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The promise and perils of industry-funded science

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Abstract

Private companies provide by far the most funding for scientific research and development. Nevertheless, relatively little attention has been paid to the dynamics of industry-funded research by philosophers of science. This paper addresses this gap by providing an overview of the major strengths and weaknesses of industry research funding, together with the existing recommendations for addressing the weaknesses. It is designed to provide a starting point for future philosophical work that explores the features of industry-funded research, avenues for addressing concerns, and strategies for making research funded by the private sector as fruitful as possible.

1 | INTRODUCTION

In 1969, the famous biologist Ernst Mayr wryly observed: "I have some five or six volumes on my book shelves which include the misleading words 'philosophy of science' in their title. In actual fact each of these volumes is a philosophy of physics" (p. 197). Mayr's concern was not merely that his discipline was being ignored by philosophers but that the claims about science drawn from physics did not generalize to or were simply irrelevant for biology. More troubling was that there were several important aspects of biology that had no analogue in physics and so were not even on the radar for the philosophers of "science." Examining our book shelves nearly 50 years later, we find a different set of books claiming to anthologize the philosophy of science, which, in part due to Mayr's efforts, no longer have such a deficiency—at least, with respect to biology.

Today, however, the overwhelming majority of contemporary works are really a philosophy of publicly funded science. Rarely, if ever, do we see a case study of scientific work done at Dow Chemicals inform a discussion about "core" philosophical topics like scientific explanation, confirmation, causation, or modeling. Yet despite its limited influence on philosophical discourse, industry accounts for roughly two thirds of all R&D funding in developed countries (OECD, 2016), and its influence is expanding to the public sector because of multiple changes to university and government policies over the past 40 years (Biddle, 2011, 2014b; Irzık, 2007; Krimsky, 2003; Mirowski, 2011; Slaughter & Rhoades, 2004; Sterckx, 2011; Washburn, 2005).

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When discussions of industry-funded science have pierced the philosophical discourse, they have typically been prompted by practical concerns about industry bias. This attention stems partly from scandals that have been uncovered in research on tobacco, acid rain, the ozone hole, climate change, industrial chemicals, and pharmaceuticals (Markowitz & Rosner, 2002; McGarity & Wagner, 2008; Michaels, 2008; Oreskes & Conway, 2010; Proctor, 2012). In addition, systematic correlations have been identified between research funded by the private sector and results that favor the funders (Barnes & Bero, 1996; Bekelman, Li, & Gross, 2003; Davidson, 1986; Lexchin, Bero, Djulbegovic, & Clark, 2003; Lundh, Lexchin, Mintzes, Schroll, & Bero, 2017; Sismondo, 2008). Nevertheless, there may well be important differences between various forms of industry funding, such as research funded by unrestricted grants versus cases where industry maintains firm control over the entire research process (Wilholt, 2012). Moreover, even in cases where all research is conducted in-house, a small body of philosophical work explores cases where industry-funded science is not only reliable but makes important contributions to scientific inquiry.

Below, we first review the strengths and weaknesses of industry-funded research (Sections 2 and 3). Section 4 introduces and evaluates proposals for reform. Section 5 reflects on the existing literature and draws some lessons for future philosophical work on this topic. We conclude that there is a great deal of work to be done. Philosophers can play an important role in evaluating and improving industry-funded science. Moreover, they can play an important role helping the public understand the scientific literature and fight against biased science (e.g., Briggle, 2015; Shrader-Frechette, 2014).

2 | THE PROMISE OF INDUSTRY-FUNDED RESEARCH

Though it has received far less consideration from philosophers than the perils of industry-funded science, we begin with a brief discussion of the benefits. This imbalance in attention is out of step with the perspective of a number of influential nonprofit and government agencies (e.g., the Gates Foundation, the Wellcome trust, and the U.S. Food and Drug Administration) that are recommending more collaboration between industry and academia (Drazen, 2015; Jasny et al., 2017). Indeed, the entire field of biomedicine is being reoriented towards industry-university partnerships under the rubric of translational medicine (Robinson, 2018). Such a reorientation is not new but rather a further consequence of changes to the economic and legal structures of scientific inquiry that have led to the global privatization of science.[1]

