

Quantum technology adoption in Japanese industry: prevalence, application interests, timelines, and barriers

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Additional Declarations:

The authors declare no competing interests.

This study involved a voluntary survey of companies. The purpose of the study was explained to respondents in advance, and informed consent to participate was implied by the submission of the completed questionnaire.

Highlights

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- Population-frame survey estimates quantum adoption among Japanese listed firms
- Only 7% of firms have begun concrete quantum-related activities
- Interest is widespread, but commercialization timelines remain highly uncertain
- Talent, decision support, and collaboration are more salient than financial support
- Adoption is concentrated among large firms with greater organizational capacity

Quantum technology adoption in Japanese industry: prevalence, application interests, timelines, and barriers

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Abstract

Public and private investment in quantum technologies has grown rapidly, yet evidence on the demand side—which firms are adopting, for what applications, on what timelines, and against which barriers—rests largely on industry surveys with undisclosed sampling frames. We report a descriptive, prevalence-style analysis of quantum technology adoption based on a census-approach survey of the complete population of listed firms in Japan. A postal questionnaire was mailed to all 3,890 firms listed on Japanese stock exchanges (December 2025–January 2026); 154 firms returned analyzable questionnaires (crude response rate 4.0%). Because the full sampling frame with firm attributes was available, response propensities were modeled (AUC = 0.671) and inverse-probability weighting (IPW) was used to adjust prevalence estimates for response bias; population totals were obtained with Horvitz–Thompson estimators. Proportions are reported with Wilson 95% confidence intervals. An estimated 59.9% (95% CI 50.5–68.6) of listed firms express at least interest in quantum technologies, but only 16.0% (10.3–24.0) have reached even the PoC-planning stage and 7.2% (3.7–13.6; $\approx$ 276 firms) have begun concrete activities. Interest concentrates in quantum machine learning (48.5% of engaged firms), chemistry/simulation (45.6%), and optimization (44.7%). Expected timelines are dominated by indecision: 64% of engaged firms answering could not name a target year for full commercial-

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ization, and only 3% expect it by 2030. The most prevalent barrier is the internal shortage of quantum talent (85.3% of engaged firms); the barriers associated with progression from interest to active engagement, however, are the lack of collaboration partners and the lack of a basis for decision-making. The most requested facilitator is expert demonstration of business potential (43.7%), far ahead of government financial support (9.7%). Interest in quantum technologies is widespread among Japanese listed firms, but concrete planning is rare and capability investments are concentrated in a small set of large firms. The findings highlight the importance of use-case demonstration, partnership brokering, and talent development alongside financial support.

Keywords: Quantum technology, Technology adoption, Emerging technology, Innovation diffusion, Organizational adoption, Japan

1. Introduction

Quantum technologies—computing, communication, and sensing—have moved from laboratory demonstrations to early commercial offerings, and a commercial ecosystem of hardware vendors, software firms, and cloud services has formed around them (1; 2). Governments have responded with national programs: the United States’ National Quantum Initiative (3), the European Quantum Flagship (4), the United Kingdom’s National Quantum Strategy (5), and, in Japan, the Quantum Technology Innovation Strategy and the Vision of a Quantum Future Society, which set explicit targets for domestic quantum technology users (6). Market analyses project rapid growth in quantum-related value creation over the coming decade (7).

The supply side of this emerging industry—hardware roadmaps, qubit counts, venture funding, the startup landscape—is closely tracked (1; 8). The demand side is far less visible. Systematic evidence on which firms are engaging with quantum technologies, for which applications, on what expected timelines, and against which barriers comes largely from consulting and industry surveys, for which sampling frames, response processes, and survey instruments are often only partially documented (9; 7). This matters beyond methodological hygiene. Research on the sociology of expectations has shown that early-stage technology fields are constituted and sustained by promissory claims, and that actors—vendors, analysts, and adopters alike—have incentives to amplify them (10; 11; 12). In such an environment, adoption statistics without denominators are not merely imprecise; they are system-

atically biased toward the engaged. Without a defined population frame, neither the prevalence of adoption nor its distribution across industries and firm sizes can be estimated.

