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Innovations, Stakeholders & Entrepreneurship

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ABSTRACT. In modern societies entrepreneurship and innovation are widely seen as key sources of economic growth and welfare increases. Yet entrepreneurial innovation has also meant losses and hardships for some members of society: it is destructive of some stakeholders' wellbeing even as it creates new wellbeing among other stakeholders. Both the positive benefits and negative externalities of innovation are problematic because entrepreneurs initiate new ventures before their private profitability and/or social costs can be fully recognized. In this paper we consider three analytical frameworks within which these issues might be examined: pre-commitments, contractarianism, and an entrepreneurial framework. We conclude that the intersection of stakeholder theory and entrepreneurial innovation is a potentially rich arena for research.

KEY WORDS: effectuation, entrepreneurship, innovation, stakeholder

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Introduction

In modern societies entrepreneurship and innovation are widely seen as key sources of economic growth and welfare increases. Yet entrepreneurial innovation has also meant losses and hardships for some members of society: it is destructive of some stakeholders' wellbeing even as it creates new wellbeing among other stakeholders. This reality might arguably be considered one of the central problems within the purview of stakeholder theory, since some of the most serious problems that challenge stakeholders result from change and uncertainty created by innovations.

Analyzing the net welfare effects of innovations by assessing their positive and negative impacts on stakeholders is not a simple task even in hindsight, let alone at the time they are being introduced. The consequences of innovations are problematic because entrepreneurs initiate new ventures before either their private profitability or social costs can be fully recognized. Therefore much uncertainty pervades the introduction of innovations by entrepreneurs. In fact, the very concepts of innovation and entrepreneurship are difficult to deal with when the epistemological implication of innovations - true novelty - is taken seriously. True novelty implies that *incalculable* are involved in innovation (Witt, 1996). This means that there are serious problems in any attempt to evaluate the social benefits and costs of innovations and, by association, the actions of individual entrepreneurs. Indeed, it is fairly easy to list examples of innovations that were thought to generate great benefits for stakeholders when they were introduced, only to find out later that they created great costs: the dis-benefits can be social (as the Luddites found when the factory system was introduced); healthrelated (as was found to be true with asbestos, years

after it was lauded for its heat-resistant properties); or environmental (as was the case for CFCs, which where initially adopted as a multipurpose innovation used as a lubricant, propellant, or fire extinguishing agent).

In this paper we take a pluralistic approach by considering a variety of frameworks for analyzing the consequences of innovations for stakeholders. Our initial analysis has persuaded us that this issue is a very difficult one that would take at least a booklength monograph to treat with the care that it requires. As a result, our remarks in this paper are necessarily incomplete and tentative. Thankfully, a growing genre of scholarship that addresses issues at the intersection of innovation, entrepreneurship, stakeholder analysis and business ethics has begun to show just how rich an arena of research this intersection is (Buchholz and Rosenthal, 2005; Fassin, 2005; Hall and Rosson, 2006; Hannafey, 2003, Lee, 2005; Vandekerckhove and Dentchev, 2005; Velamuri and Venkataraman, 2005; Venkataraman, 2002; Wempe, 2005). The current paper contributes to this body of scholarship by outlining plausible frameworks within which solutions for managing the differential impact of true novelty on stakeholders can be developed and studied.

The paper proceeds in four parts, as follows. In the first section, Conceptions of innovation and uncertainty, we begin with some remarks on the relationship between innovation and uncertainty, based on the economics literature. We then outline the salient issues from a philosophical perspective by examining the epistemology of novelty and uncertainty through the ideas of Goodman (1983) and Fodor (1987). The second section, A pre-commitment framework, takes up the first framework within which the impact of innovations on stakeholders might be considered: a pre-commitment approach, associated with the work of Elster (1984, 2000) and Sumner (1987). The third section, A contractarian framework, examines a contractarian framework (Witt, 1996), including the idea of decision making behind a Rawlsian veil of ignorance (Rawls, 1971). The fourth section, An entrepreneurial framework, articulates a third framework, this time from an entrepreneurial perspective, by considering how expert entrepreneurs incorporate elements of the two philosophical frameworks above in actually constructing new networks of stakeholders (Sarasvathy and Dew, 2005a). We conclude by

pointing out the possibilities for good and stable local solutions even in the face of global impossibilities such as those argued by Arrow's Impossibility Theorem (Arrow, 1951).

