firms getting a greater share of their revenue from new products or services. We also find that the innovations coming from fast-growing external innovation sources (universities, third-party experts, startups and crowd) are mostly digital technologies, and are ones where firms' internal capabilities are particularly weak.

This chapter's main contributions to the field are as follows. First, our research provides more geographic and industry diversity than previous work. Second, our research is recent and thus can document over a decade of open innovation practices. Third, we have focused on firm-level analysis to emphasize the managerial relevance of our findings. Lastly, much of the literature on innovation sourcing has not considered the substantial role that the digital economy has played on innovation practices, whereas the importance of this phenomena is clear in our analysis.

First, we leverage these advantages in data and survey design to understand how large firms are sourcing innovation, a major topic in the literature over the years.

In the next section, we connect these trends to characteristics of digital innovation, and how we have seen innovation practices materially evolving e.g., the challenge that businesses have in building advanced digital capabilities. Finally, in later sections, we discuss how and why our findings diverge from previous research and provide strategy and policy conclusions about how open innovation is evolving and the key role of digital innovation in changing the sourcing landscape.

2. Theory and literature review

Innovation is central to how firms compete over time; "firms that succeed in innovation prosper, at the expense of their less able competitors" ([2], p 20). This has led to extensive interest in how firms manage innovation (e.g., [3–5]) and particularly on how they can use external sources (or inbound innovation) to conduct open innovation ([6–9], and many more). Much of this open innovation work, though, has come in the form of case studies, typically covering small geographical regions, across a small number of industries or firms, and focusing on specific areas of inquiry [6, 7, 10–12]. As West et al. [13] describes these studies "provide high internal validity but offer limited external validity: as such, they are better at 'why' or 'how' questions than 'when' or 'how often'." Our paper presents a broad international view on 'when' and 'how often', adding to the existing literature in this area that has mainly focused on European firms, through the Community Innovation survey (CIS) [14–19], and the U. S. manufacturing sector [20, 21]. There have also been much-shorter, non-representative surveys that we do not consider here (e.g., [22] with a completion rate of <5%, consulting reports, etc.).

Our work makes several contributions beyond the existing literature. First, our survey provides a more representative view of global corporate innovation by offering greater geographic and industry reach than the CIS or US manufacturing surveys. Second, our survey is more current, reporting data from 2018. The other "how often" papers listed earlier report data from predominantly the 1990s, with the latest from 2010 from Arora et al. [20] (hereafter ACW). This almost-decade gap matters because, as our results show, much of the popularization of the open innovation revolution has only happened in recent years and this has been accompanied by a rapid shift in the usage of innovation sources. A more up-to-date view of corporate innovation is also important for understanding digital innovation, since the period from 1980 to 2019 has been accompanied by an enormous escalation in digital investment by firms, and thus earlier studies would underestimate the role that digital innovation is playing today. To put the size of this shift in context, US firm spending on business software over this period rose from 5 to 33% of equipment spend [23]. The post-2010 period is also when firm investment in predictive analytics becomes a key driver of productivity gains [24] and when digital co-design, for example the Open Compute Project launched in 2011, comes to the fore [25].

A third advantage of our survey is that it is more managerially relevant because we take a firm-centric definition of innovation (rather than industry-centric one [1]. This more accurately represents the decisions facing innovation managers, since their remit is broader than just the new-to-the-industry discoveries covered by industry-level analyses, and thus such analyses miss an important part of real managerial decisions. Indeed, testing in one of our geographies reveals that only 27% of firms' most successful innovations came from outside the industry. A firm-centric approach is also likely to do a better job capturing the innovations that drive overall productivity growth, since intra-industry differences also represent the bulk of variation in firm performance [26] and productivity [27]. Consistent with this claim, testing in one geography reveals that innovation projects that are new to the industry provide competitive advantage at almost exactly the same rate as innovations that are not new to the industry (we are able to test this difference because we tested the addition of this question in one geography). And thus the industry-level approach pays a high price in omitting projects that are important to firms and provide them competitive advantage. The firm-level approach does, however, come at a cost of our ability to aggregate. Whereas other papers can make a claim about the share of innovation coming into an industry from outside of it, we cannot make such statements.

3. Survey methodology & sampling

3.1 Design

The design of the survey was accomplished in two parts: a qualitative interview process to determine key issues, and an iterative piloting stage to refine the questionnaire. The qualitative interview process occurred in Fall 2017. We interviewed over 30 C-Level innovation managers working at international large firms ($500 m + in revenue). These managers were sourced from our personal and professional networks. With them, we have conducted open-ended interviews to capture qualitative insights that helped us draft the large-scale questionnaire for our final survey. We then tested those questions through live questionnaire-taking, where innovation leaders at companies agreed to complete the survey while on the phone with us (though none of these preliminary surveys are included in our results, since their sampling was not representative). Respondents narrated their interpretations of the survey questions as they progressed, and we questioned them on what they meant by their answers. Based on our observations of their survey-taking experience, as well as their direct feedback, we iterated the questions until we were confident that respondents understood what was being asked and felt the answers conveyed their companies' experiences.

To finalize the questionnaire, we followed an iterative process of rewriting and retesting. We also drew on previous innovation survey work [20] as well as guidelines from the Oslo manual [1].

The final survey was administered using random sampling (see Survey Administration and Sampling, below) to ensure statistical representativeness. It was answered by 300 innovation managers (see Survey Administration and Sampling section below) and took respondents ~25–35 minutes to complete. The questionnaire included 35 often multi-part questions (for a total of 101 questions). The main topics covered included company-level questions on the following topics:

- Which innovation sources firms are using, and for how long? (Appendix A, Exhibit 1)
- Which innovation sources are the "most important for your company"?
- What mix of internal and external resources were used when innovating with an innovation source (7-Point Likert Scale from Entirely Internal to Entirely External)?

Consistent with the Oslo manual [1] recommendation, we also asked questions about "a single, focal, most important innovation, facilitating information retrieval about enablers, features, and outcomes of business innovations", in our case the most successful innovation project that their company had completed in the last two years.

Because of the geographic and industry diversity in our sample, we do not restrict answers to a particular economic dimension, lest we force a company whose most important innovation is in one area (e.g., cost-cutting) to report on a less-important project in another area (e.g., revenue generation). While this choice comes at the cost of additional variation in the type of importance meant by respondents, we argue that this reflects true industry variation in where innovation is most important and is thus the right empirical choice if the desired outcome is to produce broad claims about the sources of the most important innovations.

