A survey on information sources used by academic researchers to evaluate scientific instruments

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Most scientific research is fueled by research equipment (instruments); typically hardware purchased to suit a particular research question. Examples range from 17th century microscopes to modern particle colliders and high-throughput sequencers. Here, we studied the information sources used by academic researchers to assess scientific instruments, and reveal evidence of a worrying confluence of incentives similar to those that drove the biopharmaceutical industry to adopt controversial practices such as ghostwriting and hidden sponsorship. Our findings suggest there are little understood incentives against disclosure in the peer-reviewed literature on scientific instruments; constituting an underappreciated threat to scientific standards of trustworthiness and transparency. We believe that a public debate and subsequent editorial policy action are urgently required.

There is a growing concern about the reliability[1,2], reproducibility[3,4], and transparency of science[5-7] and, in particular, how commercial interests might distort scientific integrity[8-10]. Studies on the biopharmaceutical industry have shown that for-profit company ('firm') sponsored research is more likely to reach conclusions favorable to the funding sponsor[11], but also that such studies are considered less reliable by academic researchers[10]. In comparison, scientific instruments have profound effects on the scientific process[12-14] and account for billions of dollars in research expenditure[13,15], yet we know little about how the activities of firms in this industry influence the scientific process. Recent qualitative research found that firms producing scientific instruments viewed mentions of their instruments in peer-reviewed studies as valuable marketing material[16]. However, firms considered the marketing value of this endorsement substantially diminished if their employees were listed as co-authors. Even when employees made significant contributions to a paper in question, some of these firms had a policy of not being listed as co-authors. Here, we report on a study conducted to investigate whether these views reflect *bona fide* concerns.

We undertook two surveys to explore whether academic researchers devalue the information found in research co-authored by firm employees. The first survey assessed what information sources the researchers rely on when evaluating scientific instruments (survey 1: 'importance'). The second survey measured whether co-authorship by employees of scientific instrument firms alters how reliable information in the (Materials and) Methods section of a given peer-reviewed manuscript is perceived (survey 2:

'reliability'). See Supplementary Note 1 for further details on the surveys, respondents, and descriptive results.

Survey 1: the importance of information on scientific instruments

With a response rate of 19%, comparable to similar studies in the social sciences (see Supplementary Note 1), we received 994 responses from U.S. and E.U. based researchers of varying academic ranks, research budgets, and academic disciplines. Our results show that input from colleagues was the main source of information (see Table S1). Peer-reviewed publications also constituted an important source, more so than scientific conferences and salespersons. We further evaluated how respondents perceived various information sources referring to scientific instruments using a 5-point Likert scale. Publications co-authored by employees from the firm producing the instrument were considered a significantly less important source than publications without firm affiliations (Table S2; $Z = 18.26$, $P < 0.0001$, Mann-Whitney *U*-test).

Survey 2: the reliability of information on scientific instruments

A second survey of the same cohort (247 respondents, response rate of 30%; see Supplementary Note 1 for further information) provided further insights on the perception of peer-reviewed publications with co-authors from scientific instrument firms. It revealed that respondents considered information in publications co-authored by firm employees less reliable (Figure 1a). In contrast to publications without firm affiliations, which ~80% deemed reliable, only 36% considered papers co-authored by someone from the firm producing an instrument used in said manuscripts reliable. This pattern also applied more broadly to papers co-authored by anyone from industry, which 55% deemed reliable (Figure 1a**)**.

These data on importance and reliability were remarkably consistent across a range of potential confounding variables. These included scientific fields (Figure 1b), as well as geographic locations, degrees of entrepreneurial activity, and source of funding (see Supplementary Note 1). Interestingly, proxies of academic success (variables such as size of research budget, and the impact factor of the best journal the respondent has published in) were associated with a lower rating of the importance and reliability of publications co-authored by firm employees (see Supplementary Note 1).

Conclusions

To our knowledge, this study provides the first systematic evidence on how academic researchers evaluate information in publications co-authored by scientific instrument firm employees. The study reveals that academics discount the importance and reliability of peer-reviewed manuscripts co-authored with scientific instrument firm employees – even when the firm's instrument was not mentioned by the manuscript in question. The published work, thus, has reduced scientific credibility.

Descriptions of commercial scientific instruments in peer-reviewed publications have been abundant for at least half a century[17], and researchers rely on this information source when deciding to use a given instrument[16] (see also Table S1). However, academic researchers face a dilemma when interpreting this information source. On one hand, commercial firms have superior knowledge of their own products and are, consequently, in position to optimize the usage of their instrument[18-20]. On the other hand, firms can have commercial incentives to misrepresent the functionalities and qualities of their instrument if it can lead to sales. Prior to this study anecdotal evidence revealed that some instrument firms prefer to hide their contributions to a scientific article[16,21]. Our data provide evidence for why: the omission of firm employees as co-authors enhances the perceived reliability of a peer-reviewed manuscript and, thus, likely sales potential of any instruments mentioned within. These dynamics are also reflected by a commercial producer of transgenic mice offering researchers monetary rewards for citations in scientific articles[22], and scientific instruments firms promising significant discounts on instrument reagents in exchange for ‘excessive usage’ of an instrument name in scientific articles (C.B. and I.S., personal observations). This mirrors incentives for controversial practices adopted by the biopharmaceutical industry, such as ghostwriting and hidden sponsorship[23,24]. Our study provides the first systematic evidence to explain the nature of the incentives driving such behavior in the scientific instruments industry, and why, if left unchecked, it is likely to continue.

Currently the editorial impetus of peer-reviewed journals, including specialist journals such as *Nature Methods*, is to disclose any financial interests[25]. Nevertheless, there appears to be a general lack of guidelines – including by top-tier science journals (see Table S15 for a comparison) – on how and when researchers should disclose the involvement of scientific instrument firms in the production of knowledge. Such non-disclosure can leave readers unable to judge potential conflicts of interest (e.g. discounts provided on instruments) and make replication more difficult (e.g. technical assistance from a scientific instrument firm was critical for data generation, but not disclosed). Editorial guidelines have helped tackle the non-disclosure challenge in the biopharmaceutical industry[26]. As the scientific instrument industry is increasingly dominated by large corporations[27], and expensive instruments are now commonplace in research institutes and individual laboratories[13,28], we believe similar considerations must be applied. Without change, the existing state of affairs will continue to undermine the reliability, reproducibility, and transparency of science.