One of the driving forces behind these changes has been the expansion of the ability of academic researchers to patent their inventions as a result of legislation like the Bayh-Dole Act in the early 1980s (Biddle, 2011; Biddle, 2014b; Brown, 2008; Irzık, 2007; Sterckx, 2011). Some critics, like John Ziman (2002), have argued that patent-focused inquiry can result in less robust knowledge claims, which are useful only for achieving pragmatic results in applied contexts. On this view, science functions best when researchers choose projects for their intellectual merit rather than being guided by market forces. Likewise, Thomas Kuhn (1962, p. 37) held that one of the virtues of normal science was that a paradigm could "insulate the community from those socially important problems that are not reducible to the puzzle form …. Such problems can be a distraction." Yet in some areas of inquiry, the choice is not between private or publicly funded science but between privately funded science and no inquiry at all (Carrier, 2008).

The origin of the ideological framework in which patenting is now understood has been explored in the work of Joseph Gabriel (2014), who details how the ethical acceptability of medical patents emerged as pharmaceutical companies began conducting scientific research. The patent system was ultimately seen to resolve tensions that existed between the norms of science (openness) and demands of business (profitability). This tension is illustrated in dilemmas faced by research-oriented pharmaceutical companies in the late 1800s when seeking a patent was a sign of quackery. For example, the Parke-Davis Company sent employees around the world in search of plants with possible medicinal properties and then openly published subsequent laboratory reports establishing the therapeutic properties of promising remedies. However, when the company complied with contemporary ethical norms and did not seek a patent for its innovations, it was undercut by its competitors who did not have to recoup the extensive costs of R&D. In contemplating his scientific success and commercial failure, Davis wrote to his lead scientist, "Our ethical course is leading us astray through a tortuous channel which abounds in rocks on either side and between these rocks of competition and of an unappreciative and hostile medical profession we shall be ground to pieces" (Davis, 1889 as quoted by Gabriel, 2009, p. 19f).

The patent-based business model has been particularly valuable for developing theoretical ideas into practical applications. As an example, consider the development of magnetic sensor technology (Wilholt, 2006). The first steps were taken by university researchers who discovered that a conducting layer sandwiched between layers of ferromagnetic films was subject to massive fluctuations of electric resistance depending on the orientation of the ferromagnetic layers. The potential commercial applications for digital data storage were clear. Importantly, the physics of the effect was not well-established when work began within both the IBM and Philips research labs, where the vast majority of the research was conducted.

Wilholt (2006) finds that over the course of resolving residual uncertainties in how to generate the effect, scientists developed *design rules*: locally applicable and empirically derived regularities that guide optimal design. While such rules may be local, they are methodologically thorough. Moreover, the case also illustrates the phenomenon of *application innovation*, where important contributions are made to high-brow theory during the course of commercially driven research (Adam, 2005; Adam, Carrier, & Wilholt, 2006; Carrier, 2004). Cases like this may well be representative of the valuable contributions that industry-funded science can make, where the improvement of theory is needed for cost-effective innovation (Carrier, 2010) or for products to function without collapsing under the pressure of real-world use (Carrier, 2011).

Indeed, another strength claimed for industry-funded research is its reproducibility. Whereas academic research has recently come under fire because of such concerns (Begley & Ellis, 2012; Begley & Ioannidis, 2015; Open Science Collaboration, 2015), some researchers contend such problems can be alleviated by working with industry (Edwards, 2016). In particular, many industry labs follow standardized protocols for performing studies and adhere to Good Laboratory Practice guidelines, which, they argue, include rigorous safeguards for ensuring that those protocols are actually followed (Conrad & Becker, 2012).

Finally, it would be misleading to suggest that industry-funded research is valuable solely for developing practical applications. A host of Nobel prizes have been awarded to scientists for work completed in the private sector. Recent examples include Shuji Nakamura's work at Nichia Corporation developing a Blue LED, Eric Betzig's invention of super high-resolution fluorescence microscopy at his own company (New Millennium Research), and Charles Kao's work on fiber optics at Standard Telecommunication Laboratories. Thus, in part because of the significant resources available to the private sector, industry-funded research has proven valuable for generating innovations in both basic and application-oriented research.