The survey also asked about a second innovation project, one that came from a different source than their first project. This innovation source was randomly chosen for respondents from amongst those they were working with. Gathering data about a second innovation project provides two main benefits. First, it allows us to understand how innovation sources are being used even when they are not producing the most-important innovation. Second, our construction allows us to use compound lottery sampling ([28], p 169) to make statistically valid inferences about their answers had we asked them about a project from a random innovation source (survey testing confirmed that respondents typically called to mind the most important innovation that they had done using this secondary source, and had no trouble providing concrete details about the "enablers, features, and outcomes of business innovations."). Project-level questions that were gathered for both the most important project and the second project included:

- Which source was used for the innovation (**Table 1**)
- How well the firm's resources and capabilities matched with the innovation that they were developing (Appendix A, Exhibit 2)

Innovation Source	Description
Business Unit (Dedicated)	Dedicated innovation staff managed and co-located with a business unit.
Business Unit (Operational)	Business unit staff who work on innovation part-time in addition to their operational responsibilities.
Central R&D	R&D entity that is centrally managed by the company and works on a range of innovations.
Competitors	Innovations developed by competitors that were open source, acquired via licensing, brought in by former employees, reverse engineered; or that arouse from industry collaborations/associations.
Customers	Customers who provide feedback to the companies' innovation, participate in co-creation or proofs of concept.
Crowd	Innovations that originate from crowd-sourcing platforms, hackathons, innovation competitions, or third-party developers.
Innovation Lab	Innovation lab dedicated to the development of a specific technology (e.g., AI), sometimes co-located with innovation hotspots (e.g., Silicon Valley).
Startups	Startups who are solicited through innovation scouting, incubators, accelerators, corporate venture capital, acquisition, etc.
Suppliers	Firms who are in, or could be in, the value chain of the company, such as the suppliers or channels.

Innovation Source	Description
Third-Party	Independent providers of products or services, including technology vendors, consulting/design firms, independent innovators, and opinion leaders; excluding startups.
University	Universities or independent researchers who are sponsored by the company or whose innovations are licensed or otherwise acquired.

Table 1.
Innovation sources.

- The extent to which the project gave the company an enduring advantage over competitors (Appendix A, Exhibit 3)

The definition of innovation provided to respondents was “the ways that companies create new products, services, business models or improve their existing ones”. Our initial interviews and survey testing confirmed that respondents had no difficulty interpreting this, which is unsurprising since so many work directly in the innovation field. We also reinforced our intended meaning through examples. The innovation sources included in the survey are shown in **Table 1**.

3.2 Survey administration and sampling

The survey was launched in August 2018 and lasted six weeks. The survey company, Phronesis Partners, administered the survey respondents via telephone (predominantly) and/or through an online platform (when needed).

The survey was conducted across seven industry sectors: Consumer Products and Retail, Manufacturing, Automotive, Financial Services (banking, insurance), Pharmaceutical & Life Science, High-Tech, and Utilities. It also covered eight countries: US, France, Germany, UK, Australia, China Mainland/Taiwan/Hong Kong, Japan, and South Korea. This allows us to provide a more global view of open innovation than previous work. It also allows us to examine country and sector differences (which we do in another paper).

Respondents were allowed to either answer in English or via a translated questionnaire in French, German, Mandarin, Japanese, or Korean. Only large firms were targeted for the survey, with one-third having annual revenues of USD $500 m-$1bn, and the remainder having revenues greater than USD $1bn.

Companies were sampled in order to be *statistically representative*, meaning that (up to sampling error, which was minimized through substantial samples) the conclusions from our sample would be expected to be quite close to those if *all* firms in that group had been surveyed. This was done as follows. For each country, a list was compiled of all companies in the target industries that had revenues greater than $500 m using Dunn and Bradstreet/Hoovers. Each country’s list was then sub-divided into lists for each industry and then each of two revenue size categories ($500 m-$1bn, and $1bn+) Then, *by random draw* from each of these sublists, firms were offered to participate in the survey. Because of this random sampling, each of these subcategories is representatively sampled. The success of this approach in producing a representative sample is shown below.

Sufficient numbers of firms were sampled such that, after response rate and screening were taken into account, respondent counts would meet target levels. The response rate to the survey was 34% (e.g., in contrast with 20–24% for large firms for [20]).

Of those who agreed to participate, 7.4% were screened out for having too little knowledge or responsibility for innovation within their company to participate in the survey. Post-survey, we matched firms to Capital IQ to gather their financial information.

3.3 Target respondents

For each company, the target respondents were innovation leaders that held managerial or higher rank and who had a holistic view of the firm's innovation activities. The respondent's seniority was determined from their job title and job description in LinkedIn Navigator, ZoomInfo, or the survey company's internal database. Job target titles included: Chief Innovation Officer, Head of R&D, Head of Open Innovation, etc., which is broadly similar to the respondents reached by the European CIS surveys [16]. To ensure our survey reached sufficiently senior innovation leaders, the target ratio of Executives, Directors, and Managers was 30–40–30%. To ensure that respondents had sufficient knowledge and responsibility for innovation within the company, early survey questions explicitly screened for these characteristics and excluded respondents that did not meet them.

3.4 Sample summary statistics

Table 2 shows the summary statistics for our sample. In order to maintain the anonymity of the firms in our sample, we present these only in aggregated form, at the level of industry or country. The column "# Companies: Sample" shows the number of observations per country and industry, which met our targets almost exactly. The sample for seniority level was also met closely, with 89 executives/CXOs, 119 Directors, and 90 Managers interviewed, as was the sampling of firm sizes, with 98 with $500 m-$1bn in yearly revenue, and 202 with $1bn + .

To compare the representativeness of our sample with the underlying populations, we use the sector and country categories in Capital IQ. This is an approximation of the population used for actual sampling, since the sample group originated in D&B/Hoover's. But approximating with Capital IQ allows us to compare revenue, profitability, growth rates, and firm sizes (one exception here is the South Korean banking industry for which only a small number of firms reported the number of employees, thus we omit that comparison to maintain anonymity). To match the sample composition, we weight the population values as one-third, two-thirds based on firm sizes of $500 m-$1bn and $1bn + .

Our results in **Table 2** show that our mean sample values are similar to the population mean values. Per the statistical guidance in Imai, King, and Stuart [29], we do not commit the fallacy of running a t-test on these variables, since that conflates sampling accuracy with test power and therefore erroneously favors small samples. Instead, we do a Q-Q plot (Appendix C), which shows that, if anything, our deviations are slightly more centrally clustered (and therefore more representative) than one would expect from a normal distribution.