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Code availability

The surveys, survey data set, and associated SPSS code are available at https://github.com/sciseim/ScientificInstruments_MS.

Author contributions

C.B and C.K. designed the research; C.B. and C.K. performed the analysis. C.B., S.M., and I.S. interpreted the results; C.B., S.M., C.K., and I.S. wrote the paper.

Competing financial interests

The authors declare no competing financial interests.

Figures

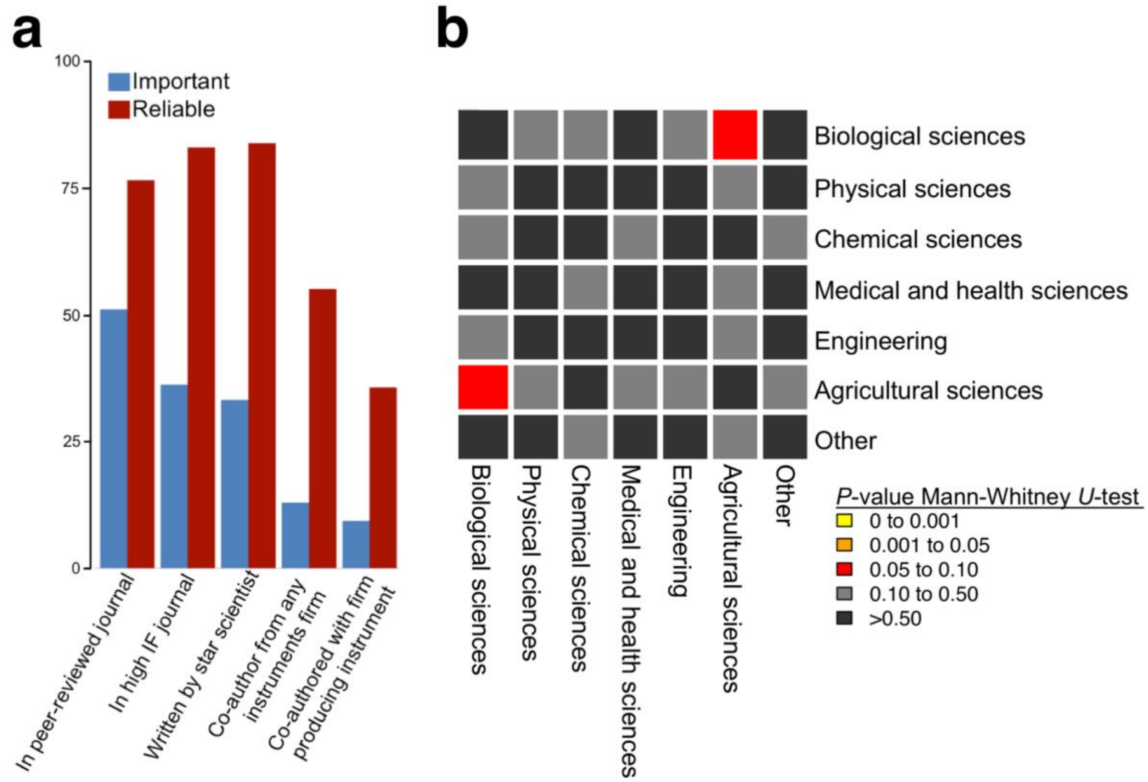

Figure 1. The reliability and importance of information sources on scientific instruments. (a) Illustration of how important and reliable respondents, indicated in per cent on the y-axis, consider information on scientific instruments to be in a peer-reviewed publications in general, and subcategories. **(b)** Heat map showing Mann–Whitney *U*-test statistics for pair-wise comparisons on the importance of firm-authored publication in different scientific fields. $P \leq 0.05$ was considered significant. The sample number per group was ≥ 38. Please see Table S5 for details.

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Supplementary Information

A survey on information sources used by academic researchers to evaluate scientific instruments

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Supplementary Tables

Supplementary Table 1. Information sources academics rely on when they are about to purchase a scientific instrument.

Information Source	All respondents (%)
Inputs from others	73.8
Colleagues one collaborates with	81.5
Conferences, workshops and fairs	26.2
Salespersons from the firm producing and selling the instrument	21.0
Brochure and website of the firm producing and selling the instrument	45.6
Brand of the firm producing and selling the instrument	20.9
Having seen the product referenced in a peer-reviewed paper	28.6
Own previous usage	62.6

Supplementary Table 2. Perceived importance of firm authored vs. other strata of peer-reviewed publications as sources of information on scientific instruments in peer-reviewed publications.

Respondents assessed how important various types of publications are as sources of information on scientific instruments on a Likert scale from 1 (very important) to 5 (not important). 'No firm authors' refers to a peer-reviewed publication with no firm authors, and not associated with a star scientist nor a high-impact publication. A Wilcoxon signed-rank test assessed if the responses in the respective categories were statistically significantly different ($P \leq 0.05$).

	Wilcoxon Signed Ranks Test	
	***Z*-statistic**	**Asymptotic significance, two-tailed**
No firm authors vs. firm-authored	-18.258	< 0.0001
Star scientist vs. firm-authored	-15.202	< 0.0001
High-impact vs. firm-authored	-15.478	< 0.0001

Supplementary Table 3. Excerpts of main characteristics of survey 1 and survey 2 respondents.

At the time of the survey, 1 EUR (€) equaled 1.25 USD ($). Numbers in parentheses show the percentage of respondents. Due to incomplete answers to questions by some respondents, rows do not necessarily sum up to the total 994 and 247 respondents for the first and the second survey, respectively.

