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Responsible innovation: A primer for policymakers

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EXECUTIVE SUMMARY

Technical change is advancing at a breakneck speed while the institutions that govern innovative activity slog forward trying to keep pace. The lag has created a need for reform in the governance of innovation. Reformers who focus primarily on the social benefits of innovation propose to unmoor the innovative forces of the market. Conversely, those who deal mostly with innovation's social costs wish to constrain it by introducing regulations in advance of technological developments. We argue here for a different approach to reform the governance of innovation that we call *responsible innovation* because it seeks to imbue in the actors of the innovation system a more robust sense of individual and collective responsibility.

Responsible innovation appreciates the power of free markets in organizing innovation and realizing social expectations but is self-conscious about the social costs that markets do not internalize. At the same time, the actions it recommends do not seek to slow down innovation because they do not constrain the set of options for researchers and businesses, they expand it. Responsible innovation is not a doctrine of regulation and much less an instantiation of the precautionary principle. Innovation and society can evolve down several paths and the path forward is to some extent open to collective choice. The aim of a responsible governance of innovation is to make that choice more consonant with democratic principles.

We present responsible innovation as an incremental program of reform and we illustrate its implementation with three practical initiatives:

Industry: Incorporating values and motivations to innovation decisions that go beyond the profit motive could help industry take on a long-view of those decisions and better manage its own costs associated with liability and regulation, while reducing the social cost of negative externalities. Consequently, responsible innovation should be an integral part of corporate social responsibility,

considering that the latter has already become part of the language of business, from the classroom to the board room, and that is effectively shaping, in some quarters, corporate policies and decisions.

Universities and National Laboratories: Centers for Responsible Innovation, fashioned after the institutional reform of Internal Review Boards to protect human subjects in research and the Offices of Technology Transfer created to commercialize academic research, could organize existing responsible innovation efforts at university and laboratory campuses. These Centers would formalize the consideration of impacts of research proposals on legal and regulatory frameworks, economic opportunity and inequality, sustainable development and the environment, as well as ethical questions beyond the integrity of research subjects.

Federal Government: Federal policy should improve its protections and support of scientific research while providing mechanisms of public accountability for research funding agencies and their contractors. Demanding a return on investment for every research grant is a misguided approach that devalues research and undermines trust between Congress and the scientific community. At the same time, scientific institutions and their advocates should improve public engagement and demonstrate their willingness and ability to be responsive to societal concerns and expectations about the public research agenda. Second, if scientific research is a public good, by definition, markets are not effective commercializing it. New mechanisms to develop practical applications from federal research with little market appeal should be introduced to counterbalance the emphasis the current technology transfer system places on research ready for the market. Third, federal innovation policy needs to be better coordinated with other federal policy, including tax, industrial, and trade policy as well as regulatory regimes. It should also improve coordination with initiatives at the local and state level to improve the outcomes of innovation for each region, state, and metro area.

1. INTRODUCTION: CAN THE SOCIAL OUTCOMES OF INNOVATION BE IMPROVED?

The strength of the American economy resides not just in its impressive size but also in the vigor of its innovation system. Aware of this premise, policymakers, industry bosses, and the leaders of science have been debating how to foster a *governance of innovation* that enables the smooth operation of markets, encourages the most creative research and entrepreneurship, and promotes the best outcomes of innovation while mitigating its worst social and environmental costs. A number of projects to reform the governance of innovation have emerged out of this debate, locating themselves somewhere between two poles: on one end the *precautionary principle* and on the other, of more recent coinage, *permissionless innovation*. Endorsed by UNESCO's World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), the precautionary principle councils that "when human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm" (COMEST, 2005, p. 12). Action, such as regulation, is thus recommended in the face of plausible harm, even when the probability of an adverse effect cannot be estimated. In contrast, permissionless innovation, born from a yearning for an unadulterated liberal disposition towards innovation, cautions that "ex ante (preemptive and precautionary) regulation is often highly inefficient, even dangerous" and "likely to come at the expense of innovation and growth opportunities" (Thierer, 2014, p. 75).

We argue here for a new approach to reform the governance of innovation. We refer to this project as *Responsible Innovation* (RI) because it seeks to imbue in the actors of the innovation system a more robust sense of individual and collective responsibility. RI, like permissionless innovation, appreciates the power of free markets in organizing innovation and realizing social expectations but differs with it in being self-conscious about the social costs that markets do not internalize. RI is not a doctrine of regulation and much less an instantiation of the precautionary

principle; the actions it recommends do not seek to slow down innovation because they do not constrain the set of options for researchers and businesses, they expand it. RI considers innovation inherent to democratic life and recognizes the role of innovation in the social order and prosperity. It also recognizes that at any point in time, innovation and society can evolve down several paths and the path forward is to some extent open to collective choice. What RI pursues is a governance of innovation where that choice is more consonant with democratic principles.

Why, one may ask, do we need to tinker with the governance of innovation? The answer is that the social outcomes of innovative activity are at the same time beneficial and taxing to society. Innovation has effectively raised living standards, improved health and increased lifespans, and contributed to military pre-eminence; it has also introduced risks to public health and safety, contributed to environmental degradation, and created social instability. Innovation has created new industries and with them new jobs, and in its wake the new economy has displaced entire industries and their workers. Moreover, the distribution of the social benefits of innovation does not always mirror the distribution of its costs: Innovation exacerbates economic inequality at least as often as it mitigates it. Innovation does swell the waters of the economy, but not all boats rise equally with this tide.

This duality of innovation invites, but does not answer, the question of whether the outcomes of innovation can be improved. A group of scholars and practitioners of innovation working under the banner of *Responsible Innovation* enthusiastically responds in the affirmative. The central concepts and motivations are stated in the seminal papers by Guston et al. (2014), Owen, et al. (2012), and Stilgoe et al. (2013), and two edited volumes by Owen, Bessant, and Heintz (2013) and Von Schomberg (2011), while further elaboration is ongoing, notably, in the pages of the year old *Journal of Responsible Innovation*. RI is at once a project of social inquiry into the innovation system and a normative project to improve its outcomes.