4. Results

To understand how firms are sourcing innovation in the Digital Age, we first examine the broad trends in how innovation sourcing is evolving within large firms. Then, in the next section, we connect these trends to characteristics of digital

	# Companies		2017 Revenue ($USDmm, $\log_{10}$)				2017 Profit ($USDmm, $\log_{10}$)				2017 Growth rate (%)				2017 Employees ($\log_{10}$)			
Country	**Sample**	**Population**	**Sample**	**Population**	**Population Standard Deviation**	**Standard Deviation**	**Sample**	**Population**	**Population Standard Deviation**	**Standard Deviation**	**Sample**	**Population**	**Population Standard Deviation**	**Standard Deviation**	**Sample**	**Population**	**Population Standard Deviation**	**Standard Deviation**
US	99	1928	3.3	3.5	0.5	−0.5	2.2	2.6	1.1	−0.3	9.5	10.2	24.3	0.0	3.8	3.9	1.9	−0.1
UK	30	806	3.5	3.4	0.5	0.2	2.6	2.1	1.0	0.4	17.7	9.5	23.7	0.3	3.8	4.0	1.7	−0.1
South Korea	20	658	3.7	3.3	0.5	0.9	2.5	2.0	0.9	0.5	22.2	34.2	489.0	0.0				
Japan	20	1116	3.9	3.4	0.5	0.8	2.7	2.2	0.8	0.6	6.5	6.9	12.3	0.0	4.1	3.8	1.3	0.3
Germany	39	1000	3.7	3.3	0.5	0.8	2.5	1.9	0.9	0.7	51.2	20.9	349.9	0.1	4.1	3.9	1.7	0.1
France	27	365	3.6	3.5	0.6	0.1	2.5	2.2	1.2	0.2	24.3	14.4	172.2	0.1	4.0	4.1	2.1	0.0
China mainland/ Taiwan/ Hongkong	40	2320	3.3	3.4	0.5	−0.2	2.1	2.2	1.0	−0.1	18.9	28.6	118.3	−0.1	4.0	3.9	2.0	0.0
Australia	20	197	3.4	3.3	0.4	0.3	2.3	2.1	0.9	0.2	25.2	9.2	23.5	0.7	3.3	3.0	1.5	0.2
Industry																		
Auto	43	698	3.9	3.4	0.5	0.9	2.7	2.0	0.9	0.8	17.4	11.3	23.1	0.3	4.4	4.1	1.9	0.2
Finance	43	1427	3.4	3.5	0.6	−0.1	2.6	2.6	1.4	0.0	42.2	14.2	92.2	0.3	3.5	3.7	1.9	−0.1
Manufacturing	42	2345	3.2	3.3	0.5	−0.2	2.2	2.2	0.8	0.0	17.1	18.2	111.1	0.0	3.8	3.9	1.9	0.0
Pharma	41	1211	3.3	3.5	0.6	−0.4	2.3	2.4	0.9	0.0	17.7	24.1	367.4	0.0	4.0	4.1	2.0	0.0
Retail	43	1078	3.4	3.4	0.5	0.1	2.1	1.9	0.9	0.2	12.0	14.3	51.9	0.0	4.0	3.9	1.9	0.1
Tech	42	740	3.2	3.4	0.5	−0.4	2.2	2.3	0.9	−0.2	15.2	16.2	33.3	0.0	4.0	4.0	2.0	0.0
Utilities	41	891	3.6	3.4	0.5	0.4	2.7	2.4	0.9	0.4	18.3	25.0	352.6	0.0	3.6	3.7	1.8	−0.1

Table 2.
Sample summary statistics.

innovation, e.g., the challenge that businesses have in building advanced capabilities in these areas that seem to be driving them.

4.1 Which innovation sources are corporations using?

The question of which innovation sources firms use and why has been a major topic in the academic literature. One area of particular focus is the usage of external innovation sources ([6, 7, 16, 30, 31]; etc.). Our research provides new, detailed evidence on this question.

Of the 11 innovation sources listed in **Table 1**, we find that five are currently used by more than half of firms: Suppliers (86%), Central R&D (79%), Universities (64%), Business Unit with staff dedicated to innovation (63%, hereafter "BU Dedicated") and Third-Party (54%), as shown in **Table 3**. Here, BU Dedicated refers to the company's innovators that are managed by their business units (not centrally) and whose principal job is innovation – in contrast to those who do so part-time who we call Business Unit staff with operational responsibilities (hereafter "BU Operational").

Of the sources used most often, it is notable that suppliers and universities, the first and third most-used, are external to the firm.[1] At the other extreme, we find much-touted sources that are used by fewer firms, including Crowd (18%), BU Operational (30%), Startups (32%), and Innovation Labs (37%). Of these, the share for BU Operational is notably low given the widespread attention given to industry manifestations of this, including the 3 m 15%-time and Google 20%-time models. The small share using innovation labs is perhaps less surprising since the costs of this type of innovation are high and much of the growth in usage has been very recent [32]. We also find that customer/user-innovation is used by 41% of companies and that 22% source innovation from competitors (e.g., through open-source software).

In addition to indicating whether their company used a given innovation source, respondents indicated how long they had been using it.[2] This provided insights on how innovation sourcing has shifted over time. For some external innovation sources, the changes have been rapid: only 2% of current users of start-ups and crowd have been doing so for more than five years, with the remaining 98% adopting since then. Other innovation sources are more stable, with most of the companies that use them having done so for more than five years, including BU Dedicated (90%), Customers (89%), BU Operational (84%), and Central R&D (67%). One, perhaps surprising, result is that one-third of the companies working with universities, a long-discussed source of innovation [33], only started doing so in the past two years. These results strongly support the argument in the open innovation literature about the growth of external sourcing of innovation (e.g., [6, 7]), but they suggest that much of this adoption has happened quite recently, despite it having been widely discussed for nearly two decades.

By multiplying the share of firms using an innovation source with the share that have adopted in the last two years, we can calculate the share of all firms that have

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[1] Later, we provide data justifying our assertions about which sources are internal and external.

[2] This was asked via "how long have you been using" type questions. In early drafts of the questionnaire, we considered asking directly about which sources were used two and five years ago, which would have had the benefit of allowing us to detect which sources were being dropped, but test-respondents indicated that they could not answer this reliably (because personnel had left, etc.).