Scientific field	Biological Sciences	Physical Sciences	Chemical Sciences	Medical Sciences	Engineering
Survey 1	484 **(48.84)**	71 **(7.16)**	119 **(12.01)**	129 **(13.02)**	56 **(5.65)**
Survey 2	122 **(49.59)**	16 **(6.50)**	32 **(13.01)**	39 **(15.85)**	13 **(5.28)**
Employment status	Professor	Associate professor	Assistant professor	Post-doc	PhD student
Survey 1	33 **(13.52)**	48 **(19.67)**	29 **(11.89)**	43 **(17.62)**	292 **(29.58)**
Survey 2	33 **(13.52)**	48 **(19.67)**	29 **(11.89)**	43 **(17.62)**	40 **(16.39)**
Research budget size	< 80.000 €	80.000 € to 400.000 €	400.000 € to 800.000 €	800.000 € to 4.000,000 €	> 4.000.000 €
Survey 1	493 (**58.21**)	270 (**31.88**)	58 (**6.85**)	21 (**2.48**)	5 (**0.59**)
Survey 2	133 (**55.65**)	84 (**35.15**)	15 (**6.28**)	6 (**2.51**)	1 (**0.42**)
Government budget	< 25%	26-50%	51-75%	> 75%	
Survey 1	206 **(24.18)**	141 **(16.55)**	158 **(18.54)**	346 **(40.73)**	
Survey 2	53 **(21.99)**	40 **(16.60)**	(48 **(19.92)**	100 **(41.49)**	

Supplementary Table 4. Perceived importance of firm-authored publications as sources of information on scientific instruments when respondents were stratified by entrepreneurial activity, geographical location, per cent governmental funding, and number of patent applications.

Respondents assessed how important information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very important) to 5 (not important). Being entrepreneurial active covers having created a firm, licensed technology, or having presented a business plan to potential investors. A Mann-Whitney *U*-test assessed if the differences were statistically significant ($P \leq 0.05$).

	Mean value of importance of firm-authored article (1=very important; 5=not important)	**Mann-Whitney *U*-test**	
		***Z*-statistic**	**Asymptotic significance, two-tailed**
Some entrepreneurial activity No entrepreneurial activity	3.90 3.93	-0.299	0.765
US respondents EU respondents	3.78 3.94	-1.379	0.168
> 75% of funds from government ≤ 75% of funds from government	3.93 3.89	-0.232	0.816
Submitted ≥ 1 patent application Submitted 0 patent application	4.02 3.90	-1.071	0.284

Supplementary Table 5. Perceived importance of firm-authored publications as sources of information on scientific instruments when respondents were stratified by scientific fields.

Respondents assessed how important information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very important) to 5 (not important). A Mann-Whitney *U*-test assessed if the differences were statistically significant ($P \leq 0.05$).

Mann-Whitney *U*-test (*P*-values)							**# of respondents**
	2	3	4	5	6	7	
1	0.473	0.101	0.580	0.407	0.088	0.715	335
2		0.673	0.806	0.996	0.489	0.802	47
3			0.383	0.700	0.664	0.439	91
4				0.704	0.248	0.946	94
5					0.430	0.731	40
6						0.302	38
7							51

1: Biological Sciences; 2: Physical Sciences; 3: Chemical Sciences; 4: Medical and Health Sciences; 5: Engineering; 6: Agricultural Sciences; 7: Other

Supplementary Table 6. Perceived importance of firm-authored publications as sources of information on scientific instruments when respondents were stratified by age, size of research budget, and impact factor.

Respondents assessed how important information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very important) to 5 (not important). The impact factor refers to the Thomson Reuter Journal Citation Reports when the survey was conducted (June 2013). A Mann-Whitney *U*-test was carried out to assess differences across the split samples. *P*-values ≤ 0.05 were considered significant.

	Mean value of importance of firm-authored article (1=very important; 5=not important)	Mann-Whitney *U*-test	
		***Z*-statistic**	**Asymptotic significance, two-tailed**
Born 1976 or before Born after 1976	4.15 3.69	-6.106	< 0.0001
Research budget < €80.000 Research budget ≥ €80.000	3.77 4.06	-3.476	0.001
Impact factor ≥ 7 Impact factor < 7	4.10 3.91	-2.144	0.032
Impact factor ≥ 18	4.25		

Supplementary Table 7. Perceived importance of firm-authored publications as sources of information on scientific instruments when respondents were stratified by employment status.

Respondents assessed how important information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very important) to 5 (not important). A Mann-Whitney *U*-test was carried out to test if the differences across different employment positions were statistically significant (*P*-value ≤ 0.05).

	Mean value of importance of firm-authored article (1=very important; 5= not important)	**Mann-Whitney *U*-test *Z*-statistic (asymptotic significance, two-tailed)**			
		Professor	Associate professor	Assistant professor	Post-doc
Professor	4.26				
Associate professor	4.26	-0.067 (0.946)			
Assistant professor	4.04	-1.345 (0.179)	-1.469 (0.142)		
Post-doc	3.88	-3.177 (0.001)	-3.491 (0.001)	-1.324 (0.186)	
PhD student	3.52	-5.476 (< 0.0001)	-5.945 (< 0.0001)	-3.324 (0.001)	-3.208 (0.001)

Supplementary Table 8. Comparison of how young respondents with publications in higher vs. lower impact factor journals assess the importance of firm-authored publications as sources of information on scientific instruments.

Respondents assessed how important information on scientific instruments was in a firm-authored article, on a Likert scale from 1 (very important) to 5 (not important). As in Table S6, a young respondent is defined as being born after 1976 and each respondent is categorized based on their publication in the journal with the highest impact factor. The impact factor refers to the Thomson Reuter Journal Citation Reports when the survey was conducted (June 2013). A Mann-Whitney *U*-test was carried out to assess the difference between young respondents with publications in higher vs. lower impact factors. *P*-values ≤ 0.05 were considered significant. The sample number per category was ≥ 79.