Conceptions of innovation and uncertainty

A good place to begin our discussion of the effects of innovations is with innovation historians who have *empirically* studied the innovation process.

Rosenberg: history of innovation \approx history of uncertainty

A particularly fine paper by Nathan Rosenberg is worth quoting at length:

I would like to begin with two generally accepted propositions: First, technological change is a major ingredient of long-term economic growth, and second, technological change is characterized by a high degree of uncertainty. Understanding the nature of these uncertainties and the obstacles to surmounting them is not a trivial matter. Rather, it goes to the heart of how new technologies are devised, how rapidly they diffuse, the ultimate extent of that diffusion, and their eventual impact on economic performance and welfare.

In view of the great uncertainties attached to the innovation process, it is hardly surprising that innovating firms have, historically, experienced high failure rates ... But to describe the high failure rate associated with past innovation is to tell only a part of the story, and perhaps not the most interesting part. Indeed, I want to suggest that *the more intriguing part of the story ... has been the inability to anticipate the future impact of successful innovations*, even after their technical feasibility has been established. This statement remains valid whether we focus on the steam engine 200 years ago or on the laser within our own lifetimes. (Rosenberg, 1996, p. 91; italics added)

With an eye for historical generalization, Rosenberg goes on to delineate three key uncertainties associated with innovations: first, an inability to predict the relative rates of improvement among rivalrous innovations; second, an inability to predict key complementarities among innovations (i.e., innovations can be analyzed as interdependent systems where the performance of the whole depends on innovations in the subsystems); and third, an inability to predict changes in consumer demand. For all three of these reasons, Rosenberg points out that to map the history of innovation is to map a history of great uncertainties. Using the example of the laser, Rosenberg carefully explains how some technologies sometimes blossom into general purpose technologies with an enormous range of uses, few of which were foreseen at the time that their technical feasibility was established. Still fewer of the consequences of these uses were foreseen.

Lupton: uncertainty due to innovation \approx shared quality uncertainty

One easy way to capture Rosenberg's intuitions about innovation and uncertainty is by using the concept of *shared quality uncertainty*, introduced by Lupton (2005). Lupton posits three categories of "indeterminate goods" which are characterized by the fact that uncertainty about the quality of these goods is shared by *all* agents in the marketplace: first, there can be shared uncertainty about the emergence of a good; second, shared uncertainty about the origins of a good; and finally, shared uncertainty about the future consequences of a good.

Of interest in the context of this paper are Lupton's shared uncertainty types one and three. The first type of goods involves situations in which entrepreneurs create a new product, but neither the entrepreneur nor consumers know exactly what is being offered for sale. This type of shared uncertainty was earlier pointed out by Hirschman,

A great deal has been written about consumer ignorance and the resulting asymmetric situation of consumer and producer. In the present case, producers are just as ignorant as consumers, at least during the earlier stages of their operations. (Hirschman, 1982, p. 42 quoted in Lupton, 2005, p. 404)

Lupton points to day care services for children as being an instance of this during its emergence in the 1970s. What this type of uncertainty highlights is the idea that the consequences of innovations remain uncertain for as long as uncertainty persists among stakeholders about the appropriate definition of an innovation. Indeed, there might be reasons for thinking that such uncertainties are, even in principle, never completely resolvable.

The third type of shared quality uncertainty is "uncertainty regarding the future impacts of a product on society" (Lupton, 2005, p. 409). Lupton suggests shared uncertainty about product safety is a good instance of this phenomenon; for example, scientific uncertainties about the long-term effects of genetically modified foods on the environment. Another example might be the Manhattan project, the consequences of which many not be clear even as this paper goes to press. Witness for example the current crisis with Iran. For this category of shared uncertainty, a credible case may be made that these uncertainties are never completely resolvable.

Based on Rosenberg's historical analysis and Lupton's conceptual distinctions, we can begin to see non-trivial difficulties in predicting impacts of innovations on stakeholders – be they positive or negative. It should be no surprise, given the deep and problematic nature of predicting the impacts of innovations, that innovations "bite back" with some frequency, sometimes negatively affecting broad swathes of society, on other occasions creating enormous harms to very specific groups of individuals in a society with negative impacts that are as uneven as they are unpredictable.