Policy is of course but one ingredient of governance. The other elements become apparent when considering the extent of the innovation system, which sits at the intersection of two massive social enterprises—the system of knowledge production and the market system. It is daunting to begin to appreciate the sheer multitude of actors in innovation, their heterogeneity and dispersion, and the organizational complexity of their interaction. The invisible hand of the market does organize a large portion of the transactions among these actors. But there is also an extensive web of incentives and constraints designed by the visible hand of public and private organizations, including laws, rules, and traditions, as well as standards, practices and patterns of organization. As Nobel laureate Oliver Williamson said of the economics of governance: “the widely celebrated ‘marvel of the market’ …joined the hitherto scorned ‘marvel of hierarchy’” (Williamson, 2005). Taken together, these market and extra-market institutions constitute the governance of innovation (see a useful conceptual framework in Borrás and Edler, 2014). Efforts to modernize the innovation policy regime may not suffice to adequately promote innovation; these governing institutions, mechanisms, and networks, as a whole, need to be taken into account.

Before describing the nature of the responsible innovation project, two caveats are in order. First, as a project of inquiry, RI seeks to identify and characterize the role of economic and political institutions critical to innovation. As a project of reform, it targets precisely these key institutions—e.g., science and technology (S&T) policies, practices and protocols in laboratories and board rooms, cultural understandings about the relationship between science and progress, codes of conduct of professional associations—and seeks to modulate the policies, public discourse and pedagogy of innovation in order to promote a cultural change in the worldviews, ideologies, and values that undergird its governance.

Reforming the governance of innovation is a tall order for RI advocates. How far can reform go? To answer that question, it is important to start by recognizing that the U.S. innovation system is highly resilient to shock. Decentralization and diversity, both among actors and institutions, is an important source of this resilience. Surely, innovative activity is susceptible to the upheavals of the business cycle, national politics and international conflict, all the while being sensitive to the waves of new knowledge flowing from emerging fields of science and engineering. Still, scarcity, recession, and red tape are known to inspire ingenuity and spur entrepreneurial spirits into action. Shocks are often produced by innovation itself, and disruption has become for some techno-enthusiasts their very aim. The resilience of the innovation system means that one might expect no more than incremental change through institutional reform. But it is also worth noting that RI is now an item on the international agenda, and innovation systems are not limited to national boundaries. The European Union as a whole and several of its constituent governments have established various research and practical frameworks that have an impact on the transnational character of research and innovation systems. Moreover, given the complex and systemic nature of innovation, one must still recognize the possibility that incremental adjustment could yield more than incremental change in outcomes.

In the following sections, we introduce responsible innovation as an approach to manage three enduring tensions in the governance of innovation: between self-organization and purposeful direction, among the market, networks, or hierarchies as means of organization, and between the roles of expert participants and lay-citizens. We then describe five general characteristics of projects of responsible innovation: anticipation, reflexivity, responsiveness, deliberation, and inclusiveness. Finally we close by recommending practical applications of these principles and practices for industry, universities and laboratories, and for federal innovation policy.

2. THREE TENSIONS IN THE GOVERNANCE OF INNOVATION

RI can be understood by elucidating its role in managing what political scientist Susana Borrás has identified as the three enduring tensions in the governance of innovation (Borrás, 2012). The first is between autonomy and the politics of purpose, that is, a tension "between the scientists' and the technicians' own organizational rules, and the state's interest in using science and technology" to advance national goals such as "defence, economic growth, public health, and others" (idem, p. 431). The second strain is about coordination mechanisms; it is a tension between decentralized organization—such as that of networks of knowledge production and the markets—and hierarchical organization also common in both the public and private sectors. The third tension is inherent to the role of citizens and the role of scientific experts in innovation decisions because different normative conceptions of democracy—e.g. participatory or representative—as well as different arrangements currently in place in functioning democracies, prescribe different expert-citizen interactions.

The first two tensions are dimensions of the question of authority over innovative activity. Who has authority or how authority is allocated among actors? What is the vehicle or regime through which authority is exercised? Entrepreneurs and researchers like to assert their capacity for self-regulation as participants in the market system or as members of the scientific guild, respectively. The government in turn can assert its authority as the patron of research performers, as the trustee of the public interest, or as arbiter that adjudicates disputes and clarifies rules for private advocates. Authority corresponds to a patronage relationship when the government supports innovation by contracting research and development (R&D) services—a significant source of funding for innovative activity—and by extending subsidies and tax incentives. In exchange for this support the government expects to keep some degree of control on direction and performance of R&D. A second form in which the government exercises its authority is acting as a trustee of the public interest; for instance, intervening in the market or in the scientific process to protect

public health or safety. Yet a third form is by clarifying law via administrative dispositions or court rulings; authority in these cases is adjudicative among interests and parties.

The claims from the worlds of research and business are analogous but distinct. Scientific research has enjoyed significant support from the U.S. government since the World War II demobilization and has kept significant latitude to self-regulate. The duplet of generous financial support for science and its self-regulation, called *blind-delegation*, has in practice never been completely blind because the federal government sub-delegates the task to federal agencies by assigning them research funds, and they in turn allocate the funds to projects aligned with their respective missions. Therefore, the government exerts a degree of political influence over the research agenda while, at the same time, agencies assign and assess research grants and contracts through hiring or subcontracting the services of scientific experts who by and large enforce peer-review and other scientific norms and standards. Perhaps the only agency not driven by an explicit mission is the National Science Foundation, which receives a paltry 4 percent of total federal R&D outlays and is nevertheless both increasingly seen as an innovation agency and subjected to political scrutiny for alleged failures to address national goals in each and every of its programs and grants. Governmental authority has also adjusted aspects of the scientific process, for instance, the National Research Act of 1974 (PL 93-348 and its regulations in FCR§45¶46) mandate safeguards for human research subjects in response to abuses including the infamous Tuskegee syphilis studies (Fisher, 2007).