	Mean value of importance of firm-authored article (1=very important; 5=not important)	**Mann-Whitney *U*-test**	
		***Z*-statistic**	**Asymptotic significance, two-tailed**
Young respondent with impact factor ≥ 7 Young respondent with impact factor < 7	4.00 3.70	-2.216	0.027
Young respondent with impact factor ≥ 9 Young respondent with impact factor < 9	3.99 3.65	-2.596	0.009

Supplementary Table 9. Perceived importance of firm-authored publications as sources of information on scientific instruments by late vs. early respondents.

Respondents assessed how important information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very important) to 5 (not important). A Mann-Whitney *U*-test was carried out to test if differences between early (first half of received responses) and late (second half of received responses) respondents were statistically significant ($P \leq 0.05$). Note that even though the averages for Assistant professors and Post-docs are different, the *Z*-statistic and *P*-values are indistinguishable.

	Mean value of importance of firm-authored article (1=very important; 5=not important)	**Mann-Whitney *U*-test**	
		***Z*-statistic**	**Asymptotic significance, two-tailed**
All respondents early All respondents late	3.98 3.86	-1.865	0.062
Professor early Professor late	4.29 4.26	-0.045	0.964
Assoc. prof. early Assoc. prof. late	4.20 4.33	-0.350	0.727
Assist. prof. early Assist. prof. late	3.89 4.24	-0.645	0.519
Post-doc early Post-doc late	3.93 3.85	-0.645	0.519
PhD student early PhD student late	3.62 3.47	-0.930	0.352

Supplementary Table 10. Perceived reliability of firm authored vs. other strata of peer-reviewed publications as sources of information on scientific instruments in peer-reviewed publications.

Respondents assessed how reliable various types of publications were as sources of information on scientific instruments on a Likert scale from 1 (very reliable) to 5 (not at all reliable). 'No firm authors' refers to a peer-reviewed publication with no firm authors, and not associated with a star scientist nor a high-impact publication. A paired Student's t-test was carried out to test if the differences in responses across different types of publications were statistically significant (*P*-value ≤ 0.05).

Paired Student's t-test	Mean difference (s.e.m.)	Asymptotic significance, two-tailed
No firm authors vs. firm-authored	-0.931 (0.075)	< 0.0001
Star scientist vs. firm-authored	-1.166 (0.078)	< 0.0001
High-impact vs. firm-authored	-1.206 (0.076)	< 0.0001

Supplementary Table 11. Perceived reliability of firm-authored publications as sources of information on scientific instruments when respondents were stratified by entrepreneurial activity, geographical location, per cent governmental funding.

Respondents assessed how reliable information on scientific instruments was in a firm-authored article, on a Likert scale from 1 (very reliable) to 5 (not at all reliable). Being entrepreneurial active covers having created a firm, licensed technology, or having presented a business plan to potential investors. An unpaired Student's t-test was carried out to test if the differences in responses across different groups were statistically significant (*P*-value ≤ 0.05).

Unpaired Student's t-test	Mean value of reliability of firm-authored article (1=very reliable; 5=very unreliable)	Mean difference (sig. two-tailed)
Some entrepreneurial activity No entrepreneurial activity	2.89 3.11	0.218 (0.229)
Submitted ≥ 1 patent application Submitted 0 patent application	2.86 3.13	0.269 (0.171)
US respondents EU respondents	3.14 3.07	0.074 (0.744)
> 75% of funds from government ≤ 75% of funds from government	3.06 3.10	0.035 (0.809)

Supplementary Table 12. Perceived reliability of firm-authored publications as sources of information on scientific instruments when respondents were stratified by impact factor.

Respondents assessed how reliable information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very reliable) to 5 (not at all reliable). Impact factor refers to the Thomson Reuter Journal Citation Reports when the survey was conducted (June 2013). An unpaired Student's t-test was carried out to test if the differences in responses across different groups were statistically significant (*P*-value ≤ 0.05).

Unpaired Student's t-test	Mean value of reliability of firm-authored article (1=very reliable; 5=very unreliable)	Mean difference (sig. two-tailed)
Impact factor >=4 Impact factor <4	3.18 2.86	0.320 (0.083)
Impact factor >= 5 Impact factor < 5	3.23 2.76	0.469 (0.009)

Supplementary Table 13. Perceived reliability of firm-authored publications as sources of information on scientific instruments when respondents were stratified by employment status.

Respondents assessed how reliable information on scientific instruments is in a firm-authored article, on a Likert scale from 1 (very reliable) to 5 (not reliable). An unpaired Student's t-test was carried out to test if the differences across different employment positions were statistically significant (*P*-value ≤ 0.05). The sample number per category was ≥ 29.

	Mean value of reliability of firm-authored article (1=very reliable; 5=very unreliable)	**Unpaired Student's t-test Mean difference (sig. two-tailed)**			
		Professor	Associate professor	Assistant professor	Post-doc
Professor	3.12				
Associate professor	3.23	0.108 (0.645)			
Assistant professor	2.79	0.328 (0.264)	0.436 (0.075)		
Post-doc	3.26	0.135 (0.611)	0.027 (0.903)	0.463 (0.096)	
PhD student	3.06	0.62 (0.817)	0.170 (0.447)	0.266 (0.347)	0.197 (0.427)

Supplementary Table 14. Scientific instrument reporting policies of the 20 most cited journals in the Google Scholars h5-index in the categories Health & Medical Sciences, Life Sciences & Earth Sciences, and Chemical & Material Sciences.

Websites for all journals were visited in order to assess the following: if their instructions for authors on how to submit had explicit guidelines describing how to reference scientific instruments. We examined a journal's own guidelines, as well as any links to the publisher's general guidelines that might contain information on how to reference scientific instruments. A key interest was if the guidelines explicitly mention the potential conflict of interest entailed by the commercial nature of the majority of scientific instruments. All guidelines were accessed July 2017. Review journals were excluded.