	Companies using this innovation source			Duration of use (years)			Most important innovation source		3 most important (whole company)		
Source Names	**N**	**#**	**%**	**⩽2 years**	**3–5**	**>5**	**Whole company**	**Most successful project**	**5 years ago**	**Now**	**In 5 years**
Central R&D	299	235	79%	4%	29%	67%	58%	34%	37%	72%	28%
Innovation Lab	300	112	37%	21%	60%	20%	13%	25%	1%	33%	73%
Business Unit Staff (Dedicated)	300	188	63%	1%	9%	90%	18%	15%	86%	50%	9%
Business Unit Staff (Operational)	299	91	30%	0%	16%	84%	2%	4%	67%	23%	5%
Universities	299	191	64%	33%	52%	15%	2%	9%	6%	43%	49%
Crowd	299	53	18%	60%	38%	2%	0%	1%	0%	6%	65%
Suppliers	299	256	86%	2%	58%	39%	3%	7%	49%	38%	13%
Customers	299	124	41%	0%	11%	89%	2%	2%	42%	11%	6%
Third party	300	162	54%	24%	56%	20%	1%	2%	6%	15%	5%
Startups	299	95	32%	42%	56%	2%	0%	1%	0%	8%	44%
Competitors	298	65	22%	0%	51%	49%	0%	0%	5%	1%	0%

Note: Study conducted in 2018.
[1] Business Unit Staff (Dedicated) = Dedicated innovation staff collocated with a business unit.
[2] Business Unit Staff (Operational) = Business unit staff who work on innovation part time in addition to their operational responsibilities.
[3] Innovation lab = Innovation lab dedicated to the development of a specific technology (e.g., A.I), sometime collocated with innovation hot spots (e.g., Silicon Valley).
[4] Third Party = Independent providers of product or services, including technology vendors, consulting/design firms, independent innovators, and opinion leaders; excluding start-ups.

Table 3.
The usage and importance of innovation sources.

adopted in the last two years. **Table 4** shows this result, revealing that despite the substantial hype around crowd and startups, it is actually universities that are the most-adopted source in the past two years, with 21% of firms starting to innovate with them. This finding is in line with Fey and Birkinshaw's [34] recommendation that "all else equal, to maximize R&D effectiveness, firms should promote university partnering" because "universities, which are not potential direct competitors, are preferable R&D partners" as well as Giannopoulou's et al. [35] view of the importance of collaboration with universities.

These results also suggest a categorization that we will use later in our analysis between fast-growing sources (Universities, Third-Party, Startups, Crowd, and Innovation Labs), and slow-growing traditional sources (Central R&D, Suppliers, BU Dedicated, BU Operational, Customers and Competitors).

With so much adoption of external innovation sources, the question arises whether these external sources are substituting for internal ones. In particular, there is a discussion in the practitioner literature that innovation may be becoming "virtual," with internal sources being jettisoned as external ones take their place [36, 37]. In contrast, academic research has argued that internal and external sources are complementary (Wuyts and Dutta [38], Thompson, Bonnet and Ye [39]), with Wuyts and Dutta saying, "the experiences gained through internal knowledge creation help firms benefit from the opportunities of portfolio diversity." Our data allows us to interrogate this empirically (**Figure 1**).

If firms were making their innovation "virtual", we would expect **Figure 1** to show a negative slope between the number of internal and external sources that firms use, as firms substitute away from internal sources. Instead, we observe a positive slope. This suggests that firms are not going to virtual innovation, but that they are instead choosing to broaden their innovation portfolio to use more sources, both internal and external. An OLS regression confirms this statistical relationship, showing that an increase of one additional internal innovation source is associated with a 0.41 increase in the number of external innovation sources used (p-value = 0.000), as shown in Appendix B.

Source Names	Adopted in last two years
Universities	21%
Third party	13%
Startups	13%
Crowd	11%
Innovation Lab	8%
Central R&D	3%
Suppliers	2%
Business Unit Staff (Dedicated)	1%
Business Unit Staff (Operational)	0%
Customers	0%
Competitors	0%

Table 4.
Most adopted innovation sources in the past two years (share of firms adopting).

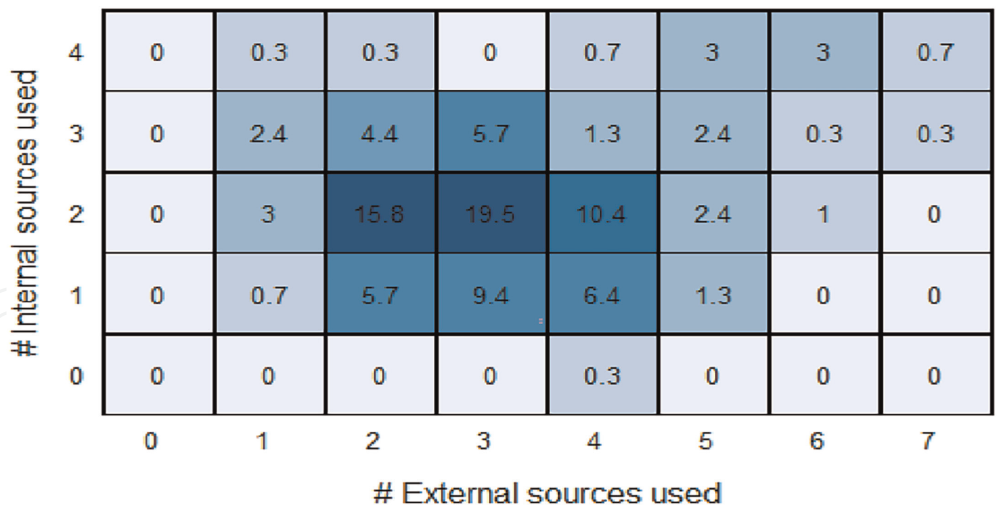

Figure 1.
Number of internal and external innovation sources used (% of companies).

4.2 Which innovation sources are the Most important?

Thus far, our analysis has been limited to which sources are used but has not considered the relative importance of sources. **Table 3** shows two ways of evaluating which sources are most important: the share of companies said that their most successful innovation project came from that source (per the Oslo manual and similar to ACW), and the share of companies said that a source was the most important innovation source for the company overall. Both results indicate that internal sources remain overwhelmingly the most important innovation sources for firms; 91% of firms said that an internal source (Central R&D, Innovation Labs, BU Dedicated, and BU Operational) was their most important, and only 9% said an external source was. Similarly, 77% of firms said that their most successful project came from an internal source, but only 23% said it came from an external source.

The contrast between which innovation sources are producing the most successful innovation projects and those that are most important to the firm overall, reveal interesting differences. Innovation labs, while only the most important source for 13% of companies, nevertheless produced the most-successful project for 25% of them. This contrasts with Central R&D, which seems to have more overall importance, ranking as 'most important' for 58% of companies, but only produces 35% of the most-successful innovation projects. Despite almost no external innovation sources being 'most important' for companies overall, universities and suppliers nonetheless provided companies some of their most successful projects (9% and 8%).