Theory gives reasons to expect that the gap between expressed interest and actual adoption is large. The innovation-diffusion and technology–organization–environment traditions distinguish awareness and persuasion from decision and implementation (13; 14), absorptive-capacity research ties the ability to act on new knowledge to prior related capability (15), and studies of earlier enterprise technologies documented wide “assimilation gaps” between acquisition and deployment (16). For emerging digital technologies, the best available population-frame evidence comes from the United States Census Bureau’s Annual Business Survey, which found that adoption of artificial intelligence was confined to a few percent of firms and steeply graded by firm size (17; 18). Comparable population-frame evidence for quantum technologies does not, to our knowledge, exist in any country; for Japan, firm-level evidence on expectations toward emerging technologies is limited to surveys of selected panels (19).

This study addresses that gap with a design borrowed from descriptive epidemiology. Rather than sampling from an opaque panel, we mailed a questionnaire to the *complete population* of firms listed on Japanese stock exchanges ($N = 3,890$), giving the study a fully enumerated sampling frame with known firm attributes (industry, market segment, size, age, location) for respondents and non-respondents alike. Because response rates in organizational surveys are low and declining (20), and nonresponse bias cannot be assessed from respondent data alone (21), the frame is the study’s central methodological asset: it permits an explicit response-propensity model with inverse-probability weighting (22), and population-scale estimates of the number of firms at each stage of engagement.

This study aims to characterize the current state of quantum technology adoption among Japanese firms and the factors shaping the transition from awareness to organizational action.

The survey instrument also contained a psychometric readiness scale whose development and validation are reported in a companion paper (23); the present paper analyzes the survey sections not used there (application domains, milestone roadmaps, barriers, facilitators, and firm attributes) and addresses a different, population-descriptive question.

2. Methods

2.1. Design, sampling frame, and data collection

We conducted a cross-sectional postal survey between December 2025 and January 2026. The sampling frame comprised all 3,890 firms listed on Japanese stock exchanges, enumerated from the Kaisha Shikiho (Japan Company Handbook), 2025 Fall edition (24), which also provided firm attributes (listing market, industry classification, consolidated employees, paid-in capital, founding year, and headquarters address). Questionnaires were addressed to each firm’s corporate planning or technology function; one response per firm was requested. A total of 155 questionnaires were returned; one contained respondent information only, with no substantive answers, and was excluded as a blank return, leaving 154 responding firms (crude response rate 4.0%), of which 153 provided their adoption stage. A companion analysis suggests that the practically relevant denominator of firms for which the topic is salient is substantially smaller, placing the effective response rate at roughly 8–11% (23).

2.2. Questionnaire and measures

The questionnaire covered: respondent characteristics (position; involvement with quantum technology); the firm’s adoption stage on a six-point ordinal item (no interest; interest but no examination; PoC under consideration/planned; PoC ongoing; pilot/limited operation; full deployment); approximate annual quantum-related budget (six categories) and dedicated quantum personnel (five categories); interest in 17 application domains (multiple selection); expected timing for four adoption milestones (information gathering/preparation, proof of concept, limited commercialization, full commercialization; response options: by 2030, by 2035, by 2040, undecided, no plans); nine barrier items rated 1 (not a barrier) to 5 (very much a barrier); and a single-choice facilitator item. By questionnaire routing, the budget, personnel, domain, roadmap, barrier, and facilitator sections were answered only by firms reporting at least interest; all denominators below state the answering population explicitly.

For analysis, firms were grouped as *engaged* (interest or beyond), *active* (PoC planned or beyond), and *advanced* (PoC ongoing or beyond), and into three stage groups (no interest; interest only; active). Industries were aggregated into six groups (IT/services, electronics/precision, chemicals/pharmaceuticals, other manufacturing, finance, other), and firm size into

four consolidated-employee classes (<300 ; 300–999; 1,000–4,999; $\geq 5,000$). Headquarters prefecture was parsed from the registered address and grouped into seven regions.