Google Scholar Impact factor rank (2016)	Thomson Reuters Journal Impact Factor (2016)	Journal	Guidelines on reporting the use of scientific instruments	Relevant quote from author guidelines
1	23.76	Nature	No	A subsection on 'image integrity' states: '*In the Methods, specify the type of equipment (microscopes/objective lenses, cameras, detectors, filter model and batch number) and acquisition software used. Although we appreciate that there is some variation between instruments, equipment settings for critical measurements should also be listed.*'[29]
2	33.90	New England Journal of Medicine (NJEM)	No journal specific guidelines on scientific instruments, only for drugs	General guidelines require that the author '*Identify methods, equipment (give the manufacturer's name and address in parentheses), and procedures in sufficient detail to allow others to reproduce the results.*'[30]
3	19.58	Science	No	
4	25.79	The Lancet	No	
5	23.55	Cell	No	
6	9.38	Proceedings of the National Academy of Sciences (PNAS)	To some degree	'*Names of suppliers of uncommon reagents or instruments should be provided.*'[31]

7	16.89	Journal of Clinical Oncology	No; only for drugs	
8	13.51	Journal of the American Chemical Society	No	
9	17.76	Advanced Materials	No	
10	13.82	the Journal of the American Medical Association (JAMA)	Yes	'*Use nonproprietary names of drugs, devices, and other products, unless the specific trade name of a drug is essential to the discussion. In such cases, use the trade name once and the generic or descriptive name thereafter.*'[32]. General publisher guidelines are even more specific (see Supplementary Note 2).
11	14.84	Circulation	No	
12	22.69	Nature Genetics	No	General Nature Publishing guidelines (see above)
13	12.58	Nano Letters	No	
14	11.81	Angewandte Chemie International Edition	No	
15	9.23	Nucleic Acids Research	No	
16	13.59	ACS Nano	To some degree	'*Articles must include, as the last text section, a clear, unambiguous description of materials, methods, and equipment in sufficient detail to permit repetition of the work elsewhere.*'[33]
17	16.94	Journal of the American College of Cardiology	No	
18	30.44	Nature Materials	No	General Nature Publishing guidelines (see above)
19	2.86	PLOS ONE	No, only for antibodies	
20	21.03	Nature Medicine	No	General Nature Publishing guidelines (see above)

Supplementary Note 1 - Methods and survey data

The overall aim of this study was to compare perceptions – from various geographical areas, scientific fields, academic ranks, publication records, size of research budgets, and entrepreneurial activities – concerning the importance and reliability of information on scientific instruments. In order to detect such diversity, we selected universities from both North-America (USA) and Europe (EU). US-based universities were first grouped according to their research budgets, using information from the National Science Foundation (NSF). We next randomly selected universities within each of the four groups, in order to include universities from all sections of the NSF top 100 ranking. In Europe we selected the top universities in the Netherlands and Denmark, both countries with strong natural science research traditions and research output[34,35]. The final sample consisted of 5,290 individuals. We gathered written consent from each individual.

Emails were collected from the universities' websites, including only individuals with an academic title and excluding technical and administrative staff. The first survey (survey 1) was sent out in the summer of 2013. After sending out two email reminders, the survey received 994 responses (see demographics in Table S3). Adjusting for ineligible and retired respondents, this constitutes an 18.79% response rate, and is within the range of previous surveys directed towards non-US academic researchers[36-38]. Because of non-response for specific items, the number of respondents for a given item can be less than 994. As explained below, we sent out a short follow-up survey (survey 2) to the original respondents in the spring of 2014 and received 247 responses, constituting an effective response rate of 30%. Table S3 illustrates the similarity of respondents in the different samples.

In order to ensure reliability, all questions related to demographics (age, gender, education, scientific discipline, tenure, and number of publications), size of research budgets, and extent of entrepreneurial activities are based on studies of similar respondents[8,39]. Entrepreneurial activities were defined as (an intention of) starting a new firm, holding patents, or actively licensing technology. We also asked about the cost of the most expensive scientific instrument purchased by the respondents, frequency of purchasing instruments, and if respondents had collaborated with the firm they purchased their last instrument from. Questions about which sources of information are used were inspired by previous work[8,39]. These questions inquired whether colleagues, conferences, salespersons, written brochures, the brand of the firm, or being mentioned in a paper were key sources of information about instruments. Similar to previous studies on the reliability of information originating from firms[40-42], key questions asked respondents how they perceive their own behavior. This main line of inquiry – on which sources of information were considered important and reliable when assessing scientific instruments – is novel, and inspired by recent qualitative research of the field; where 27 individuals from academia and scientific instrument firms were interviewed by one of the authors[16] (C.B.)

Given the noteworthy lack of knowledge in the literature on information sources used for instruments, the first survey was exploratory and established some stylized facts about the information sources used by academics. We asked respondents to rate how *important* (on a five-item Likert scale, from very important to not important at all) they found references to scientific instruments in various academic outlets. The academic outlet could either be a i) journal publication in general; ii) a high-impact journal publication; iii) a journal publication co-authored by a star-scientist (researchers with extraordinary reputation in his/her respective field[43]); iv) a journal publication co-authored by a firm; or v) a journal publication co-authored by one of the firms producing an instruments employed in the study. To evaluate whether the lack of importance emanated from a lack of perceived reliability (and not out of the limited scope of firm-authored publications), we sent out a follow-up survey to those that completed the first survey fully (820 out of the 994 respondents). Here, we specifically asked respondents about how *reliable* (on a five-item Likert scale; from not reliable at all to very reliable) they perceived various sources of instruments to be, in order to generate an estimate of how credible (i.e. perceived reliability) they found these different types of academic sources.

While the analysis in the main text identifies the two most important features of the data, in what follows we present some key statistics which provide additional, more fine-grained details of the surveys and demonstrate the robustness of our findings. We focus here on how respondents assessed the importance and reliability of information about scientific instruments in publications authored by someone from the firm that has produced the given instrument (labeled 'firm co-authored publication').