The three right-most columns of **Table 3** also show the overall importance of innovation sources changing over time. For example, only 1% of firms considered innovation labs as one of their three most-important innovation sources five years ago, but 33% do today, and 73% anticipate that it will become one in five years. This rise in importance is echoed by startups and universities (although universities are expected to plateau near current levels). Crowd has grown slowly over the last five years but is expected to grow dramatically in the next five years (although few companies have experience with crowd, so this may just reflect hype).

Other innovation sources are falling in importance, for example BU Dedicated: 86% of firms thought it was one of their top three sources five years ago, whereas 50%

do today, and only 9% project that it will be in five years. Other sources falling in importance include BU Operational, Suppliers, and Customers.

Although there has been a dramatic broadening of the external innovation sources being used, our analysis reveals that internal sources remain the most important ones for firms. Consistent with this, internal innovation sources also produce innovation projects that are more likely to provide competitive advantage. When firms are asked "How enduring was the advantage that your company gained from this innovation?", 89% of the projects undertaken internally were rated as providing "an advantage which persisted." But this share falls to 61% for projects done using external sources, a drop of 28 percentage points (statistically significant at p-values <0.01).

A natural explanation for the positive correlation between doing innovation internally and getting more competitive advantage is that innovations sourced externally may be easier for competitors to access – and thus they will provide less competitive differentiation. It may also be harder to protect IP when innovating externally, making it easier for competitors to mimic an innovation [40]. Thus, it is not surprising that internal innovation sources are viewed as more important than external sources for firms because they are more likely to provide competitive advantage.

4.3 How internal or external is each innovation source?

Up to this point, we have asserted that the internal innovation sources are Central R&D, Innovation Labs, BU Dedicated, and BU Operational, and that other sources are external. But this is not a foregone conclusion. Innovation Labs are often located within innovation hubs, and thus could be more external than internal. Similarly, the literature of absorptive capacity [41, 42] argues that internal expertise and resources makes the usage of external innovation sources more successful. Hence, some external innovation sources might have a substantial internal component. We investigate this question by having respondents report the mix of internal and external resources that they use when innovating with each innovation source. These answers are reported on a 7-point Likert scale, which for ease of interpretability we recode to: −1 (relies solely on internal resources) to 1 (relies solely on external resources), with 0 indicating an equal mix.

Figure 2 shows that Central R&D, Innovation Labs, and BU Dedicated and BU Operational use primarily internal resources, whereas the others are primarily external. Interestingly, four of the five fastest-growing innovation sources (Innovation Labs, Universities, Crowd, and Third Party) use a more equal mix of internal and external resources than do traditional sources.

5. The role of digital innovation

One of the strengths of our survey is the ability to examine the importance of digital innovation, which has expanded considerably since the surveys from 2010 and earlier. We find extensive evidence that digital technologies are amongst the most important in firm innovation. Out of 600 innovation projects, 88.5% of them were "primarily digital" (vs. not). This share varied little across industries, with High Tech and Finance having similar shares to Manufacturing, Utilities, and Pharmaceuticals. Indeed, no industries were statistically significantly different from each other (**Table 5**). At first glance this is somewhat surprising, but it is consistent with the enormous gains that have been made in computing [43, 44] and arguments that only

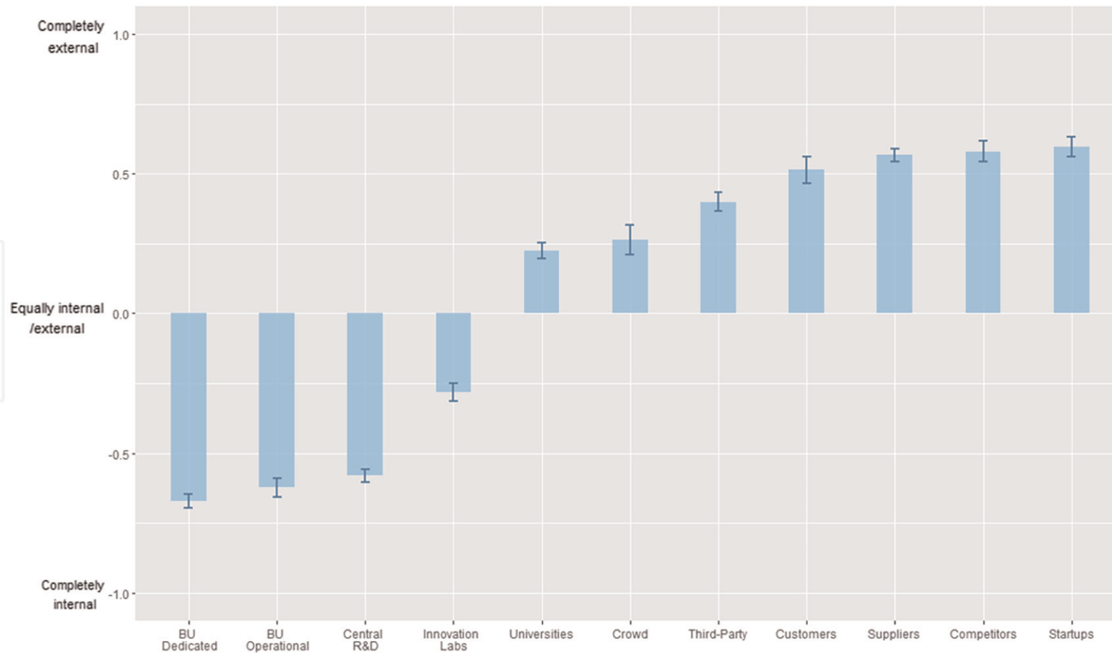

Figure 2.
How external are different innovation sources?

in recent years has the confluence of several processes converted firm digital transformations from quantitative progress to qualitative change [45].