So, how do we begin to grapple with the differential impact of innovations on different stakeholders? The first step might be to examine what philosophers have already pointed out about the epistemology of "true" novelty.

Issues in the epistemology of novelty

Unpredictability

Reviews of epistemology and philosophy of mind indicate that the problems posed by true novelty are even deeper than Rosenberg's and Lupton's analyses reveal. Consider Lupton's third concept of shared uncertainty: "uncertainty regarding the future impacts of a product on society" (Lupton, 2005, p. 409). Conventionally understood, as in the case of mainstream economics, the problem here is one of predicting the consequences of novelty for stakeholders. The core of this problem seems to be the issue of what we can claim to know about the future, given the possibility of real novelty (Buchanan and Vanberg, 1990, p. 170). While some schools of economic thought argue that such consequences can be assessed - at least in principle - by a thorough program of research, others argue that our unknowledge about the future is not a deficiency that can be remedied by

sufficient study but in fact derives from the originating, creative force of human choice – that such uncertainties are even in principle imponderable (Buchanan and Vanberg, 1990, p. 172).

The frame problem

Outside of economics, philosophers have a different approach to shared uncertainty regarding future consequences. For them the problem this poses is how anyone could ever know that they had sufficiently thought through the consequences of a novelty, such that they knew they had not missed anything important? In other words, the debate is not about whether individuals can know, but how they can know which of their beliefs about the future need to be re-evaluated. For many philosophers this issue suggests a wider epistemological problem known as "the frame problem" (McCarthy and Hayes, 1969). According to Lormand (1990), "The frame problem is widely reputed among philosophers to be one of the deepest and most difficult problems of cognitive science." The epistemological frame problem is "whether it is possible, in principle, to limit the scope of the reasoning required to derive the consequences of an action." (Stanford Encyclopedia of Philosophy, 2004)

Isotropy

This problem has been displayed in a number of ways in the philosophy literature: by Dennett (1984) as the problem of ignoring obviously irrelevant knowledge; by Haugeland (1987) as the problem of keeping track of salient side effects; and - best known - by Fodor (1987) as the problem of avoiding the use of "kooky" concepts. Fodor refers to the fact that in decisions and actions involving uncertain future consequences it is not always clear ex ante which pieces of information are worth paying attention to and which not, a problem that he calls isotropy. A problem is isotropic if there is no a priori limit to what information is relevant to it: in principle, anything could be relevant. (Fodor, 1983, p. 105). There are no ex ante definable limits to the properties of a situation that *might just* be relevant.

This might seem just a philosophers' quibble, but it is not. Consider once again Rosendberg's summary of empirical findings in the history of innovations: "the more intriguing part of the story ... has been *the inability to anticipate the future impact of* successful innovations, even after their technical feasibility has been established." In the case of the laser, the *relevant* list of consequences burgeoned as new uses for the laser were continually invented. In other words, historical observation suggests that in the realm of innovations, the frame problem/isotropy has real, practical relevance.

The grue paradox

Isotropy is also closely related to "the new problem of induction," a mind-bending twist on David Hume's original problem of induction introduced by Nelson Goodman (Goodman, 1983) and commonly referred to as the "grue paradox." Here is a restatement of the problem:

Take the inductive conclusion, "All emeralds are green." This induction is derived from the fact that all instances discovered so far have been green. From this we can make the inductive projection that emeralds discovered in the future will also be green. In other words, all emeralds, past, present, and future, are, in fact, green. At this point, Goodman introduces the disjunctive predicate "grue," which applies to all those things that are green before time t, and blue after time t. We can set t at any arbitrary point, as long as it is in the future - say, June 1, 2080. Inductively we have to conclude now that all emeralds that we have observed till date are not only green, but are also grue. In other words, there is as much evidence for accepting the hypothesis, "All emeralds are green," as there is to accept the hypothesis, "All emeralds are grue," we have no way of refuting this "fact." But by confirming the fact that emeralds are green and grue, we are also confirming the fact that they will be blue (or any other color we choose for that matter) in the future. As Abrams (2002) puts it: "... using what seems to be a standard inductive pattern on a property, i.e., being grue, seems to give us reason to believe that each emerald, somehow, will actually turn blue."