2.3. Statistical analysis

The study is descriptive; estimation, not hypothesis testing, is the primary goal. Proportions are reported with Wilson 95% confidence intervals (25). To address response bias, a logistic response-propensity model was fitted on the full frame (predictors: market segment, industry group, log-transformed employees, capital, and firm age; $AUC = 0.671$) (22). Respondent weights were the inverse predicted propensities, trimmed at the 99th percentile and normalized (Kish effective sample size 109.8 vs. nominal $n = 154$) (26); weighted proportions are reported with Wilson intervals computed on the effective sample size. Population totals use untrimmed Horvitz–Thompson weights (27). Barrier ratings were compared across stage groups with Kruskal–Wallis tests restricted to groups with $n \geq 5$ (in practice, interest-only vs. active firms, where the two-group case is equivalent to the Mann–Whitney test), with Holm correction across the nine barrier items (28) and ε^2 effect sizes. Analyses used Python 3.11; the full analysis code is available as supplementary material. The report follows STROBE guidance for cross-sectional studies (29).

3. Results

3.1. Sample characteristics and representativeness

Table 1 compares responding firms with the full frame. Respondents were larger (median consolidated employees 1,679 [IQR 648–6,784] vs. 872 [309–2,719] in the frame), better capitalized (median paid-in capital JPY 6,750M vs. 2,310M), older (median 73 vs. 53 years), and more often listed on the TSE Prime market (55.8% vs. 41.4%). Manufacturing and electronics/precision firms were over-represented and the residual “other” category under-represented. All prevalence estimates are therefore reported both unweighted and IPW-adjusted; because larger firms both respond more and engage more, unweighted figures overstate population engagement.

Respondents were predominantly senior: 30.5% executives, 28.6% division heads, 24.7% managers. Their personal involvement with quantum technology was limited—41.6% reported no involvement and 40.3% information gathering only—which we return to as a limitation.

Table 1: Responding firms versus the full sampling frame.

	Respondents ($n = 154$)	Frame ($N = 3,890$)
<i>Industry group, %</i>		
Other	32.5	44.8
Manufacturing	20.8	17.6
Electronics/precision	15.6	10.2
IT/services	14.3	15.1
Chemicals/pharma	13.0	7.9
Finance	3.9	4.5
<i>Market segment, %</i>		
TSE Prime	55.8	41.4
TSE Standard	29.9	40.3
TSE Growth	10.4	15.6
Other	3.9	2.8
<i>Firm attributes, median [IQR]</i>		
Employees (consolidated)	1,679 [648–6,784]	872 [309–2,719]
Paid-in capital (JPY M)	6,750 [2,183–22,976]	2,310 [700–8,640]
Firm age (years)	73 [39–86]	53 [24–77]

3.2. Prevalence of adoption

Among the 153 firms reporting their stage (Table 2), 32.7% expressed no interest and 47.7% interest without any concrete examination. Only 19.6% (95% CI 14.1–26.6) had reached at least PoC planning (*active*), and 11.1% (7.1–17.1) had begun concrete activities (*advanced*); a single firm reported full deployment. IPW adjustment shifts all engagement estimates downward: engaged 59.9% (50.5–68.6), active 16.0% (10.3–24.0), advanced 7.2% (3.7–13.6). Horvitz–Thompson totals put the corresponding population sizes at roughly 2,340 engaged, 620 active, and 280 advanced firms among Japan’s 3,890 listed companies.

Engagement showed a strong size gradient: among firms with $\geq 5,000$ consolidated employees, 97.1% (85.5–99.5) were engaged and 40.0% (25.6–56.4) active, against 8.9–16.7% active in the smaller classes ($\chi^2(3) = 13.30$, $p = .004$). TSE Prime firms were more often active than Standard firms (24.4% vs. 6.7%). Tokyo-headquartered respondents (52.3% of the sample) showed the highest activity (25.3%), though regional differences were not statistically distinguishable at this sample size. Industry-group differences in

Table 2: Adoption-stage distribution among firms reporting a stage ($n = 153$).