In recent years however, political polarization, tighter budgets, and a tendency to operationalize public accountability as performance measurement have led policymakers to demand the scientific establishment to better justify the public largesse it enjoys. The demands from legislators have not always been reasonable. Identifying and lampooning individual research projects—as the former Wisconsin Senator William Proxmire did with his "Golden Fleece" awards—or asking researchers to link every research project to economic growth and job creation (see HR 1806 which is likely to pass in the House) disregards the fact that a research project cannot be directly mapped onto aggregate economic indicators; rather, individual projects contribute indirectly as integral parts of a body of knowledge which only taken together yields economic returns. The response to such demands has not always been wise, either. Too often the scientific establishment has recoiled defensively responding in a tone that presumes that the scientific enterprise would be ineffectual if it were to pay heed to concerns articulated from the outside.

Responsible innovation considers academic freedom paramount to a democratic society and construes this freedom—as most freedoms ought to be construed—as not unlimited and occasionally in conflict with other important values. This perspective legitimizes the competing claims to authority not by creating a division of labor that maps onto different authorities, but by recognizing explicitly the various considerations that research must internalize.

One might be tempted to argue that experts should retain decision on all technical questions of innovation insofar as they defer social questions to public authority. In fact, not that long ago, one of the most astute observers of science and public affairs, Don Price, proposed that a division of innovative labor among scientists, technical professionals, and public officials was adequate for a democratic society (Price, 1965). His proposal, contrary to shielding science from purposeful service to society, sought to organize it to achieve social aims that would be set by legitimate political power while keeping science's internal organization unsullied by politics. In principle, this design should work well. In practice, however, science is regularly implicated in the quarrelling of political parties when called to inform public policy (Jasanoff, 1998) and historical and empirical studies of the organization of science have shown science to have politics itself—like all social activity, reason is not the only logic governing science's organization (the ample literature on this perspectives is referenced in Hacket, et al., 2007 and Jasanoff et al., 2001).

Public values such as the commercial worth of academic research have already been exerting a subtle but powerful influence on quotidian decisions in the laboratory (Kleinman, 2003). Why then not make routines, practices, and lab management more self-aware about the external values that influence laboratory life? This suggestion is far less radical than it sounds because it is not proposing any specific change of behavior, but rather a new way for scientists to think about their research decisions. The modest proposal of responsible innovation is to add a habit of thought in the laboratory, the reflexive incorporation of broader considerations. A new habit needs learning and practice to take hold. The pedagogy proposed by responsible innovation as training the social imagination of researchers so that their self-knowledge, their identity, expands from that of a denizen of its discipline to a citizen of the larger society.

If the question of authority in science is about setting the research agenda and using peer-review to allocate and evaluate research grants, the question for businesses in a free market economy is the authority to set constraints on new production processes or on the production and commercialization of new products. Most of the design of new products is entirely left to private initiative. Yet, when product development is itself regulated by statute, it is primarily in response to serious risks observed or actual harm on record. Take for instance the close regulation of drug development, a regime built incrementally in response to tragedy and public health scares (Carpenter, 2011). Environmental impact assessments began only in the 1970s; before that time, for example, the energy sector was not required to manage the public impact of their projects—with the telling exception of nuclear power, where innovation was closely regulated because both a clear and present danger for public safety and the potential for turning the technology into a weapon (Aron, 1998).

Responsible innovation proposes a cooperative solution to manage the tension between the private sector and regulators. Specifically, it expands the notion of "market failure"—that grants the government authority to intervene in free markets over areas in which the price system fails—to include "public value failure" or situations in which the innovation system fails to deliver outcomes consistent with widely held public values, even when the market system works (Bozeman 2007, Bozeman and Sarewitz 2005, 2009). The market success of innovation does not guarantee public value success, that is, the furtherance or preservation of widely accepted public values—such as safety, privacy, and choice. Fraught with paradoxes and trade-offs, innovation has, at once, advanced and undermined public values dear to democratic societies.

Consider an example of privacy: With so much of our personal information stored online, surveillance of our actions and preferences has become technically easier. The Snowden disclosures that the government collects metadata fueled a scandal, and yet the open secret that online businesses regularly collect personal data to better target their marketing to each user has been received with far less public dismay. The asymmetry of the public's reaction may be expected in a political culture that is skeptical of government and friendly to private initiative, but what is truly surprising, however, is that no level of scandal has changed our online privacy habits; as a collectivity, we are just as likely as ever to air unedited opinions and private matters in social media as before. An analogous example can be drawn from the perceived value of safety. Safety devices are added to our most familiar tools and gadgets inducing psychological complacency; under the illusion of greater safety because of the device, we tend to lower overall alertness and therefore undermine our general safety. Automobile rearview cameras designed to show blind spots behind the cars are now suspending the habit of drivers to turn backwards when backing up. Likewise, innovation has enabled the rise of customization as a standard in many businesses. Such is the case of the ubiquitous mobile phone, whose original function of verbal telecommunication has become secondary to the other uses we lodge in that platform. It is that wide range of other services—from geolocation, to health monitoring, to video recording—that enables us to customize our phones to such a degree that no two devices in use, of the same brand

and model, are likely to be the same. Yet, many users find the shopping experience in the immense market of apps to be overwhelming because, ironically, large choice-sets lead people to doubt their own decisions when compared to small choice-sets where preferences are clear and decisions reassuring (Schwarts, 2004). The market success of the app economy in providing ample choice-options may be the very reason for its failure in enabling choice.