3 | THE PERILS OF INDUSTRY-FUNDED RESEARCH

Philosophers have long accepted that science can progress even though scientists are not driven by pure motives (e.g., Kitcher, 1993). Thus, one might think that science already has the means to deal with industry bias. However, at least in some cases, industry actors advocate a position irrespective of the evidence. That is, they are not just biased, they are *intransigently biased* (Holman & Bruner, 2015). Court proceedings and anonymous leaks first revealed how cigarette companies manipulated scientific data to resist public health measures and confuse the public about the health risks of tobacco (Glantz, Slade, Bero, Hanaur, & Barnes, 1996; Proctor, 2012). Internally, tobacco companies knew their products were dangerous. Publically, they took extensive action to prevent others from drawing the same conclusion. More recently, similar issues have been examined in philosophical discussions of chemical safety (Douglas, 2009; Elliott, 2011; Mushak & Elliott, 2015), medicine (Biddle, 2007; Holman, 2015, 2017; Krimsky, 2003; Stegenga, 2018; Wilholt, 2009), and climate research (Oreskes & Conway, 2010). Moreover, what is concerning about the types of biases reviewed below is not (just) that they result in individual instances of unreliable research but that they produce a systematic bias in the community's body of knowledge. In this section, we consider the perils of industry-funded research roughly in the order of the research process (see Table 1).

Accordingly, we start with the choice of topics and questions for investigation. Privately funded research has been criticized for its potential to influence these choices in questionable ways (Brown, 2008). For example, even if exercise can alleviate depression, it is unlikely to receive attention from the private sector because it is unlikely to generate profits (Musschenga, Steen, & Ho, 2010). Moreover, gaps in knowledge can result not only from the failure to investigate particular topics but also from deliberate efforts to suppress or cast doubt on information that threatens the financial interests of industry. By treating ignorance as a social product rather than just the absence of knowledge, it becomes possible to trace strategies and mechanisms that lie behind it (McGarity & Wagner, 2008; Michaels, 2008; Oreskes & Conway, 2010). *Agnotology* has emerged as the study of how ignorance is created and maintained (Fernandez Pinto, 2015, 2017; Proctor, 2012; Proctor & Schiebinger, 2008).

An additional problem is that private companies can fund research selectively to manipulate the overall body of evidence (Elliott & McKaughan, 2009). Such effects underscore the need to go beyond conflicts of interest and pay attention to the social structure of science. Holman and Bruner (2017) show that industry funding can systematically bias a community, even if every individual scientist is rational, truth-seeking, and unbiased by the funding. For example, in the 1980s, hundreds of thousands of people died from drugs prescribed to prevent cardiac arrests. Prior to FDA approval, there was legitimate debate within the academic community about methodology, with many researchers finding the drugs to be unsafe. However, industry selectively funded researchers who used methods that cast their drugs in the best light. These researchers were able to produce a significant amount of research, rise to prominence in their field, and build a consensus around their methods of assessing harm. Crucially, though these researchers had conflicts of interests, their views did not change as a result of receiving industry funding. Nevertheless, the community did become biased "because of the *industrial selection effect*: It was because of the views researchers antecedently held that industry contracted them in the first place" (p. 1011, emphasis in original).

In some cases, data are fabricated or falsified (Elliott, 2011, p. 132); however, it appears that such egregious activities are relatively rare (Doucet & Sismondo, 2008). A more common problem appears to be *design bias*, which occurs when companies shape science by designing studies in ways that are most likely to generate results that are favorable to them (Bero & Rennie 1996; Lexchin et al., 2003; McGarity & Wagner, 2008). Safer (2002; Smith, 2005) catalogs a long list of strategies that pharmaceutical companies have used to manipulate the image of their product. Researchers can give a competitor's drug in an overly high dose to make their drug look safe by comparison or in a low dose to make theirs look more effective. They can also selectively report outcomes or positive subgroups, secondary analyses, or post hoc analyses as if they were always the intended focus of the paper. Though such

TABLE 1 Overview of major epistemic concerns with industry-funded research and potential solutions

Epistemic concerns	Potential solutions
Choice of topics and questions	● Incentives to explore other topics ● Public funding to augment private funding
Design bias and skewed data collection/analysis	● Good laboratory practice guidelines ● Firewalls and collaborations ● Standardized protocols
Questionable data interpretation and rhetoric	● Scrutiny by regulatory agencies ● Reporting guidelines
Publication bias	● Trial registries
Skewed concepts and categories	● Critical evaluation by the scientific community
Erosion of communalism and openness	● University and federal policies
Corruption of communal processes	● Lawsuits ● Disclosure policies ● Media attention ● Public funding

practices do not involve falsifying or fabricating data, they are designed to mislead their audiences and rightfully considered a source of bias (Steel, 2018).