Stage	n	Unweighted % [95% CI]	IPW % [95% CI]
No interest	50	32.7 [25.8–40.5]	40.1 [31.4–49.5]
Interest only	73	47.7 [40.0–55.6]	43.9 [34.9–53.2]
PoC planned	13	8.5 [5.0–14.0]	8.8 [4.8–15.6]
PoC ongoing	13	8.5 [5.0–14.0]	5.9 [2.8–12.0]
Pilot/limited	3	2.0 [0.7–5.6]	1.1 [0.2–5.3]
Full deployment	1	0.7 [0.1–3.6]	0.1 [0.0–3.7]

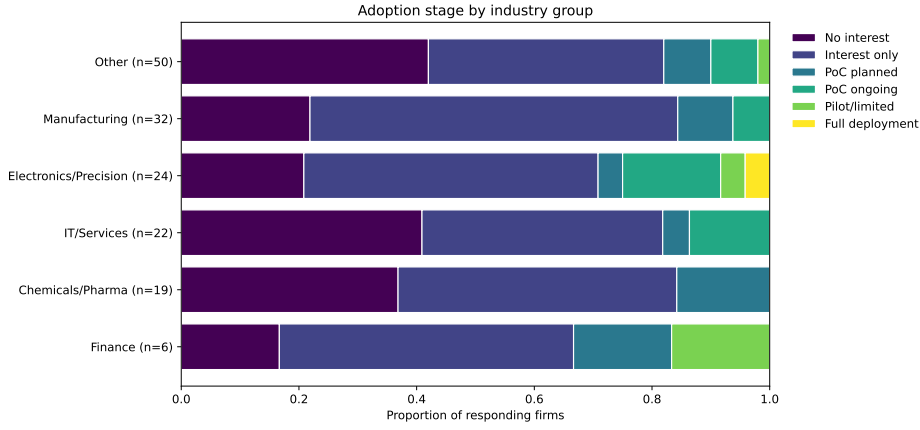


Figure 1: Adoption stage by industry group (proportions within group; $n = 153$).

activity were likewise small relative to their uncertainty (Fig. 1).

3.3. Application-domain interests

Among engaged firms ($n = 103$), interest concentrated in near-term computational applications: quantum machine learning (48.5% [39.1–58.1]), chemistry/simulation (45.6% [36.3–55.2]), optimization (44.7% [35.4–54.3]), CAE (35.9%), and supply chain (32.0%) (Fig. 2). Hardware-side domains attracted far less interest (quantum computing hardware 10.7%; control/readout 9.7%; chip fabrication/packaging 1.9%), consistent with a user—rather than supplier—population. Quantum sensing (22.3%) and quantum communication/networks (21.4%) formed a middle tier; quantum-safe security was named by only 10.7%, a notably low figure given finalized post-quantum cryptography standards (30) and the migration urgency argued in the secu-

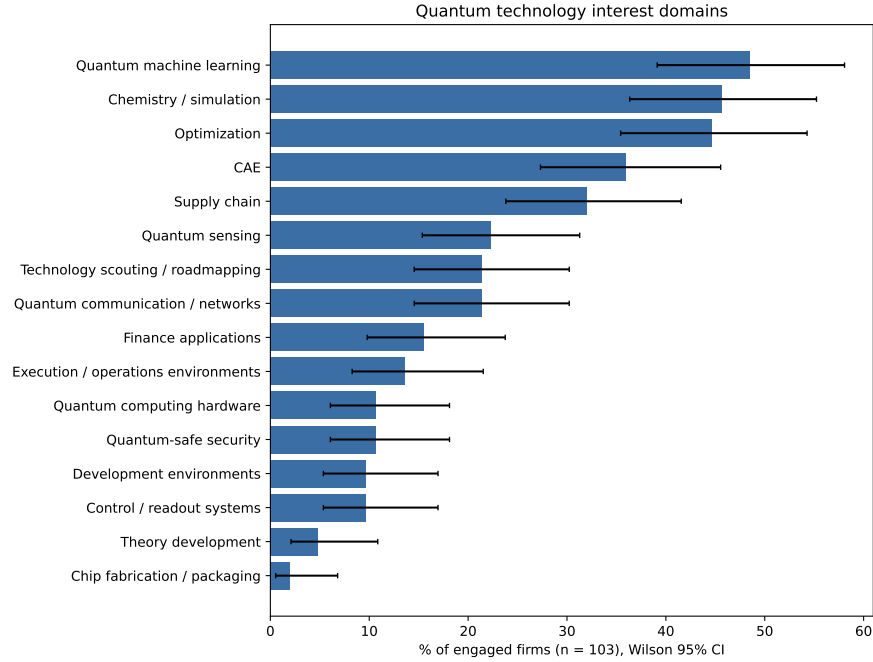


Figure 2: Interest domains among engaged firms ($n = 103$); Wilson 95% CIs.