When comparing sub-samples of responses to survey 1 we employed the non-parametric Mann-Whitney *U*-test, in order not to make any assumptions about the underlying distribution (Student's t-tests comparisons lead to the same results, however). The respondents' perceptions were remarkably similar across a range of researcher characteristics such as being entrepreneurially active or not, having submitted a patent application or not, geographical origin, and scientific field. Comparing respondents from the EU vs. the US revealed no significant difference (Mann-Whitney *U*-test, $Z = -1.379$, $P = 0.168$) in their perception on the importance of firm-authored publications as a source of information on scientific instruments (see Table S4). A similar two-sample comparison of entrepreneurially active vs. inactive respondents not did not reveal a difference (Mann-Whitney *U*-test, $Z = -0.299$, $P = 0.765$; see Table S4). A comparison of researchers that had submitted at least one patent application vs. those that had not, also did not lead to a significant difference (Mann-Whitney *U*-test, $Z = -1.071$, $P = 0.284$; see Table S4). Whether a researcher receives most of his/her funding (+75%) from the government or less, had no effect on perceived importance since the average importance assigned was 3.93 and 3.89 for the respective groups (Mann-Whitney *U*-test, $Z = -0.232$, $P = 0.816$; see Table S4). Finally, when comparing how respondents from seven distinct scientific fields assessed the importance of information on scientific instruments in firm-authored publications, no differences were identified at a 0.05 significance level (see Table S5 and Figure 1b) – even though many dyadic (21) comparisons were drawn. Overall, a strong homogeneity of perceptions about how to assess scientific instruments information sources is prevalent, and norms seem to be deeply embedded in the academic culture. This is noteworthy; previous survey-based studies reported heterogeneous perceptions of academic norms across divides such as scientific fields[13,44].

As outlined in the main text, one overall type of variable was associated with a tendency to be more 'skeptical' about the value of information found in firm-authored publications: proxies for academic success. These included size of research budget, respondent's age, (Thompson Reuters) impact factor of the best publication, and employment status. If the respondent over the last five years had an average annual research budget of over €80,000 (equivalent to $100.000), they on average rated importance 4.06 on a Likert scale from 1 to 5 (where 5 is the least important option). This is in contrast to researchers with a research budget at less than €80,000, who assigned a value of 3.77, and thus considered information in firm-authored publications relatively more important (Mann-Whitney U-test, $Z = 3.476$, $P = 0.001$; see Table S6). Similarly, older respondents were more critical when assessing the reliability of information on scientific instruments in firm-authored publications compared to younger respondents. A cut-off point of people born either before or after 1976 split the sample into almost equal halves, with the older, more senior, half assigning an average importance of 4.15 vs. 3.69 for the younger half (Mann-Whitney U-test, $Z = -6.106$, $P < 0.0001$; see Table S6). Focusing on the impact factor of a respondent's best publication, revealed the same trend. When respondents' top publication were in a journal with a Thompson Reuters impact factor above 7 (the cut-off closest to dividing the sample in half), they assigned a value of 4.10 vs. 3.87 for the group in the lower half of impact factors (Mann-Whitney U-test, $Z = 2.144$, $P = 0.032$; see Table S6). Selecting different cut-off points lead to same results. For academics with higher impact factor outputs, the difference increased. All respondents that had published in a journal with an impact factor above 18, assigned an average importance value of 4.25. Examining differences across employment status revealed a similar disparity. Both the professor and associate professor categories assigned a value of 4.26 on average, while PhD students assigned a value of 3.52 (see Table S7), one of the least critical respondent categories in the dataset in terms of assigning importance.

Since the variables assessed in our study were related to academic success and not merely age, it is less likely that the differing perceptions are solely due to cohort effects; older academics being more skeptical in general than younger academics. To corroborate this interpretation, we analyzed the heterogeneity within a given age group. We split the young scholars into different samples dependent on their publication record, as measured by impact factor. Young scholars (defined as born after 1976) who had published in higher-ranking journals (impact factor ≥ 7) assigned a lower importance to information on scientific instruments in firm-authored journals, compared to young scholars who had published in lower-ranking journals (Mann-Whitney *U*-test**s**, $Z = -2.216$, $P = 0.027$; see Table S8**)**. Young scholars who had published in journals with an impact factor less than 7 assigned a mean value of 3.70, while young scholars who had published in journals with a higher impact factor assigned a mean value of 4.00. When employing an impact factor cut-off at 9, the difference increased (Mann-Whitney *U*-test, $Z = -2.596$, $P = 0.009$; see Table S8**)**. Assessment of the data, thus, suggests that the survey results are not solely due to a cohort effect. Overall, the results reflect a general underlying trend of less experienced researchers requiring time to fully embed the norms and behaviors of their peers and, accordingly, to have formed an opinion on firm-based research similar to more experienced faculty. Our data and interpretation is also in line with research within the life sciences showing that senior researchers have more collaboration with industry[45].

Table S9 presents a Mann-Whitney *U*-test comparing the answers to a question on the importance of firm-authored publications among early (first half of received responses) and late respondents (second half of received responses). A comparison of the overall average of early and late respondents to survey 1 revealed a marginally significant difference (Mann-Whitney *U*-test, $Z = -1.865$, $P = 0.062$; see Table S9). This result could be due to certain subgroups (that assign a relatively high or low value) being more prevalent in one half vs. the other, or evidence of a different type of response emerging later in time. In order to establish if a response bias was influencing the data, it is more meaningful to analyze if responses within a certain category, e.g. employment status, shifts over time. When comparing early and late responses within each employment category (PhD student, post-doc, assistant professor, associate professor, and professor), no differences were significant at a 0.05 *P*-value cut-off (see Table S9). Since late respondents usually are more similar to non-respondents[46], this analysis suggests that there is no systematic bias and supports the assumption that the respondents represent the total sample receiving our survey.

Table S3 shows an overview of selected characteristics of the surveys' respondents in, order to illustrate how similar respondents in each category are across the two surveys. For instance, in the first survey (survey 1) 48.84% of respondents were conducting research related to biological sciences – in the second survey (survey 2) the corresponding percentage was 49.59. Similarly, in the first survey 58.21% of all respondents had a yearly research budget of less than €80.000, while the equivalent number is 55.65% in the second survey.