Paradox and contradiction amplify the differences of interpretation and application of public values in specific contexts of innovation decision-making. This is the source of the third tension shaping the governance of innovation—between the role of experts and the role of citizens—because the division of innovative labor leaves it to each actor the task of internalizing (or not) public values into their own decisions. Experts see their role as ruling over their parcel of the innovation ecosystem. Citizens in turn are not required and rarely invited to give their input on innovation decisions; that is not their territory, and they must remit to express their values as consumers only. But if the received wisdom is true—that technological change is revolutionary—it begs the question of how democratic this revolution is. If citizens are not participating in the development of technologies that will re-shape the social landscape – but their role is never more substantive than consumer of final products – are they practicing the full extent of their political rights? Responsible innovation rejects the notion that citizens must play only the role of consumers of innovative new products, even while it recognizes the significant efficiency of the market system in conveying public values to product development decisions. In this respect, responsible innovation is also incremental rather than radical because it proposes to add incentives for actors to expand the scope of considerations to the existing political economy of innovation. Responsible innovation advocates for an expansive view of the proper set of considerations, but it does it so recognizing that such broad considerations will only happen when the actors of innovation see a benefit for themselves and their work to do so. They will take a long view in their decision-making processes if they have adequate incentives to do so.

Here are two examples of how certain incentives have brought to bear public values to the work of distinguished researchers and successful entrepreneurs. In the early stages of designing a new product, private firms bring focus groups composed of potential customers to study their responses to various proposed designs. The ultimate aim of capturing new markets or expanding their market shares drives them to consider values outside of the firms' equation; for instance, popular aesthetics, usability, and affordability are things not inherent to the research agenda or the cost structure of businesses, but they become relevant and even determining. This importation of external considerations is also practiced by the distinguished scientists who are called on to offer their advice to Congress or to the National Academy of Sciences. The prestige afforded to them for participating, as well as the inherent reward of doing a public service, are strong enough incentives for most scientists to contribute their time and effort. Preparing their advice, they must carefully consider their technical knowledge in the larger context of matters of public concern. If customers signal a preference for sustainable practices, industry responds by catering to that market niche. If policy recommendations of an expert panel seem too unfeasible or controversial in the political realm, they are rethought or at least rephrased in order to be more effective in conveying a message to legislators. These are examples of external values that industry and science internalize in order to be effective in business or when providing policy advice.

We have developed thus far an intuition as to how RI will manage the enduring tensions described above. We can now take this intuition a step further and formalize the practices that characterize responsible innovation.

3. FIVE PRACTICES OF RESPONSIBLE INNOVATION

Initiatives to implement responsible innovation share five intersecting characteristics: anticipation, reflexivity, deliberation, inclusiveness, and responsiveness (Owen, et al., 2013; Stilgoe, et al, 2013).

We premised RI on the fact that all innovation creates both beneficial and unwelcome effects and yet decisions must be made in the face of great uncertainty about the intended and unanticipated consequences of innovation. We intimated as well that a central motivation of RI is to balance the competing interests of innovation and that in order to accomplish this task, RI seeks to incorporate public values—that are widespread and relevant but often excluded—into key innovation decisions. In other words, RI initiatives have two dispositions, the first toward action under uncertainty and the second toward learning the relevant considerations needed to inform action. Anticipation and reflexivity are features of RI projects that translate these dispositions into practice.

It is easier to understand *anticipation* in contradistinction to *prediction*. Prediction, informed by a strong body of knowledge in applied statistics, is a tool used in all sciences and sometimes is even considered their aim. When decision-makers adopt prediction as a paramount consideration, wittingly or not, they thus bestow on their decisions the cultural authority of science. For this reason, decision-makers in public and private organizations have made prediction a requisite condition before taking preventive action. Yet, there are several problems with requiring predictions in decisions concerning innovation. The first challenge for prediction in innovation is that prediction depends on historical data, while the social impacts of new fields of knowledge and new technologies are, by definition of new, lacking in historical data. Moreover, the history of innovation has shown that its effects are transformative at a macro-social scale; therefore, the stable structure on which predictive models are built is rendered fluid by the very phenomena to be predicted. Further complicating the use of prediction in innovation, the level at which predictions are useful to inform decision making of organizations is not atomic but systemic (Sarewitz and Pielke, 1999); as models add the parts of a system arithmetically, uncertainty compounds (Meyer, 2012), and confidence intervals expand geometrically (see also Oreskes, 2000). In addition, even when historical data begins to accumulate, there is still an irreducible uncertainty inherent to the future (Stewart, 2000) that is amplified by the transformative character of innovation. The usefulness of prediction in innovation is further in doubt because of the growing list of cases in which prediction has failed to counsel sensible preventive measures; either the Cassandras are ignored (financial bubbles, Hurricane Katrina) or confident scientific predictions of doom fail to realize (the Year 2000 panic or the impending Northern California earthquake) (see cases in Sarewitz and Pielke, 2000).

If innovation is indeed revolutionary, we cannot afford to invest our scarce resources in the weak promise of prediction. That is why anticipation stands as an alternative. Put simply, anticipation counsels that in the face of uncertainty about future consequences, we invest our energy in developing our individual and collective capacities—as citizens, organizations, communities, and as a polity—to withstand shock and adapt to a changing environment. We should think of anticipation as building adaptive capacity, cultivating resilience, enhancing preparedness, for the preservation of democratic life and those values that enable societies to prosper. If innovation is indeed revolutionary, then we need to anticipate its impact on our very conception of democracy.

It is important to note that anticipation is concerned with the plausible futures (Ramirez and Selin, 2014) that emerge from innovation. For this reason, stewards of anticipation need a careful understanding of emerging science and technical fields and their interaction to society in order to discipline the imagination of those plausible futures. In contrast with prediction, anticipation does not put an impossible requirement of knowing the future with probabilistic precision before taking action; instead, understanding plausible developments from innovation is sufficient to guide

our capacity building efforts. The more we know about emerging sciences and technologies and their societal impacts, the more we can refine those plausible scenarios of the future, but the honing of resilience and adaptive capacity is an ongoing project from the start.

Responsible action is warranted in spite of our temporary technical ignorance and uncertainty about the future because the knowledge necessary for resilience is that of our own collective capacities to adapt. How to acquire this knowledge? What disposition is required to understand our collective resilience? RI proposes *reflexivity* as the practice of individuals and organizations to situate themselves in their socio-technical context. As institutional practice, reflexivity means that organizations must probe their own innovation procedures and goals and go even further to examine their very methods of self-evaluation. It also means that organizations must submit to scrutiny the received assumptions and pre-conceptions about the moral division of innovative labor (Swierstra and Rip, 2007).