160 rity literature (31). Breadth of interest rose with stage: active firms selected
 161 a mean of 4.77 domains versus 3.03 among interest-only firms. Domain co-
 162 occurrence was highest within the computational cluster (e.g., quantum ma-
 163 chine learning with CAE, Jaccard = .49, and with chemistry/simulation, .46;
 164 Fig. 3).

165 3.4. Expected timelines

166 Milestone expectations (Fig. 4; $n = 95$ –97 engaged firms answering per
 167 item) show a steep gradient from preparation to commercialization. A major-
 168 ity (57%) expect to complete information gathering and preparation by 2030,
 169 and 29% expect a completed proof of concept by 2030 (44% by 2035). For
 170 commercialization the picture inverts: only 10% of answering firms expect
 171 limited commercialization by 2030 (33% by 2040), and for full commercializa-
 172 tion 3% answer “by 2030” and 25% “by 2040”, while 64% are undecided and
 173 a further 11% have no plans. Indecision, not pessimism, dominates: firms
 174 neither commit to a year nor rule commercialization out.

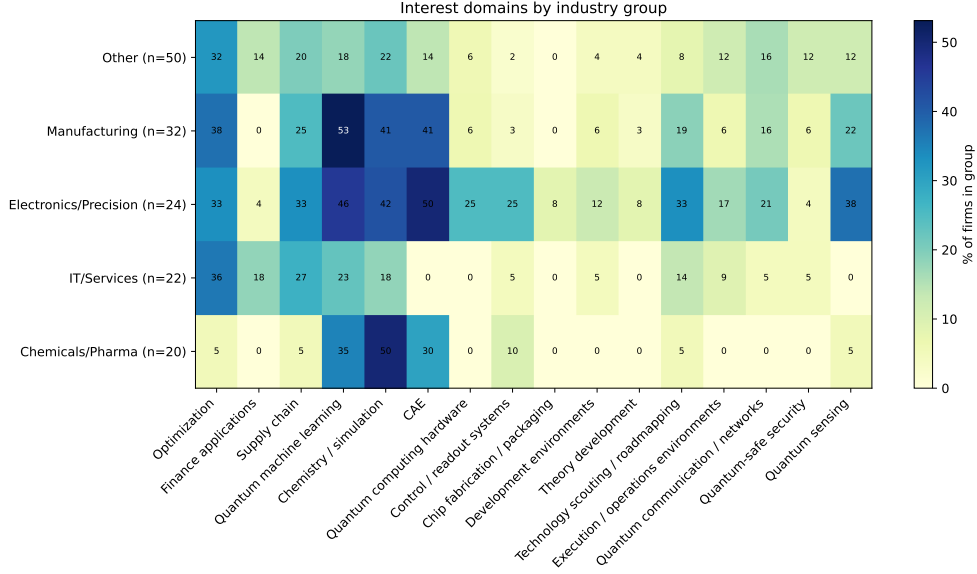


Figure 3: Interest domains by industry group (% of firms within group).

3.5. Barriers and facilitators

Barrier ratings (engaged firms; $n = 102\text{--}103$) are summarized in Table 3 and Fig. 5. The internal shortage of quantum talent was the most prevalent barrier (85.3% [77.1–90.9] rating it 4–5; mean 4.26), followed by an insufficient basis for decision-making (76.7%) and unclear use cases (69.6%). Information-security requirements ranked last (27.2%).

Comparing stage groups, talent shortage was high in *both* interest-only (mean 4.39) and active (3.97) firms (Holm-adjusted $p = .269$): it is a universal barrier that engagement does not remove. By contrast, two barriers were significantly lower among active firms: the lack of collaboration partners (3.67 vs. 2.63; $H = 21.48$, Holm $p < .0001$, $\varepsilon^2 = .205$) and the insufficient basis for decisions (4.19 vs. 3.37; $H = 13.92$, Holm $p = .0015$, $\varepsilon^2 = .129$). The barriers that recede as firms move from interest to action are thus informational and relational, not technical or financial.