The importance of digital innovation is even more clear when innovation projects are disaggregated to separate out firms' most-successful innovations from their other

		Project is primarily digital		
	All (1)	**All (2)**	**Most successful (3)**	**Other (4)**
Most successful	0.18			
	(0.02)			
	p = 0.000			
Finance		−0.02	−0.02	−0.02
		(0.05)	(0.03)	(0.09)
		p = 0.635	p = 0.478	p = 0.793
Manufacturing		−0.01	−0.05	0.02
		(0.05)	(0.03)	(0.09)
		p = 0.812	p = 0.157	p = 0.793
Pharma		0.03	0.00	0.07
		(0.05)	(0.03)	(0.09)
		p = 0.476	p = 1.000	p = 0.430
Retail		−0.01	−0.05	0.02
		(0.05)	(0.03)	(0.09)
		p = 0.812	p = 0.157	p = 0.793

	Project is primarily digital			
	All (1)	**All** (2)	**Most successful** (3)	**Other** (4)
Tech		0.003	−0.02	0.03
		(0.05)	(0.03)	(0.09)
		p = 0.957	p = 0.486	p = 0.750
Utilities		0.02	−0.02	0.06
		(0.05)	(0.03)	(0.09)
		p = 0.706	p = 0.462	p = 0.489
Constant	0.79	0.88	1.00	0.77
	(0.02)	(0.03)	(0.02)	(0.06)
	p = 0.000	p = 0.000	p = 0.000	p = 0.000
Observations	600	600	300	300
R^2	0.08	0.003	0.01	0.01
Adjusted R^2	0.08	−0.01	−0.01	−0.01
Residual Std. Error	0.31 (df = 598)	0.32 (df = 593)	0.15 (df = 293)	0.41 (df = 293)
F Statistic	53.82 (df = 1; 598)	0.33 (df = 6; 593)	0.67 (df = 6; 293)	0.27 (df = 6; 293)
Note:	The omitted industry for columns 2 to 4 is Automotive. First value is the estimate, second value is the standard error, and the third value is the p-value.			

Table 5.
Share of projects that are primarily digital.

ones, as shown in **Table 5**. Whereas 79% of 'other' projects were digital, an overwhelming 97% of the most-successful ones were fueled by digital technology (an 18-percentage point increase, statistically significant at $p < 0.01$).

5.1 Investment in digital innovation and growth of revenue

The importance of digital was also clear in firm innovation investment decisions. Firms in our sample also reported their investment in innovation was split: 37% went to digital innovations, 24% to non-digital, and 39% to hybrid technologies that combined them. 99% of companies said that they had increased their investment in digital over the past five years, with 39% saying that they were investing 'a little bit more', 52% saying 'more', and 8% saying 'a lot more'. These increases in digital investment are highly correlated with increases in firm revenue. Inspired by Arora et al. [20], we asked about the share of firm revenue that was being generated from new or significantly improved goods or services from the past two years. We find a strong correlation between these measures. **Table 6** shows that firms that invest "much more" in digital are 32 percentage points more likely to have more than 50% of their revenue coming from new/improved offerings, and 49 percentage points more likely to have more than 25% of their revenue coming from those offerings.

	Dependent variable:	
	New revenue >50% **(1)**	**New revenue >25%** **(2)**
Invested more in digital	−0.01	0.08
	(0.03)	(0.05)
	p = 0.823	p = 0.078
Invested a lot more in digital	0.32	0.49
	(0.06)	(0.09)
	p = 0.000	p = 0.000
Constant	0.06	0.13
	(0.02)	(0.04)
	p = 0.014	p = 0.0003
Observations	300	300
R^2	0.10	0.09
Adjusted R^2	0.10	0.09
Residual Std. Error (df = 297)	0.26	0.39
F Statistic (df = 2; 297)	17.05	15.58
Note:	First value is the estimate, second value is the standard error, and the third value is the p-value.	

Table 6.
Share of revenue from new or improved goods or services.

It is important to note that the causal direction of this relationship is ambiguous. For example, investment in digital could generate new revenue, plans for new revenue (e.g., a marketing push) could call for more digital investment, or other plans (e.g., new product launches) could generate more revenue and necessitate digital investment.

5.2 External innovation and firm capabilities

King et al. [46] highlight the importance of accessing capabilities outside the firm for technological innovation, since "complete sets of technology- and non-technology-based resources that facilitate progress through all stages or the technological innovation process may be uncommon among firms." We observe this directly in our data, where only 8.5% said that their firm's internal resources and capabilities were a better match ("superior") for their innovation project than were their competitors. Another 40% said that their capabilities were equal to leaders in the field ("strong"), and 50.5% of the firms reported that their firm's internal resources and capabilities were only on par with many others ("reasonable"). Faced with these capability shortfalls, firms often look externally to find expertise for these innovation projects, as shown in **Figure 3**.

Consistent with a view that the primary purpose of using external innovation sources is to get access to skills that the firm lacks, we find that those firms who rated their internal capabilities "reasonable" were only 34% likely to source that

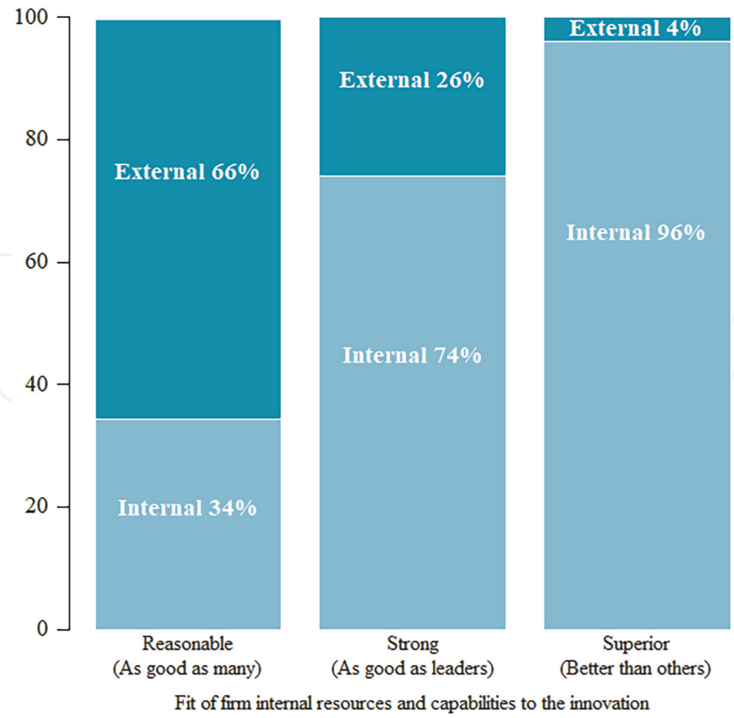

Figure 3.
Variation in innovation sourcing by firm capabilities (n = 600 projects).

innovation internally, whereas when their capabilities were equal to leaders in the field ("strong") this number rose by 40 percentage points (statistically significant at $p < 0.01$) and when firm capabilities were superior to all others it rose an additional 22 percentage points (statistically significant at $p < 0.01$). Thus, for areas with the best match between capabilities and the desired innovation, 96% of projects were sourced *internally*, but for those with the worst match, 66% of projects were sourced *externally*.