In order to cultivate a social self-awareness, individuals and organizations from both research and business, are advised to practice self-examination. Questioning, for instance, the motivation of a given research grant application should help researchers think beyond the publication of their findings. Likewise, questioning the impacts of a new production process may help entrepreneurs plan beyond the next round of capital investment, for instance, to envision sustainable processes for mass production of a successfully tested prototype. Taking a longer more expansive view than what has been hitherto habitual should make decisions more robust in terms of being more responsive to public values, in addition to intellectual merit and commercial success. Technical understanding gives experts a sense of the importance of their research within their discipline or field of application; reflexive understanding gives them a sense of its importance to society. Business acumen gives the firm a clearer picture of the commercial prospects of a new product; reflexive understanding opens the entrepreneurial imagination to the potential uses of that product, to the asymmetries in its diffusion and adoption, and to its cultural resonance.

In addition, considerations of social, political, or ethical order will reveal to the actors of innovation trade-offs and opportunities at key junctures of the innovation activity that were not evident to them when considering merely technical or financial questions. In expanding the scope of considerations in innovation decisions, RI seeks to include concerns beyond the traditional questions of intellectual merit and commercial success, and to be responsive to those public values and societal expectations. This begs two questions: To whom must innovation be responsive? And, how to go about having those values bear on key innovation decisions? RI responds to these questions through *inclusiveness* and *deliberation.*

While organizational introspection is part of reflexivity, the actors of innovation will not readily identify their own blind spots in their decision-making; responsibility demands considering other stakeholders perspectives in a public forum (Wynne, 2011). To this effect, RI recommends the vehicle of deliberation to give voice to stakeholders and to promote the exchange of ideas. Incorporating those concerns will help innovation decision-makers to better balance competing interests and values.

There is a significant amount of intellectual work devoted to envisioning modes of deliberation that reconcile democratic aspirations with practical constraints (see reviews in Mutz, 2006; and Carpini et al., 2004). However, RI can draw from existing institutionalized deliberative practices, for instance, those of the Danish Board of Technology Foundation that pioneered the *consensus conference*, a deliberative exercise that gathers lay citizens to engage and discuss emerging technologies and make suggestions on their development. The Board was supported by the Danish ministry of education until November of 2011 and continues to work as a not-for-profit organization since

June 2012. In addition to consensus conferences, other methods used in the deliberation of sustainability research include citizen juries, deliberative mapping and deliberative polling (see Chilvers, 2010) as well as focus groups, partnerships (such as university-industry ventures), and balancing the composition of decision/advisory bodies (in this case, adding lay citizens to scientific advisory committees).

Who should participate in deliberation? Whose values count? Under RI, the guiding principle is inclusiveness. The ideal of including all stakeholders of an innovation project who have a legitimate concern is somewhat unrealistic; many stakeholders will not have the inclination, time, or resources to engage arcane scientific debates or controversies in product design. For that reason, inclusiveness in practice entails an effort to represent all relevant views in deliberation (see for a discussion Brown, 2002).

Innovation decisions can be *responsive* to stakeholder values and expectations by introducing appropriate opportunities and incentives for the actors of innovation to internalize those values. An example of institutionalized responsiveness is the Administrative Procedure Act (APA) of 1946 (PL 79-404), which requires federal agencies to publish proposed rules in the Federal Register in advance of their implementation and to invite public comments. The law does not require agencies to modify their rule or directly respond or address comments, but agencies do so acting with the aspiration of being responsive to public concerns and at the same time to shield themselves from possible court challenges to the rule in question. In a similar manner as agencies acting under the APA, and without making the outcomes of the consultation binding, private organizations could be encouraged to adopt as a standard practice the submitting of significant research and innovation programs to public consultation. Critics of APA may point out that this mechanism makes federal agencies responsive only to well-organized and well-funded interest groups and that a non-binding consultation further alienates powerless interest groups. There is some merit in this critique; however, in some important instances, public minded agencies have been deferential to concerns raised by less-powerful or marginalized interests.

Professional scientific associations could benefit from a public dialogue on the social impact of their research. Likewise, private firms or trade associations could be more responsive to extra-market concerns if they added substantive deliberation on social issues and concerns to trade expositions and fares where the debates would add to the gloss of products coming to the market as well as the futuristic prototypes in display.

A good example of the institutionalization of responsiveness and the implementation of the aforementioned practices of responsible innovation is the “stage-gate” review process on a project called Stratospheric Particle Injection for Climate Engineering (SPICE). The UK’s Research Councils funded the project as well as the review process. The project consisted of testing the technical feasibility of a method to spray a water aerosol at high altitude. The ultimate aim of the project was to explore a rudimentary technical capacity to increase the reflection of the earth’s surface, by spraying a reflective aerosol in its stratosphere, as this technique may become an effective and inexpensive method to engineer the earth’s weather and thus to reduce global warming (Keith, 2013). Stage-gate is a method used by business in the development and commercialization of new products and consists of a sequence of stages through which the product advances progressively. Before crossing a gate from one stage to the next, a product needs to meet certain criteria. Inspired by responsible innovation, five criteria were set for the SPICE experiment to cross the “gate” that included all the characteristics just discussed. The review of September 2011 recommended postponing the experiment given that only two criteria were met—identification of acceptable risks and regulation compliance—while three other criteria had not yet been fully satisfied—clear communication of the project goals

to the public, a description of future impacts and process to assess those impacts, and understanding stakeholder views. The reviewers did not think anticipation, inclusion, and deliberation had been fully served (Stilgoe et al., 2013).

Before the stage-gate review was released, the SPICE team had announced the imminent conduct of the experiment, angering concerned members of the civil society. A total of 50 NGOs demanded in a letter to the Secretary of State for Energy and Climate Change the cancellation of the experiment. Adding to the suspicion of skeptics, a team member had filed a patent for a technology to be used in the experiment, raising questions about a financial conflict of interest. Under pressure, the SPICE team decided to abandon the experiment (Cressey, 2012; Editor Nature, 2012). Had the SPICE team not rushed to declare the imminence of the experiment, and had it later followed the stage-gate review recommendations, it is not altogether improbable that the experiment could have eventually taken place.