The facilitator item points the same way: among the 103 engaged firms answering, the most chosen facilitator was *expert demonstration of business potential* (43.7%), followed by support for internal talent development (20.4%) and technical/development-environment support (18.4%). Government financial support was chosen by 9.7% and regulatory/legal development

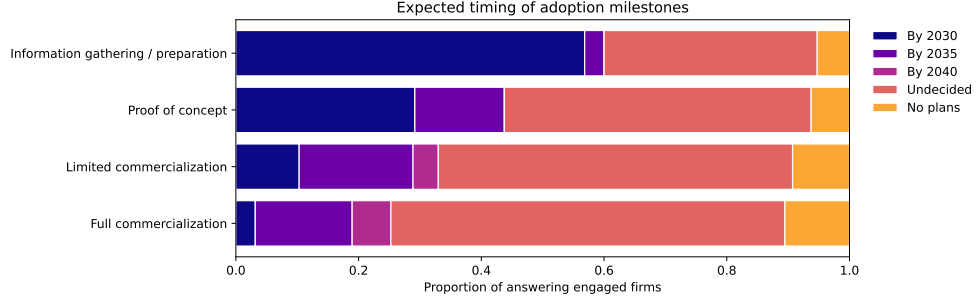


Figure 4: Expected timing of adoption milestones among engaged firms answering each item ($n = 95\text{--}97$).

Table 3: Barrier ratings among engaged firms and comparison across stage groups. Means on a 1–5 scale; group comparison by Kruskal–Wallis (interest-only vs. active firms), Holm-corrected across the nine items.

Barrier	n	Mean (SD)	% rating 4–5 95% CI	Interest only	Active	Holm p
Internal quantum-talent shortage	102	4.26 (0.81)	85.3 [77.1–90.9]	4.39	3.97	.269
Insufficient basis for decisions	103	3.95 (0.93)	76.7 [67.7–83.8]	4.19	3.37	.002
Implementation horizon too distant	103	3.87 (0.93)	64.1 [54.5–72.7]	3.97	3.63	.348
Cost too high	103	3.82 (0.92)	62.1 [52.5–70.9]	3.96	3.47	.132
Unclear use cases	102	3.80 (1.00)	69.6 [60.1–77.7]	3.96	3.41	.060
Unclear return on investment	103	3.67 (0.99)	60.2 [50.5–69.1]	3.64	3.73	.982
Lack of standards/specifications	103	3.67 (0.83)	53.4 [43.8–62.7]	3.79	3.37	.132
No collaboration partners	103	3.37 (0.99)	42.7 [33.6–52.4]	3.67	2.63	<.001
Information-security requirements	103	3.04 (0.93)	27.2 [19.5–36.5]	3.10	2.87	.634

194 by only 1.9%.

195 3.6. Resource commitments and population-scale estimates

196 Even among engaged firms, resource commitments were thin: 63.1% re-
 197 ported no quantum budget and 74.5% no dedicated personnel. Commitments
 198 separated sharply by stage: 87.5% of interest-only firms reported no budget
 199 versus 3.3% of active firms, and 91.5% of interest-only firms reported no
 200 dedicated personnel versus 33.3% of active firms. Treating no-interest firms
 201 as having no budget, an estimated 25.0% (18.8–32.4) of stage-reporting re-
 202 spondents had any quantum budget and 17.2% (12.0–24.0) any dedicated
 203 staff. Horvitz–Thompson estimates translate the survey to population scale
 204 (Table 4): of Japan’s 3,890 listed firms, roughly 740 are estimated to hold