Even if data are presented accurately, flexibility exists in how results are discussed (Doucet & Sismondo, 2008; Matheson, 2008). For example, because early studies suggested that the drug Vioxx increased risks for cardiovascular events (e.g., strokes and heart attacks), the FDA warned Merck (its manufacturer) not to minimize this danger in its advertising material. Yet the FDA could not stop industry-funded academic researchers from presenting the adverse cardiovascular effects of Vioxx as a result that "may represent the play of chance" (Fitzgerald & Patrono, 2001, p. 440). Vioxx would ultimately be pulled from the market after causing over 50,000 deaths (on Vioxx, see Biddle, 2007). The potential for this rhetorical spin increases substantially when papers are "ghostwritten" by medical communication companies on behalf of industry sponsors (Elliott, 2010; Healy & Cattell, 2003; Sismondo, 2007).

Unwelcome results can also be hidden by withholding the publication of negative results (McGarity & Wagner, 2008). The problem of selective publication arises with publicly funded research as well, because academic researchers are more likely to submit studies that provide new and interesting results than those that do not observe any effects (Song et al., 2010). Nevertheless, publication bias is an important mechanism by which the epistemic quality of industry-funded research can be compromised (Chan et al., 2014). In one effort to study this problem, researchers used the Freedom of Information Act to retrieve every antidepressant study submitted to the FDA between 1987 and 2004. Of the results reported, 38 studies found the antidepressants to be effective, and 36 found them to be no better than a placebo. However, while nearly every positive study was published, only three of the 36 negative studies were published as such (although 11 of the negative studies were published as if they were positive). Thus, whereas the FDA saw 38 positive studies and 36 negative studies, doctors and patients saw 48 positive studies and three negative studies in the published literature (Turner, Matthews, Linardatos, Tell, & Rosenthal, 2008).

One might hope that bias could at least be restricted to the evaluation of products (Carrier, 2010). Unfortunately, scientific concepts and categories can also be altered in an effort to promote the profits of private companies. One of the most famous examples of this concern has been described by James Robert Brown (2002; see also Moynihan & Cassels, 2005). He notes how Eli Lilly developed a strategy for extending patent protection on its blockbuster antidepressant fluoxetine (marketed as Prozac). Lilly could keep the drug under patent longer if fluoxetine were found to be an effective treatment for another disorder. The company pushed hard for psychiatrists to recognize a new disorder, called premenstrual dysphoric disorder, which could also be treated by fluoxetine. More broadly, many physicians and ethicists have contended that pharmaceutical companies routinely push to expand disease categories to create larger markets of potential consumers for their drugs (Biddle & Kukla, 2017; Elliott, 2010; Fishman, 2004; González-Moreno, Saborido, & Teira, 2015; Moynihan & Cassels, 2005; Moynihan & Mintzes, 2010).

Concerns about the reliability of scientific knowledge extend beyond individual experiments to the social context in which scientific information is disseminated (Cosgrove, Vannoy, Mintzes, & Shaughnessy, 2016; Holman & Bruner, 2015, 2017; Jureidini, Amsterdam, & McHenry, 2016; Sismondo, 2007, 2009, 2017; Vedula, Goldman, Rona, Greene, & Dickersin, 2012). Such concerns dovetail with those of philosophers of science who claim that one cannot develop an adequate understanding of scientific epistemology without focusing on the social interactions among scientists (Biddle, 2007; Elliott, 2018; Holman, 2015, 2017; Intemann & de Melo-Martín, 2014; Longino, 2002; Rolin, 2017; Wilholt, 2009). In the environmental arena, companies have developed a variety of strategies for manipulating the spread and uptake of scientific information (Elliott, 2016a). For example, they provide funding for think tanks and front groups that spread their preferred scientific messages and that attack opposing messages, they fund conferences that explore their preferred ideas, and they create journals that are sympathetic to their perspective (Michaels, 2008). The tobacco industry pioneered many of these strategies, but they have been replicated by many other industries, including the petroleum industry in recent conflicts over climate change (Biddle & Leuschner, 2015; Markowitz & Rosner, 2002; Oreskes & Conway, 2010; Proctor, 2012; White & Bero, 2010).