Interestingly, much of the movement to new, fast-growing external innovation sources that we documented earlier seems to be driven by the desire to innovate in digital technologies while facing skill shortfalls in these areas. In particular, all of the most-successful projects that these fast-growing sources produced for companies were digital innovations. These sources also worked on digital projects where firms had particularly weak capabilities, as **Table** 7 shows. In **Table** 7, we discretize capabilities into as good, or better, than industry leaders ("superior" or "strong" coded as 1) or not (coded as 0). That is, capability is a dummy variable for whether the firm's capabilities for an innovation project are cutting-edge or not. As **Table** 7 shows, on average firms had cutting-edge capabilities for 68% of the projects that they did internally, but that number dropped 38 percentage points for innovations sourced from traditional external sources (suppliers, customers, and competitors) and 47 ppt for innovations sourced from new external sources (universities, third-party, startups, and crowd). As columns (2) and (3) show, these internal capability shortfalls are particularly pronounced in the digital technologies outsourced to new external sources, where the difference of 11 ppts is weakly statistically significant (p-value = 0.08), whereas for non-digital projects the 5 ppt difference is not statistically significant. That is, firms have particularly weak capabilities for the digital projects that they outsource to universities, third-party, startups, and crowd.

	Dependent variable:		
	Capability		
	All projects (1)	**Digital projects (2)**	**Non digital projects (3)**
Traditional external sources	−0.38	−0.38	−0.25
	(0.05)	(0.06)	(0.12)
	p = 0.000	p = 0.000	p = 0.042
New external sources	−0.47	−0.49	−0.30
	(0.04)	(0.04)	(0.23)
	p = 0.000	p = 0.000	p = 0.195
Constant	0.68	0.69	0.50
	(0.02)	(0.03)	(0.10)
	p = 0.000	p = 0.000	p = 0.000
Observations	600	531	69
R^2	0.19	0.20	0.07
Adjusted R^2	0.19	0.20	0.04
Residual Std. Error	0.45 (df = 597)	0.45 (df = 528)	0.47 (df = 66)
F Statistic	70.64 (df = 2; 597)	66.79 (df = 2; 528)	2.38 (df = 2; 66)
Note:	First value is the estimate, second value is the standard error, and the third value is the p-value.		

Table 7.
Share of projects where firms' capabilities were as good or better than industry leaders.

6. Discussion

A natural comparison point for our survey is ACW, which also looked at innovation sourcing, although only for the most important projects and not for any secondary projects or any firm-level usage (at least as reported). They find that customers and suppliers are much more important sources of innovation projects (27% and 14% of most-important innovations[3]), whereas eight years later we find 2% and 8%, respectively (**Table 3**). This drop over time aligns with the drop in the importance that firms report five years ago until today.

We observe a bigger difference with ACW in the share of most-important innovations that came from internal sources. ACW find that 51% came from an internal source, whereas we find that 77% do. This difference is even larger if we account for the rise of external sourcing that we observe in our data. There are many reasons why our results could differ from ACW. One important difference is the firm size distribution. Around 73–95% of their sample were firms with fewer than 500 employees, and the median firm size was 10–99 employees. In our survey, the median firm had 6000 employees, placing it at the high-end of ACW's "Large Firms" category. Even on its own, this might explain many of the reported differences, since such small firms

[3] 22% and 25% for their Large Firms category (500+ employees).

are less likely to be able to have substantial Central R&D departments or to found innovation labs.

Another potential difference is sample scope. The ACW data focuses on manufacturing, whereas our data covers seven industries. There is also a geographical difference, with ACW reporting US values, whereas we cover eight countries. However, subsetting our data to only US manufacturing firms reveals an even stronger contrast, with 86% of the most important innovation projects coming from internal sources. Thus, this difference in sample construction does not explain the differences in results, it heightens them.

Likely the biggest explanation for the difference between the two sets of results comes from the types of innovation projects included in each analysis. ACW takes an industry-level approach, as recommended by [1], which has the benefit of providing a view of the frontier of knowledge in that industry. In contrast, we take a firm-level approach which has the benefit of being more managerially relevant since many of a firm's most important innovations do not originate outside the industry (we see this quantitatively in single-geography testing that we did, where only 27% of the most important innovations to the firm were new to the industry). It is, therefore, not surprising that by including these other ~73% of projects – which firms report as being their most important innovation but which are not new to the industry – we see a different pattern. In particular, since known-to-the-industry innovations are more likely to be areas of expertise for internal innovators, it is not surprising that we see a higher share of internal innovation than do ACW.

Thus, we conclude that our analysis provides a significantly different window on innovation than ACW. Whereas their analysis covers greater firm size variation, ours covers more geographic and industry variation. More importantly, our results cover a broader range of the innovations that are important to firms and drive their competitive advantage, and thus our findings are more directly relevant to innovation leaders for managing their entire innovation portfolio.

In addition to the strengths of the survey, highlighted above, our design also implies limitations. Like many surveys in this area, we only gather a single wave of responses. This limits our analysis to cross-sectional analysis, whereas repeating the survey over multiple years would allow panel analysis that typically allows for better covariate controls and thus better causal analysis. Hence, our analysis should typically be understood as implies that "the relationship with X and Y is consistent with explanation Z," rather than asserting the stronger "Z causes X and Y." Another limitation of the survey arises out of our sampling choice. By sampling only large firms, $500 M+ revenue per year, our analysis excludes innovation trends occurring in smaller firms. This exclusion also has differential effects across countries, based on the share of firms above this threshold in each country.

These differences also highlight an important implication for policy. Policymakers must be vigilant to distinguish between industry- and firm-level views of innovation, lest their view of innovation be incorrectly biased. In particular, industry-level surveys are particularly useful to understand innovators drawing most successfully from outside their industry. By contrast, policymakers should use firm-level analyses when considering managerial behavior or firm productivity, where a majority of the most important innovations would be missed if industry-level analyses were used.

Our findings also have implications for future research. First, they suggest that more surveys should directly compare firm - and industry- level views of innovation. This will allow them to answer many important questions, such as whether firms that adopt first gain the most benefit, or whether those that wait until the idea is more mature do better.

Another area that should be explored in future research is how the deepening of firm capabilities in an area changes its innovation sourcing. Our research suggests that we would expect firms to move from external to internal innovation sourcing as they build industry-leading capabilities. That said, our data is entirely cross-sectional. This makes causal claims hard to make. Future research should look to panel data with plausible exogenous shocks to establish the causality of this and other findings in our paper.

7. Conclusion

In recent years, there has been an explosion of literature on the external sourcing of innovation, particularly under the auspices of open innovation. Collectively, our results provide a view of what West et al. [13] described as the "when" and "how often" of innovation; providing (to the best of our knowledge) the first detailed, representative data of the internal and external innovation done by firms across three continents.