With the application framework of RI introduced and illustrated, we can now offer a few practical recommendations for the institutions of the U.S. innovation system.

4. INITIATIVES AND OPPORTUNITIES.

Any program to reform the governance of innovation, including responsible innovation, must go beyond the federal government and carefully consider how it will resonate with the business and research communities. A look at the national research and development (R&D) expenditures hints at the relative importance of these actors to innovation. Industry performs 70 percent of national R&D, universities perform nearly 14 percent and federal laboratories 12 percent (see Table 1).

Table 1. US R&D Expenditures (2007 v. 12)
(In $ billions)

Sector	2007		2012[a]	
	$ Bn	%	$ Bn	%
All performing sectors	380		453	
Business	269	70.8	317	70.0
Federal government	44	11.6	55	12.1
Universities and colleges	51	13.4	63	13.9
Other nonprofit	15	3.9	18	4.0
All funding sectors	380		453	
Business	247	65.0	285	62.9
Federal government	107	28.2	135	29.8
Universities and colleges	11	2.9	14	3.1
Nonfederal government	3	0.8	4	0.9
Other nonprofit	12	3.2	15	3.3

Source: NSF (2014). Note: 2012 is preliminary data.

Furthermore, businesses are the main recipients of federal R&D funds, with 41 percent of the portfolio, compared to the combined receipts of universities (22 percent) and federal laboratories (25 percent)—and this is excluding Federally Funded R&D Centers that perform an additional 7 percent of the federal funds (NSF, 2014). Let's then consider initiatives to promote responsible innovation within industry and within universities and national labs and then we will return to federal policy.

4.1 INNOVATION IN CORPORATE SOCIAL RESPONSIBILITY

There are two primary avenues to promote responsible innovation in industry: economic incentives and a change in business culture. *Corporate social responsibility* (CSR) combines both mechanisms.

CSR has evolved from a call for business managers to act as moral agents (Ackerman and Bauer, 1976) to entering the regular business ethics curriculum (Donaldson and Dunfee, 1994; Jones, 1991) to a set of strategies to gain and retain a "license to operate" from society (Post, Preston; Sachs, 2002). More recently scholars have reformulated CSR as a business theory that causally connects good *stakeholder management* to profitability (Freeman, 1984). The promise of long-term profitability (Serafeim, 2014; Burke and Logsdon, 1996) has promoted wider acceptance of CSR in the business community. This formulation, we may hazard, combines the profit motive with cultural change.

Current debates about CSR, however, discuss innovation only in two general contexts: entrepreneurial action aimed at social causes—hence the new idiom of *social entrepreneurship*; and innovation driven by an environmental consciousness, in particular, innovation in *clean technologies*. Both cases are good examples of responsible innovation insofar as businesses internalize public values including affordability of new necessities, access to healthcare, and reduction of carbon emissions. However, both cases are emerging forms of entrepreneurship—ideas with great potential but that are small relative to the totality of innovative activity. CSR must be extended to innovation in emerging technologies in order for responsible innovation to influence both new entrants and incumbent firms working at the forefront of innovation.

One good example is nanotechnology. Ample opportunity can be observed for applying CSR to the development of nano-enabled products (see Table 2). One study found that older and larger firms participating in the Environmental Protection Agency's voluntary program for Nanoscale Materials Stewardship were more likely than start-ups to volunteer information about their product development for public consumption (Kuzma and Kushabekova, 2011a). This finding is not surprising, given that start-ups may err on the side of caution about secrecy to preclude susceptibility from potential investors while more established firms can tap in a greater variety of funding sources for their new products and allow themselves to make public some product development data.

Table 2. CSR in emerging nanotech companies

Public Values of Concern	Relevant firm activities	Possible firm responses
Health and environmental impacts	Waste management, conduct of environmental impact studies, safety studies, dissemination of information about risks and benefits	Adoption of voluntary standards or risk management frameworks for nanotechnology; participation in national or international data sharing programs; commission independent impact studies
Occupational health and safety	Workplace environment, job stability, competitive wages, internal policies for good work environment.	Internal research on workplace exposure and risk; adopt and use worker-protective equipment; collaboration with OSHA on standards setting
Public transparency	Classification of business information (public/secret). Dissemination of public information.	Publish on website the general types of products on market and results of safety studies; core meetings with stakeholders about activities
Conflicts of interest in safety studies	Conduct of safety studies. If regulated, product approval applications (e.g. clinical trials).	Funding independent consultants to conduct safety studies and opening them out to external peer-review
Ethical concerns about tampering with nature	Decisions to proceed with certain applications of nanotechnology, such as human enhancement, genetic alterations, and nano-machines	Host wider societal dialogue and engage the public early in product development. Incorporate public views into decision making about product development.

Source: Excerpted from Kuzma and Kushabekova (2011b)

Capital investment is another area where CSR practices can shape innovation. Over the last two decades, a new type of financial capital has become available: sustainability-investment vehicles, also known as "green funds." Internalizing the values of individual investors concerned with sustainability, portfolio managers have developed mutual funds that select only companies that meet certain criteria. Green funds that emphasize investment in environmentally friendly companies are the largest segment of *socially responsible investment*, which also includes funds focused on a wide range of social causes. Dating back to 1989, the Coalition for Environmentally Responsible Economics, known today as Ceres, has provided economic incentives through the availability of such funds to publicly traded companies to adjust their behavior and environmental impact management. Among its greatest accomplishment, Ceres has created the Global Reporting Initiative, a widely accepted set of standards that firms use to measure (and advertise) its commitment to sustainability. Ceres has also been behind the creation of the UN-sponsored Investors Summit on Climate Risk, where significant players in the asset management industry meet corporate leaders to discuss the management of risks related to climate change. What is more, socially responsible investment funds are becoming more active shareholders, attempting to steer companies into compliance with their criteria. For instance, Bennett Freeman from Calvert Investments points out that Calvert opened a category of funds where companies do not yet meet the given sustainability criteria but whose management is targeted to bring business practices in compliance (Freeman, 2013).