Another common social practice is the restriction of access to data, materials, patented innovations, or other confidential business information. Many scholars have worried that the culture of corporate science clashes with traditional Mertonian norms, especially the norm of communal ownership and sharing of scientific information (Irzık, 2007; Krimsky, 2003; Radder, 2010b; Resnik, 2010; Sterckx, 2010). Though patents are supposed to facilitate openness and provide incentives for researchers to develop new innovations, researchers are sometimes hampered by “patent thickets,” where so many of the materials or necessary technologies are patented that they can hardly continue their research (Biddle, 2014a; Sterckx, 2010).

There are numerous other methods of manipulating the social context in which scientific information is produced, evaluated, and disseminated. For example, companies sometimes intimidate scientists in an effort to prevent them from spreading information that threatens their products (Elliott, 2016a; McGarity & Wagner, 2008). Similarly, industries have recently lobbied for legislation that would curtail federal agencies' ability to use and disseminate research; bar some independent scientists from sitting on peer review panels (without curtailing the recruitment of scientists whose funding is from industry); and redefine “best available evidence” in ways tailored to industry interest (Young, 2017). They also foster sympathetic scientists by funding their research; paying them to write editorials, articles, and even books; and making them “key opinion leaders” (KOLs) in educational and advertising campaigns (Elliott, 2010; Holman & Bruner, 2017; Krimsky, 2003; Moynihan, 2008; Proctor, 2012; Sismondo, 2013). In order to reduce public pressure for regulation, companies fund campaigns designed to manipulate the public's understanding of science by promoting the idea that much of environmental science is “junk science” because it fails to live up to standards of “sound science” and/or the idea that regulations should be delayed because there is still ongoing scientific debate (Elliott, 2016a; McGarity, 2003; Michaels, 2008; Ong & Glantz, 2001; Oreskes & Conway, 2010). Finally, as a consequence of their growing entanglement with the private sector, other institutions, such as universities, may be less able to serve the public interest (Krimsky, 2003).

4 | STRATEGIES FOR ADDRESSING WEAKNESSES

Scientists and philosophers of science have proposed a wide range of potential strategies for alleviating these epistemic concerns (see Table 1). This section organizes these strategies roughly in order of the problems that they are designed to address.

With respect to the problematic choice of topics and questions, one important insight of Sheldon Krimsky's (2003) *Science in the Private Interest* is that the division between intellectually motivated and profit-motivated research omits an important third category of *public interest science*. Unfortunately, there are many unanswered scientific questions that the public would benefit from answering but are neither intrinsically interesting to scientists nor potentially profitable to some private interest. (Indeed, often these questions threaten the profits of some private interest.) One solution to this problem is to create special incentives for doing public interest research that would not otherwise be profitable. This could include the Health Impact Fund proposed by Thomas Pogge (2009), advance market commitments, or prizes for developing innovations that serve disadvantaged populations (Elliott, 2017). However, it is unclear whether these strategies can be employed widely enough. Some problems may be irremediable, such as private companies amplifying preferred lines of research. Perhaps the best approach is to try to generate enough funding for public interest-oriented research to override the effects of industry funding (Elliott, 2011; McGarity & Wagner, 2008; Shrader-Frechette, 2007; but see Holman & Bruner, 2017).

With respect to the collection and analysis of data, the Good Laboratory Practices (GLP) record-keeping system may provide an important strategy for preventing outright fabrication and falsification of data (Conrad & Becker, 2012). However, it is doubtful that GLP and other efforts at standardization are adequate for addressing the more common problems of design bias and rhetorical presentation of study results, and standardization can lock outdated or questionable methods in place (Elliott, 2016b; Wickson & Forsberg, 2015). Another strategy is to create “firewalls” between those who design and perform studies and the private companies that fund them (Angell, 2004; DeAngelis & Fontanarosa, 2008; Krimsky, 2003; Volz & Elliott, 2012). In some cases, regulatory agencies can evaluate the interpretation of important studies, but they are often limited by time and money. Moreover, as seen above in the cases of Vioxx and antidepressants, publically available data can vary considerably from the information available to the regulator.