The second survey relied on a smaller sample (of the survey 1 cohort), but, importantly, it showcases the same trends as the first survey. Due to the nature of the distribution of responses, all reported response comparisons to survey 2 are based on Student's t-tests (Mann-Whitney *U*-tests lead to the same results, however). When comparing how reliable (rather than important) respondents considered information on scientific instruments in peer-reviewed, non-firm authored publications, a stark difference emerged. On a Likert scale, where 1 is the most reliable and 5 is the least reliable, information in a peer-reviewed article was rated at an average of 2.15; in contrast to information in a firm-authored publication, which in a comparison rated at 3.08 (paired Student's t-test, $P \leq 0.0001$; see Table S10). Firm-coauthored information was, thus, considered significantly less reliable. A publication co-authored by industry, but not by the firm that produced an instrument employed in a manuscript, was rated at an average of 2.62 – less reliable than publications where commercial actors are not involved, but not as 'unreliable' as a publication by the firm that produced the particular instrument in question. Furthermore, as in the first survey no differences (at a 0.05 *P*-value cut-off) emerged across relevant divides; such as how much governmental funding one receives, being located in the US vs. EU, having submitted a patent application, or being entrepreneurially active or not (see Table S11). Again, the perceptions of how to assess information in various types of publication outlets were homogeneous across many different comparisons.

In the analysis of the first survey (importance), success-related variables stood out. In the case of assessing the reliability of information on scientific instruments in firm-authored publications, the picture was less clear. Respondents that had not published in journals with a high impact factor, assigned less reliability to firm co-authored research compared to respondents who had not. In general, their averages were smaller; and if we set impact factor 4 (unpaired Student's t-test, $P = 0.083$) or 5 (unpaired Student's t-test, $P= 0.009$) as a cut-off point, a two-sample mean comparison indicated a significant difference between higher vs. lower impact factor outputs (see Table S12). Comparing respondents with different employment statuses, from PhD students to professors, revealed no significant differences at a 0.05 *P*-value cut-off (see Table S13). It can be argued that these differences between successful vs. less successful respondents are difficult to tease out by simple proxies for success (such as impact factors) in a quantitative survey. In any case, our data illustrate a stark disparity between how important and reliable information about scientific instruments are perceived to be in papers co-authored by academic researchers vs. researchers employed by a scientific industry firm.

Supplementary Note 2 - Author guidelines for reporting the use of scientific instruments in peer-reviewed journals

In the following section, we illustrate how author guidelines have been coded (see Table S14). If an author guideline stated '*The Materials and Methods section should provide enough detail to allow suitably skilled investigators to fully replicate your study*' (extract from *PLOS ONE*), we considered this to not constitute an adequate guide for disclosure on involvement of scientific instrument firms in the generation of a manuscript. Similarly, many guidelines specify how to handle references to animal models, cells, genes, et cetera (see e.g. *Nature* or *Science*), but – in our opinion – this also does not constitute a guide for how to reference scientific instruments. The AMA (American Medical Association) guidelines exemplify how to be specific with regards to how and when to list the contribution of a scientific instrument firm: '*As with drugs and isotopes, nonproprietary names or descriptive phrasing is preferred to proprietary names for devices, equipment, and reagents, particularly in the context of general statements and interchangeable items (eg, urinary catheters, intravenous catheters, pumps). However, if several brands of the same product are being compared or if the use of proprietary names is necessary for clarity or to replicate the study, proprietary names should be given at first mention along with the nonproprietary name [...]. If a device is described as "modified," the modification should be explained or an explanatory reference cited. If equipment or apparatus is provided free of charge by the manufacturer, this fact should be included in the acknowledgment*'[47].

Supplementary Materials

In the following section, the two surveys are presented, as they were emailed to the respondents.

First survey (survey 1)

Instructions

A 'scientific instrument' is any kind of equipment used while conducting research (both measurement and analysis). Such scientific instruments are usually listed in the methods section of a peer reviewed paper. If the product has been purchased, the firm producing the product will often also be named.

When a product and the producing firm is mentioned in the methods section of a paper, this constitutes a 'reference' to the scientific instrument.

Please answer the questions based on your best recollections. It is not necessary for you to investigate your files to collect data. If you have any questions, please contact us via e-mail.

First, a few questions about you and your research

What is your primary field of research?

(1) ❑ Biological sciences
(2) ❑ Physical sciences
(3) ❑ Chemical sciences
(4) ❑ Medical and health sciences
(5) ❑ Engineering
(6) ❑ Agricultural sciences
(7) ❑ Other __________

What is your current employment status?

(1) ❑ Professor
(2) ❑ Associate professor
(3) ❑ Assistant professor

(4) ❑ Post-doc
(5) ❑ PhD student
(6) ❑ Other __________

You are
(1) ❑ Male
(2) ❑ Female

In what year where you born?

____

What is your highest academic degree?

____

In what year did you receive this degree?

____

What has been your average annual research budget, over the last 5 years?
(1) ❑ Less than 100.000 $ / 80.000 €
(2) ❑ 100.000 to 500.000 $ / 80.000 to 400.000 €
(3) ❑ 500.000 to 1.000.000 $ / 400.000 to 800.000 €
(4) ❑ 1.000.000 to 5.000.000 $ / 800.000 € to 4.000.000€
(5) ❑ More than 5.000.000 $ / 4.000.000 €

What percentage of your ongoing research budget comes from Government research programs or other governmental funds?
(1) ❑ 0-25 %
(2) ❑ 26-50 %
(3) ❑ 51-75 %
(4) ❑ 76-100 %

In the following we ask questions about your use of scientific instruments and the role of the price of the scientific instruments that you use

Do you use scientific instruments in your research?

(1) ❑ Yes
(2) ❑ No

How **important** is the use of scientific instruments for your work?

(1) ❑ Very important
(2) ❑ Important
(3) ❑ Moderately important
(4) ❑ Slightly important
(5) ❑ Not important at all

How frequently do you purchase instruments?

(1) ❑ At least once every month
(2) ❑ At least once every quarter
(3) ❑ At least twice every year
(4) ❑ At least once every year
(5) ❑ Almost never

How important is the price of the instrument when planning to purchase an instrument?