We are suggesting, in short, that RI can be reconciled with corporate social responsibility, considering that this is a language in use in the private sector, and given that many of its prescribed practices can be seen as creating a space for the consideration of values that are not traditionally included in industry decision-making.

4.2 CENTERS FOR RESPONSIBLE INNOVATION

Universities are ideal centers for *reflexivity* in innovation, as their various intellectual perspectives cultivate critical thinking. These resources – if well-coordinated – could produce compelling reviews of the social and human dimensions of the university's own research program. Already universities have Institutional Review Boards—commonly known as IRBs and dedicated to protecting human subjects of research. Research universities also have Technology Transfer Offices—or TTOs dedicated to patenting and licensing their research. But the territory of responsibility in innovation is far larger than the provinces of economic integration and safeguarding humans participating in research. This untapped territory includes questions about how legal and regulatory frameworks are affected, about economic opportunity and inequality, about sustainable development and the environment, as well as ethical questions that go beyond the integrity of research subjects. Centers for Responsible Innovation (CRIs) would undertake the needed coordination to deploy university resources to organize the aforementioned considerations in research and research commercialization (Guston, 2004; 2007).

CRIs would thus help research organizations internalize public values on at least three fronts: First, CRIs could serve as a hub within universities and national laboratories to provide a resource base for research, education, and service in the human and social dimensions of innovation. Such centers could bolster the existing research and education capacity in this domain, bringing scholars from the social sciences and the humanities closer to their peers in the natural sciences and engineering disciplines. This proximity is precisely where and how a reflexive capacity can be built within research organizations and where faculty affiliated with the CRI are invited to offer commentary and constructive criticism about research projects throughout campus.

Second, natural scientists and engineers affiliated with CRIs would enjoy an advantage over their unaffiliated peers in the contest for research funds where funding lines require the integration of the social and natural sciences. For a number of years, the National Science Foundation has required in addition to scientific merit the description of the broader impacts of research. CRIs would be the perfect knowledge center to provide a more rigorous approach to the "broader impacts" called for in grant applications. In addition, at the federal policy level, this integration of social and natural sciences has been mandated since the Human Genome Project, albeit concerns of environmental, legal and social impacts (ELSI) were inadequately integrated to HGP (see Cook-Deegan, 1994). More recently they were mandated and more adequately built-in to the National Nanotechnology Initiative. Other federal efforts to organize multi-agency funding for emerging fields will likely carry similar requirements of socio-technical integration (Fisher, 2011; Rodriguez, et al., 2013). Faculty affiliated with CRIs could then tap into a pool of resources at their disposal to improve the social robustness of their research programs. By social robustness, we mean that in addition to observing scientific values such are originality and intellectual merit, this research would by design aim at serving other social values, such as curing disease, expanding economic opportunity, or promoting gender equity (Nowotny, 2003).

Third, CRIs would provide critical input to the university lobby regarding advocacy for policies that better balance the competing interests of the constituencies of the university. In fact, CRIs could distill common public values internalized in their processes and convey them to the American Association of Universities (an invitation-only club of 62 universities) and the American Association of Public and Land-grant Universities (including 238 public research universities, land-grant institutions, and state university systems) informing their policy advocacy. This approach would certainly improve the quality of representation these associations provide to their members.

An example of implementation of CRI-like centers is Arizona State University's Center for Nanotechnology in Society (CNS-ASU)—which one of us direct—funded by the National Science Foundation as part of its contribution to the

ELSI-like work constituted under the National Nanotechnology Initiative (NNI) and fashioned it to some degree after the CRIs described above. CNS-ASU has helped promote responsible innovation (or what the NNI calls "responsible development") in numerous ways. It has anticipated societal ramifications of emerging technologies by partnering with science and engineering colleagues and stakeholders to conduct scenario developments of emerging technologies like pre-symptomatic diagnostic tools for personalized medicine, and thus helped societal concerns influence the research agenda. It has engaged lay-publics in dialogue with emerging scientific research priorities to help elicit public values that can feed into science policy decisions. It has integrated social and technical considerations by embedding social scientists into scientific research laboratories to increase the ability of scientists and engineers to reflect self-consciously on the choices they make in their laboratories and how those choices might affect the rest of us. It has created an intellectual vision of anticipation, engagement and integration—called anticipatory governance (Guston, 2014)—that serves as the root for various policy frameworks promoting responsible innovation, including one articulated and adopted by the Engineering and Physical Sciences Research Council of the United Kingdom.

National laboratories could also set up CRIs drawing from the ranks of university social scientists and humanists to partner with their own investigators. Many large laboratories work in close physical and substantive proximity to universities and could set up capacities similar in spirit to our proposed CRIs and possibly coordinate with universities to serve their own research projects.

The gradualism of responsible innovation manifests again. We are observing pressures from the government and from civil society to improve the social robustness of scientific research and we are observing projects at universities and laboratories moving in the direction of responsible innovation. University and laboratory administrators would do well for their institutions in setting up CRIs.

4.3 UPDATING INNOVATION POLICY

It is ironic that innovation policy is itself in need of innovation. A primary reason for the obsolescence of the current innovation policy regime is the understanding of the relationship between innovation and the society on which it is based. The foundations of the current regime were conceived and designed at the end of World War II when the theoretical and practical knowledge of innovation and state-of-the-art technology were quite different than today. In the intervening period, scholars have shed new light into how innovation takes place but this learning has not been fully incorporated into our governing tools.