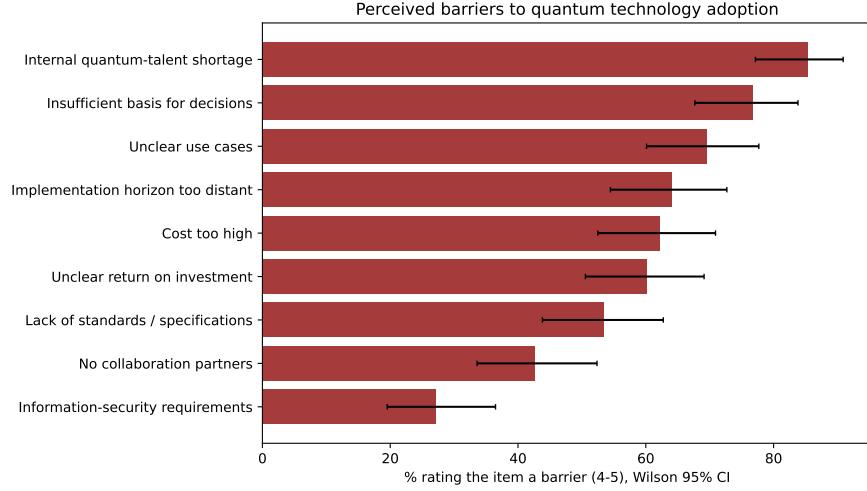


Figure 5: Perceived barriers to adoption among engaged firms; % rating the item 4–5 with Wilson 95% CIs.

Table 4: Population-scale Horvitz–Thompson estimates (untrimmed inverse-propensity weights; firms with missing outcomes excluded). Estimates are assumption-laden context, not precise population parameters.

Outcome	Estimated firms	Estimated % of frame
Engaged (interest or beyond)	2,338	60.1
Active (PoC planned or beyond)	615	15.8
Advanced (PoC ongoing or beyond)	276	7.1
Any quantum budget	742	19.1
Any dedicated quantum staff	534	13.7

any quantum budget and roughly 530 any dedicated quantum personnel.

4. Discussion

4.1. Principal findings

Three findings characterize the transition from technological expectation to organizational action. First, broad interest has not yet translated into widespread planning or implementation. Six in ten listed firms (IPW-adjusted) express interest in quantum technologies, yet fewer than one in six has even planned a proof of concept, and the modal answer for every commercialization milestone is “undecided.” These results suggest that the demand

side of the quantum economy remains characterized more by broad attention and exploratory interest than by widespread organizational commitment.

Second, informational, relational, and human-capital constraints appear more salient than financial support alone in distinguishing passive interest from active engagement. The talent shortage is the most prevalent barrier and remains high even among active firms; meanwhile the barriers that differentiate active from interest-only firms—lack of collaboration partners and lack of a decision basis—are informational and relational. Consistently, firms ask first for expert demonstration of business potential (43.7%) and far less for government funding (9.7%) or regulation (1.9%). These findings suggest that financial support may be less immediately salient than decision support, access to expertise, and opportunities for collaboration for firms that have not yet moved beyond interest.

Third, concrete engagement remains concentrated among larger firms with greater organizational capacity. Nearly every very large firm is engaged and 40% of them are active, while activity drops to single digits in the 1,000–4,999 employee class; budgets and dedicated staff are confined to a thin sliver of firms (≈ 530 –740 of 3,890). The pattern is what absorptive-capacity theory predicts—firms with prior related capability are the ones able to act on an emerging knowledge base (15)—and it mirrors the size gradient documented for AI adoption (17). The current demand base is therefore highly concentrated among large firms, consistent with the view that organizational scale and prior capability shape firms’ ability to act on emerging technological opportunities.

4.2. Comparison with prior evidence

Industry-focused reports generally portray a more advanced stage of quantum engagement and substantially greater investment activity than observed in our broader firm sample (9; 7). The discrepancy is consistent with their reliance on self-selected panels of technology-engaged firms: in an expectation-rich field (10), the engaged are precisely the firms most likely to answer. Our population-frame design and IPW correction suggest such figures should be read as upper bounds for the broad corporate population.

The structure of our findings closely parallels the population-frame evidence on artificial intelligence. The US Annual Business Survey found AI adoption in the low single digits of firms, steeply graded by firm size and concentrated in young, large, urban firms (17; 18); we find the same configuration for quantum technology at an earlier point in the diffusion curve

251 (7% advanced adoption, a near-deterministic size gradient, and Tokyo con-
252 centration). The gap between 60% interest and 16% activity is, in Fichman
253 and Kemerer’s terms, an assimilation gap (16)—and a wide one. The dom-
254 inance of “undecided” timeline answers adds a quantitative footnote to the
255 sociology of expectations: most engaged firms participate in the field’s collec-
256 tive expectations without committing to any schedule of their own (10; 11).
257 Expectation, in this population, is cheap and nearly universal; planning is
258 expensive and rare.