(1) ❑ Very important
(2) ❑ Important
(3) ❑ Moderately important
(4) ❑ Slightly important
(5) ❑ Not important

How much did the most expensive instrument that you currently use cost?

(1) ❑ Less than 1.000$ / 800 €
(2) ❑ 1.000 - 10.000$ / 800 - 8.000 €
(3) ❑ 10.000 - 100.000$ / 8.000 - 80.000 €

(4) ❑ 100.000 - 1.000.000$ / 80.000 to 800.000 €

(5) ❑ More than 1.000.000$ / 800.000 €

In order to answer the following questions, please think about your most recent purchase of a scientific instrument. We define a purchase here as you having actually purchased or formally applied for the scientific instrument.

Did you purchase this instrument in collaboration with others?

(1) ❑ Yes, other researchers in my group

(2) ❑ Yes, other research group(s)

(3) ❑ No

Were you in charge of purchasing this most recent scientific instrument?

(1) ❑ Yes, alone

(2) ❑ Yes, with others in my group

(3) ❑ Yes, with other research group(s)

(4) ❑ No

Did you collaborate with the firm producing the scientific instrument, after you purchased the instrument?

(1) ❑ Yes, extensively

(2) ❑ Yes, to some degree

(3) ❑ No

What was the price of this last instrument you purchased?

(1) ❑ Less than 1.000$ / 800 €

(2) ❑ 1.000 - 10.000$ / 800 - 8.000 €

(3) ❑ 10.000 - 100.000$ / 8.000 - 80.000 €

(4) ❑ 100.000 - 1.000.000$ / 80.000 to 800.000 €

(5) ❑ More than 1.000.000$ / 800.000 €

I think the functionality of the instrument is more important than the price

Strongly agree	Agree	I don't know	Disagree	Strongly disagree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

I think the academic reputation (among scientists and in journals) of the instrument is more important than the price

Strongly agree	Agree	I don't know	Disagree	Strongly disagree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

I think the commercial brand of the instrument is more important than the price

Strongly agree	Agree	I don't know	Disagree	Strongly disagree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

I think the academic reputation (among scientists and in journals) is more important than the commercial brand

Strongly agree	Agree	I don't know	Disagree	Strongly disagree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

I think the commercial brand is more important than the functionality of the instrument

Strongly agree	Agree	I don't know	Disagree	Strongly disagree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

I think the academic reputation (among scientists in journals) is more important than the functionality of the instrument

Strongly agree	Agree	I don't know	Disagree	Strongly disagree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

In the following we would like you to consider a situation where you are about to purchase a scientific instrument

What kind of information do you rely on?

	Always	Very often	Sometimes	Rarely	Never
I rely on input from others	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I rely on colleagues that I am currently collaborating or have collaborated with	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I rely on getting input at technical conferences, workshops and fairs	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I rely on salespersons from the firm producing and selling the instrument	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I rely on written information (website, brochures) of the firm producing and selling the instrument	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I rely on the brand of the firm producing and selling the instrument	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I rely on having seen the product referenced in a peer reviewed paper	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

	Always	Very often	Sometimes	Rarely	Never
I rely on having used the product myself	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

In the following we would like you to consider a situation where you are about to purchase a scientific instrument

How important are references to the instrument in

	Very important	Important	Moderately important	Slightly important	Not important
a peer reviewed journal	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
an article written by a star-scientist	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
a journal with a high-impact factor	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
an article that is (co)authored by someone from industry	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
an article where the product and firm referenced is (co)authored by someone from the particular firm that produced the instrument	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

In the following we would like you to think of your typical use of scientific instruments

When choosing to buy a scientific instrument, references in high-impact journals are more important for expensive instruments than for cheap instruments.

(1) ❑ Strongly agree
(2) ❑ Agree
(3) ❑ Neither agree nor disagree

(4) ❑ Disagree
(5) ❑ Strongly disagree

When choosing to buy a scientific instrument, input from colleagues is more important for expensive instruments than for cheap instruments.

(1) ❑ Strongly agree
(2) ❑ Agree
(3) ❑ Neither agree nor disagree
(4) ❑ Disagree
(5) ❑ Strongly disagree

Finally a few questions about your publications, patents and affiliation

In the past five years, how many new patent applications have been submitted on your inventions?
(if none, please enter 0)

____

Have any of your inventions led to any commercial activities?

(1) ❑ Exploration of the possibility of creating a new firm (such as presenting a business plan to potential investors)
(2) ❑ Creation of a new firm
(3) ❑ Receipt of licensing income
(4) ❑ Negotiation with an existing firm over the use of your invention
(5) ❑ Other kinds of commercial activities
(6) ❑ No commercial activities

In the past five years, how many papers have you published in refereed journals (including co-authored papers)?
(if none, please enter 0)

____

What do you consider to be the highest-ranked journal that you have published in?

____
____

How many publications do you have in this journal?

____

What is your current academic affiliation?

University ____________________

Department ____________________

In what year did you join your current organization?

____

Second survey (survey 2)

1) In the following we would like you to consider a situation where you are about to purchase a scientific instrument.

When you consider the different options, how **reliable** do you find

	Very reliable	Moderately reliable	I don't know	Slightly reliable	Not at all reliable
a reference in a peer reviewed journal	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
a reference in a peer reviewed article written by a star-scientist	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
a reference in a peer reviewed journal with a high-impact factor	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
a reference in a peer reviewed article that is (co)authored by someone from industry	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
a reference in a peer reviewed article where the product and firm referenced is (co)authored by someone from the particular firm that produced the instrument	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

2) How reliable do you find the following sources of information

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I find input from colleagues that I am currently collaborating or have collaborated with reliable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I find input from technical conferences, workshops and fairs reliable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I find salespersons from the firm producing and selling the instrument reliable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I find written information (websites, brochures) of the firm producing and selling the instrument reliable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I find the brand of the firm producing and selling the instrument reliable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
I find references in peer reviewed papers to be reliable	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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