Other approaches to limit design bias and rhetorical abuses include creating collaborations with other stakeholders and requiring standardized protocols and reporting guidelines (Elliott, 2014; Moermond, Kase, Korkaric, & Agerstrand, 2016). Unfortunately, it is often unrealistic to expect companies to develop good-faith collaborations, and standardized study protocols have a number of limitations (Elliott, 2016b). Similarly, the effectiveness of reporting guidelines at addressing rhetorical abuses may be limited (Doucet & Sismondo, 2008).

Some cases of publication bias can be detected and remediated statistically (Holman, 2018). Better still, trial registries may be able to make such procedures unnecessary. Optimally, they provide records of all studies that are begun so that it is more difficult to hide results if they turn out to be unfavorable to the funders (Goldacre, 2012). While trial registries have a great deal of potential for addressing publication bias, their effectiveness depends on the details of how they are implemented. The current registry system in the United States is limited in a number of important ways: (a) it is not retroactive, so only new studies are registered; (b) compliance with the law is spotty at best; (c) some kinds of trials are not required to be registered; and (d) it requires only a summary of trial results rather than more detailed descriptions of the data (Goldacre, 2013; Goldacre, et al., 2016; Prayle, Hurley, & Smyth, 2012). What should not be lost is that registries are not an end in themseleves, but rather an infrastructure which facilitates audits of the available data. This, in turn, should lead to both a more accurate assessment of the reliability of the available body of knowledge by providing a window into what percent is publicly available and create pressure on poor performers by naming and shaming them (Goldacre, 2015). Recently, the AllTrials movement has launched "Open Trials," a collaborative open database project which aims to greatly increase the comprehensiveness and accessibility of public registries, and the FDAAA trial tracker which specifically aims at assessing compliance with the FDA's trial reporting requirements (DeVito, Bacon, & Goldacre, 2018; Goldacre and Gray, 2016).

With respect to the concern that scientific concepts and categories can be skewed, there appear to be few easy solutions. Some authors have called for the broader scientific community to challenge new concepts or categorizations that are questionable, though the effectiveness of this strategy depends on the availability of adequate venues for critically reviewing new ideas and taking up this criticism (see e.g., Elliott, 2018; Longino, 2002; Rolin, 2017). Numerous authors have argued that such venues are insufficient to combat commercial pressures in science (Biddle, 2007; Fernández Pinto, 2014; Jukola, 2015). Moreover, even when such venues become established, industry has been able to capture them to further their own aims (Holman & Geislar, 2018).

To some degree, limited access to confidential business information and patented innovations can be addressed by altering university policies and federal legislation. For example, universities can require that their investigators share research data and materials in a timely fashion even if they are receiving funding from the private sector, and they can pursue nonexclusive licenses for their patented innovations. Federal patent policies could also be altered in order to ensure stronger research exemptions and to lessen the probability of "patent thickets" that crowd out innovation (Biddle, 2014a; Biddle, 2014b; Brown, 2008; Irzık, 2007; Radder, 2013; Sterckx, 2010). In the medical domain, patent laws could be strengthened so that patents are granted only to drugs that offer significantly greater effectiveness, safety, or convenience over existing products (Angell, 2004). However, the potential for making significant changes to the patent system could be severely limited because of pressure from the private sector to protect their research investments.

The possibilities for lessening the private sector's influences on the social context also appears to be limited. Nevertheless, Tom McGarity and Wendy Wagner (2008) have argued that lawsuits could be used to discourage companies from engaging in particularly egregious activities, such as harassing other scientists or disseminating deceptive scientific information. Efforts by journalists, lawyers, and academics to uncover financial relationships between private companies and university scientists, physicians, think tanks, and front groups might also be somewhat helpful at discouraging and lessening problematic influences (McGarity & Wagner, 2008). Another strategy would be to provide aggressive public funding for research on sensitive topics so that there is an extensive body of high-quality research available that can overwhelm efforts to skew the scientific discourse (Elliott, 2011; Shrader-Frechette, 2007). In the extreme, all such research could be socialized (Brown, 2008, 2017).

5 | RECOMMENDATIONS FOR FUTURE WORK

This overview of scholarship on industry-funded research suggests several lessons. First, it is striking that most of the solutions discussed in Section 4 are not particularly promising. They are typically either limited in their potential to alleviate epistemic concerns or they are very difficult to implement effectively (Elliott, 2018). It is particularly striking that the most commonly proposed solution, disclosing financial conflicts of interest, is of very limited effectiveness in addressing most of the concerns mentioned in Section 3 (de Melo-Martín & Intemann, 2009; Doucet & Sismondo, 2008; Elliott, 2008). Thus, there is clearly much for philosophers of science to do in terms of diagnosing and addressing concerns in privately funded research.