259 One specific null finding deserves emphasis. Quantum-safe security at-
260 tracted the interest of only 10.7% of engaged firms, although post-quantum
261 cryptography standards were finalized in 2024 (30) and migration timelines
262 are widely argued to be urgent for data with long confidentiality horizons
263 (31). Whatever is driving corporate quantum interest in Japan, it does not
264 appear to be the defensive use case that much of the policy literature em-
265 phasizes; closing this awareness gap is a concrete, near-term policy target.

266 *4.3. Implications for policy and practice*

267 The findings suggest three priorities for demand-side policy and practice.
268 First, credible use-case demonstration and decision support may be more
269 effective than financial incentives alone in helping hesitant firms evaluate
270 whether quantum technologies are relevant to their business (2). Expert-
271 led demonstrations, sector-specific reference cases, and structured opportu-
272 nities to assess business applicability may therefore play an important role
273 in moving firms from general interest toward concrete planning. Second,
274 interorganizational collaboration and brokerage appear to be important en-
275 abling conditions. The marked difference in perceived lack of collaboration
276 partners between interest-only and active firms suggests that access to ex-
277 ternal partners may help organizations translate technological interest into
278 action. Policies that connect firms with technology vendors, universities, and
279 other experienced organizations may therefore reduce relational barriers to
280 adoption. Third, human-capital development remains a broad structural re-
281 quirement. The high prevalence of perceived talent shortages across stages
282 indicates that engagement alone does not resolve capability constraints. Sus-
283 tained investment in internal skills, cross-disciplinary expertise, and access
284 to external technical knowledge is therefore likely to remain necessary as the
285 technology matures.

286 4.4. *Strengths and limitations*

287 The study’s strengths are its fully enumerated population frame, explicit
288 response-bias modeling, and transparent denominators. Several limitations
289 qualify the results. The crude response rate was 4.0%—low in absolute terms,
290 though organizational surveys without incentives or follow-up increasingly
291 see single-digit rates (20). IPW adjusts for observable attributes (and shifts
292 estimates materially downward), but nonresponse bias is a property of the
293 covariance between response propensity and the outcome, not of the response
294 rate alone (21); selection on unobservables—most plausibly, topic salience—
295 cannot be ruled out, and engagement estimates should be read as upper
296 bounds even after weighting. The analytic sample is modest ($n = 153$ with
297 stage data), so subgroup intervals are wide and regional and industry con-
298 trasts are imprecise. Eighty-one percent of informants were not directly in-
299 volved with quantum technology; answers reflect the corporate vantage point
300 of planning functions rather than technical insiders (though for prevalence
301 of *organizational* stance this is arguably the relevant informant). The design
302 is cross-sectional, so the stage gradients in barriers and resources describe
303 differences, not transitions.

304 5. Conclusion

305 In the first population-frame survey of quantum technology adoption
306 among Japanese listed firms, we find widespread interest, rare and concen-
307 trated activity, dominant timeline indecision, a universal talent barrier, and
308 a stronger expressed need for demonstration, partnerships, and talent devel-
309 opment than for financial support. The quantum economy’s demand side can
310 now be described with denominators; the next step is to track these firms
311 longitudinally as expectations meet capability.

312 Declarations

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315 **Competing interests:** The authors declare that they have no competing
316 interests.

317 **Data availability:** The analysis code is available as supplementary mate-
318 rial. Firm-level survey data cannot be shared publicly because responses are

identifiable at the firm level; aggregated data are available from the corresponding author on reasonable request.

Authors' contributions: Kazuya Taira contributed to the conception and design of the study, data analysis, interpretation of the results, and preparation of the original manuscript. Yusuke Kodaira and Emi Kamada contributed to the study design and data collection. Osamu Kamatani, Yusuke Kobayashi, and Miyuki Imada contributed to the interpretation of the findings and critical revision of the manuscript. All authors reviewed and approved the final manuscript.

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