Using a new, representative survey of firms in seven industries in eight countries, we show that there has been pervasive recent adoption of external innovation sources such as universities, third-party experts, startups, and crowd. Despite this, internal sources remain the most important innovation sources for firms in three ways. They are most important for overall firm innovation, for producing the most-successful innovation projects, and for delivering competitive advantage. Why, then, are firms turning to external innovation sources? Our results suggest that it is because digital technologies have become so important and because firms lack the digital capabilities to innovate competitively in these areas.

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A. Selected survey questions

Exhibit 1 – Usage question: There are many ways to source innovation. Please indicate the sources of innovation your company uses, and how long they have been using it.

(By "sourcing innovation" we mean sourcing ideas, prototypes, or working products)

	Innovation sources	Use this source?			For how long?			
		Yes	No	Do not know	0–2 years	3–5 years	>5 years	Do not know
1	Central R&D *R&D entity that is centrally managed by the company and works on a range of innovations*	○	○	○	○	○	○	○

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	Innovation sources	Use this source?			For how long?			
		Yes	No	Do not know	0–2 years	3–5 years	>5 years	Do not know
2	Special-purpose innovation lab *Innovation lab dedicated to the development of a specific technology (e.g., A.I.), sometimes collocated with innovation hot spots (e.g., Silicon Valley)*	○	○	○	○	○	○	○
3	Business-unit – dedicated staff *Dedicated innovation staff managed and collocated with a business unit*	○	○	○	○	○	○	○
4	Business-unit – staff with operational responsibilities *Business unit staff who work on innovation part time in addition to their operational responsibilities*	○	○	○	○	○	○	○
5	Universities/Researchers *Universities or independent researchers who are sponsored by the company or whose innovations are licensed or otherwise acquired*	○	○	○	○	○	○	○
6	Crowd *Innovations that originate from crowd-sourcing platforms, hackathons, innovation competitions, or third-party developers*	○	○	○	○	○	○	○
7	Suppliers/Extended enterprise *Firms who are in, or could be in, the value chain of the company, such as the suppliers or channels*	○	○	○	○	○	○	○
8	End-customers/Users *Customers who provide feedback to companies' innovation, participate in co-creation or proofs of concept*	○	○	○	○	○	○	○
9	3rd-party vendors/Innovators/Experts *Independent providers of products or services, including technology vendors, consulting/design firms, independent innovators, and opinion leaders; excluding start-ups*	○	○	○	○	○	○	○
10	Startups *Startups who are solicited through innovation scouting, incubators, accelerators, corporate venture capital, acquisition, etc.*	○	○	○	○	○	○	○
11	Competitors (including pre-competitive R&D) *Innovations developed by competitors that were open-source, acquired via licensing, brought in by former employees, reverse-engineered; or that arose from industry collaborations/associations*	○	○	○	○	○	○	○

	Innovation sources	Use this source?			For how long?			
		Yes	No	Do not know	0–2 years	3–5 years	>5 years	Do not know
12	Other, please specify: ____________	○	○	○	○	○	○	○

Exhibit 2: Project-level Capabilities Question.

Q: How well did your firm's resources and capabilities fit with this type of innovation?

Select one

A. A superior match, we could develop it better than others ☐

B. A strong match, we could develop it as well as few other leaders in the area ☐

C. A reasonable match, we could develop it as well as many others ☐

D. A poor match, we could develop it but less well than others ☐

E. A terrible match, it was difficult / nearly impossible for us to develop in-house ☐

Exhibit 3: Project-level Competitive Advantage Question.

Q: How enduring was the advantage that your company gained from this innovation?

Select one

A. It gave the company an advantage which persisted ☐

B. It gave the company an advantage, but then competitors in our industry matched or overtook us ☐

C. It gave the company an advantage, but then others outside our industry matched or overtook us ☐

D. It did not give the company an advantage because competitors in our industry out-innovated us ☐

E. It did not give the company an advantage because others outside of our industry out-innovated us ☐

F. It did not give the company an advantage for other reasons ☐

G. Unclear / too early to say ☐

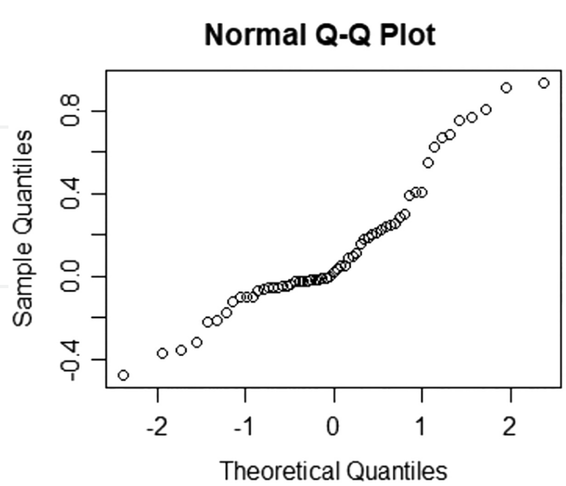
A version of this question, modified into the Past Conditional tense, was used when the innovation project was sourced externally (i.e., "Had you developed this innovation within your firm, how well would it have fit your firm's resources and capabilities?")

B. Positive relationship between external and internal innovation count

	Dependent variable:
	External source count
Internal source count	0.41
	(0.08)
	p = 0.000
Constant	2.29
	(0.19)
	p = 0.000
Observations	300
R^2	0.08
Adjusted R^2	0.07
Residual Std. Error	1.21 (df = 298)
F Statistic	25.22 (df = 1; 298)

Note:	First value is the estimate, second value is the standard error and the third value is the p-value.

C. Comparison of sample representativeness



D. Correlation matrix

Variable	N	Mean	SD	Digital	Most successful	Investment in digital	New revenue	Capability	Traditional external source	New external source	External source count	Internal source count
Digital	600	0.88	0.32	1								
Most successful	600	0.50	0.50	0.29	1							
Investment in digital	600	5.67	0.63	0.06	0	1						
New revenue	600	3.80	1.08	0.12	0	0.25	1					
Capability	600	0.48	0.50	0.11	0.33	0.05	0	1				
Traditional external source	600	0.19	0.39	−0.36	−0.23	0	−0.16	−0.18	1			
New external source	600	0.26	0.44	0.15	−0.28	0.02	0.11	−0.33	−0.28	1		
External source count	600	2.09	0.85	−0.06	0	−0.01	−0.08	0.14	−0.04	−0.23	1	
Internal source count	600	3.15	1.26	0.04	0	0.19	0.21	0.02	−0.08	0.17	0.28	1

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