Consider these three examples. We need to update the policy of funding research in order to build within it forms of oversight that render scientific productivity more legible to tax payers without hindering scientific advancement. Ironically, the scientific establishment demands from government something that no other patron would give: more generous financial support and less stringent oversight. Scientific research is an essential function of an open society, but so is public accountability. This tension has long been debated. In the UK in the 1930s these contrasting views were represented by Karl Polanyi and J.D. Bernal (Freeman 1993, Ch. 1) and in the U.S. in the 1940s by Vannevar Bush and Senator Harley M. Kilgore (D-WV) (Brooks, 1967). Polanyi's article *The Republic of Science* argues that "[a]ny attempt at guiding scientific research towards a purpose other than its own is an attempt to deflect it from the advancement of science." (Polany, 1962, p. 62), but J.D. Bernal saw instead science as instrumental to society for meeting its challenges and advancing its aspirations. For that reason, he insisted, science must take a direction set by public deliberation and enforced by governmental authority (Bernal, 1939). As the Cold War came to an end, the debate resumed. This last iteration had the benefit of decades of practical implementation of science policy and

an important conclusion from this experience has been that the *social contract for science* characterized by *blind-delegation* is in the process of being retired (Guston, 2000).

A second and related example is the inconsistency between the justifications for the public funding of research and the reasoning behind the policy for the commercialization of that research. Policymakers still cite as a justification of federal support that research is a public good. The standard economic definition, owed to Paul Samuelson (1954, 1955), is of a good that once produced or provided, cannot be made exclusive of an specific group (non-exclusivity), and that can be enjoyed by an additional person without detriment to the last person enjoying it (non-rivalry). This status means that once provided, a public good can be consumed by free-riders; without a way of exacting a price greater than zero, firms will not have an economic interest in producing it (see a survey in Cowen, 1992). The canonical example of a public good is national defense. For over half a century, the work of Richard Nelson (1959) and of Nobel laureate Kenneth Arrow (1962) has informed the opinion that scientific research is too a public good because once produced and placed in the public domain, it is non-excludable and non-rival, and thus without public support, the private sector would underprovide it to society (see also the critique by Callon, 1994). At the same time, the policy regime of technology transfer leaves to market forces the determinations of what research is useful. Market forces are quite efficient in making that decision about private goods but, by definition, they are inadequate to assess public goods.

The third example is that we now know that innovation boosts economic activity in regional clusters, and we have learned that these innovation ecologies require several elements to thrive, among the most important being: an industrial base plugged into global supply chains, a knowledge base and trained labor force (often by proximity to a research university), liquidity in financial markets, an entrepreneurial culture, and a comparative advantage for the arrowhead industries. It follows that innovation policy can only be successful if designed in coordination with other relevant government efforts, including regulatory, tax, education, financial, immigration, transportation, and trade policies; and all of this coordinated at the federal, state, and municipal levels. Despite this knowledge, policymakers have built frustratingly little coordination measures into innovation policy.

In addition to the internal contradictions, innovation policy is hard to reform and even small changes may upset the rare political balance achieved around its principal tools, to wit: federal funding of R&D, strong patent protection, and tax incentives for R&D investments. This political balance commands legislative support that in turn results in a well-funded and obdurate status quo. For instance, the appropriations bill passed in the House in May 2014 included partial approval for a large portion of the President's federal 2015 R&D budget and the total funding level for some agencies surpassed the President's proposal—an unusual concession from a fiscally conservative House. The same year, the House passed a bill to make permanent the R&D tax credit (HR 4438) and although it ultimately failed to pass the Senate—which did however approve a temporary extension—the near-agreement is telling of the larger consensus on this one tax credit. Likewise, there is such a large agreement on both sides of the aisle on the importance of strong patent protection that even corrections to the current regime are received with skepticism. For example, the *Innovation Act*, proposed in the last Congress (HR 3309), aimed at curbing the abuses of patent assertion entities, pejoratively known as patent trolls, passed the House last year but stalled in the Senate after meeting strong and well-organized opposition.

Reflexivity turned upon responsible innovation itself leads to recognize the two aforementioned features of the current policy regime, that it is internally inconsistent and stubborn. Consequently, responsible innovation strives

to sort out the inconsistencies by updating the knowledge base of innovation policy at the same time it proposes initiatives that will not upset the political balance supporting the current policy regime.

In order to illustrate the policy implication of the responsible innovation program, consider these examples. Increasing federal funding of research remains a corner stone of good innovation policy, but any increase in public funding will come with increased demands for public accountability. Responsible innovation is an approach that may help avoid the impending standoff between the scientific community and Congress because it advises the research community to increase its *responsiveness* to public values and to communicate them effectively to the wider public. The result will be entirely different than the heavy-handed approach currently proposed by Congress (see Rep. Lamar Smith's statement) because negotiated terms recognize the scientific establishment's autonomy far more than dictated terms. Likewise, the R&D tax credit is an effective incentive for industry to invest in innovative activities; the credit thus could be extended to include the costs of non-binding stakeholder consultations that would enhance businesses *reflexivity* on innovation decisions.

5. CONCLUSION

Responsible innovation is an incremental program of reform even though it encompasses the totality of innovative activity. It proposes policy change that is more of a re-calibration than an overhaul of the policy tools of consensus. Aware that policy is only one element of the governance of innovation, RI also entails institutional reform in universities and national laboratories and cultural change in the business sector. Specifically, we proposed here Centers for Responsible Innovation to organize ongoing efforts of reflexivity at universities and national laboratories, building upon a tradition of institutional reform in ethics review of research proposals and commercialization of research. We also recommended here to incorporate responsible innovation into the corporate social responsibility agenda, bringing innovation to the foreground of a movement that is already part of the language of business from the classroom to the board room, and that is effectively shaping, in some quarters, corporate policies and decisions.

Responsible innovation is a project for a governance of innovation that is self-conscious of the social costs of innovation and that seeks to better balance the trade-offs inherent to innovative activity. Ultimately, its aim is to improve the outcomes of innovation by enabling the actors of innovation themselves to internalize public values in their innovation decisions.

The two caveats mentioned in the introduction, that innovation is immensely complex and that it is resilient to shock must not discourage the pursuit of responsible innovation. If gradual change can curb some persistent outcomes—such as increasingly internalizing externalities, mitigating the social costs of innovation, or promoting a more fair distribution of benefits and risks—reform is indeed an effort worth undertaking.

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