In addition, it is important not to become too focused on individual problems without considering the full array of concerns. While in some cases there may be good solutions to individual problems, such as creating trial registries in response to publication bias, there is significant potential to “miss the forest for the trees” by focusing only on individual problems. For example, even if implementing GLP guidelines alleviated concerns about data falsification or fabrication, it would do little to address concerns about design bias or publication bias (Myers et al., 2009). Accordingly, one approach would be to develop a combination of many different solutions.

One such example is Justin Biddle's (2013) proposal for a “science court” in which controversial policy-relevant questions would be debated. Importantly, industry would be explicitly recognized as advocates rather than dispassionate fact-gatherers, this advocacy would be counter-balanced by a team of scientists that actively take the contrary position, and the process would be presided over by a group of scientists with no intellectual or financial stake in how the question is resolved. Beyond the court structure, Biddle also considers supplementary strategies which would be necessary to make the proposal work. These include the maintenance of researchers without conflicts of interest and other epistemic scaffolding such as trial registries.

An alternative is to approach industry-funding as part of an evolving system. Bennett Holman (2015) has argued that the dynamic between reformers and profit-oriented companies is an asymmetric arms race in which each party is constantly innovating to undermine the strategies of the other side. In subsequent work, he uses the arms race framework to evaluate policies to manage industry funding, suggesting three lessons (Holman & Geislar, 2018). The first is that policies should include means to assess when they have been undermined by an opponent's countermeasure. Next, policies must not only be reliable in addressing the problem at hand, they must be robust to foreseeable responses by the other side. Before implementation, researchers should assess robustness by trying to think like industry and devise ways to undermine the proposed solution; a proposal that can be easily circumvented should not be implemented even if it would be effective in the short run. Finally, the most durable solutions often change the underlying incentive structure driving the interaction. As long as epistemic and financial goals run at cross purposes, there will be continued pressure to undermine reform.

Following up on this insight that underlying incentive structures need to be examined, it may be at least as important for philosophers to focus on identifying the conditions in which epistemic concerns are most likely to arise rather than focusing their attention solely on how to solve them (Elliott, 2014). For example, when industry is funding early-stage research to develop new products, such as the magnetic sensor technology described in Section 2, there may be less reason for epistemic concern than when industry funds research to fight environmental liability or regulations. Similarly, when it is relatively easy to assess the success or failure of research (such as in the case of consumer products that clearly work properly or malfunction), industry funding may be relatively unproblematic. However, when companies have very strong financial incentives to obtain results that are favorable to their products, it may be almost impossible to prevent them from having a negative impact on the epistemic quality of research. In such cases, perhaps the most important role for the philosophical community is to highlight potential problems with the research and to explore ways to promote effective critical interaction within the broader scientific community. In other cases, where there are fewer incentives for generating misleading research, it may be much easier to develop effective solutions and maximize the benefits of industry funding.

6 | CONCLUSION

Ernst Mayr would now be quite at home at a philosophy-of-science conference, and the discipline has been strengthened tremendously by the broadening of its scope. We believe that the same potential exists today in the study of industry-funded science. While there is still work to do in identifying the weaknesses of industry-funded research, there is an especially strong need to develop our collective understanding of the benefits of industry-funded science. Without doing so, critiques will remain somewhat provincial. Philosophers who prefer to work at some remove from the rough and tumble world can still improve our understanding of the conditions under which industry produces reliable science so that we can structure our scientific institutions to maximize the benefits of this research. Those who value public engagement and who take the time to understand these issues can play a vital role in society by helping public interest groups deconstruct biased science; such an opportunity offers a profound sense of meaning to "doing philosophy." It is our opinion that we could use much more of both.

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ENDNOTES

[1] See Mirowski and Sent (2002) for a concise history of the economic organization of science. The present changes are significant enough to engender a debate on whether there has been an "epochal break" from science as practiced previously (Carrier, Howard, & Kourany, 2008 [esp. part 3]; Carrier & Nordman 2011; Nordmann, Radder, & Schiemann, 2011; Radder, 2010a).

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