The grue paradox has been re-stated and studied in a variety of domains other than philosophy (for instance, Akeroyd, 1991). Fodor, in his exposition of isotropy, uses a version of Goodman's logic to introduce the concept of a "fridgeon" (Fodor, 1987, p.140). Fridgeon defines any particle at a given time if and only if Fodor's fridge is switched on at that time: "x is a fridgeon at t if x is a particle at t and [Fodor's] fridge is on at t" (Fodor, 1987, p. 144). Were you to learn now that Fodor's refrigerator had been turned on, you could infer that every particle in the Universe is a fridgeon, i.e., that this change in state resulted in an astronomical number of changes in the world. This takes us straight back to the isotropy problem: how is it possible to determine the extent of changes made to the world by the introduction of a novelty? It now seems that the answer will depend on which predicates we choose.

Toward solutions to the epistemological issues in true novelty

If the problem the grue paradox presents is which predicates are the right ones to describe a situation, one promising way of tackling this problem might be by making an appeal to convention, i.e., to adopt an ontology that is conventionally agreed by stakeholders (Skryms, 2004). However, there are two problems with this appeal. First, sometimes conventions might be stable; at other times there might be considerable dispute over conventions. Certainly history testifies to the fact that conventions are subject to change over time, which justifies some stakeholders having very different views on other stakeholders' purported conventional wisdoms about the properties of a situation. Second, innovations introduce novelty, which is the very enemy of convention. The entrepreneurial habit of injecting new artifacts into the world might very well precede the advancement of conventional wisdom about the "right" choice of predicates, i.e., new artifacts may be the handmaiden of changes in conventionally understood inductive inferences.

In the rest of the paper we explore three ways – two of them suggested by philosophers and one empirically observed in entrepreneurship – we can go beyond pre-existing conventions to develop solutions to manage the differential, yet unknowable impacts of true novelty on stakeholders. The first one we consider is a pre-commitment framework.

A pre-commitment framework

The idea of pre-commitments can be traced to its ancient origins in the paradigmatic case of Ulysses who, Homer tells us, had himself bound to the mast of his ship in order to resist the irresistible song of the Sirens, whose call would lead him to drive his ship onto the rocks, to be dashed into pieces. Knowing that he will succumb to the Sirens, Ulysses made the decision to bind himself, and this self-binding became known in the literature as making a pre-commitment (Elster, 1984, 2000). According to Elster (2000, p. 1), pre-commitment is about why and how individuals might want to restrict their freedom of choice. The basic idea is that while individuals might in general prefer to have more options, they might sometimes benefit from having fewer options, and at other times it might be especially beneficial if some options were somehow made entirely unavailable. In other words, sometimes less is more, even in the case of freedom.

In the case of innovations, the key intuition from the pre-commitment framework is that, both for the individual entrepreneur as well as society as a whole, less might indeed be more. A pre-commitment framework argues for restraining ourselves from unleashing the destructive potential of innovations through self-imposed constraints. A couple of examples of such constraints help to illustrate the point. In the 1970s there was a moratorium on DNA recombinant research and many restrictions placed on the Human Genome Project. The argument given was that constraints were needed on the kinds of genetic innovations that could be pursued in order to lower the risk of destructive consequences (Elster, 2000, p. 3). The underlying thrust of the pre-commitment framework is to provide a rational justification for such constraints.

In order to develop the above intuition before applying it more generally to innovations, let us consider a well-known example of pre-commitment, namely, the principle of "presumption of innocence" in the U.S. justice system. The operative principle here is that a judgment "beyond reasonable doubt" is required to convict someone of a crime, but this standard need not be met in order to acquit someone. This seems strange, since we might simply expect that an individual should be tried on the basis of the available evidence and a judgment would be reached based on the preponderance of evidence. The presumption of innocence seems, instead, to be making it harder for the courts to do their job, i.e., of enforcing obligations on some people (ex: not to wreak havoc or murder) in order to protect the rights of others (ex: not to have havoc wreaked on them, or be murdered).

Instead, the point of the pre-commitment is to deliberately create an asymmetry in legal process. The idea is that, if mistakes are made in the evaluation of a criminal, they are more likely to be in acquitting the guilty than in convicting the innocent. To find an innocent person guilty, we will call a Type I error (a false positive); a second of error is a Type II error (a false negative) which involves acquitting a guilty person (Sah and Stiglitz, 1988). The pre-commitment in legal process increases the probability of one type of error over another - i.e., it "stacks the deck" on the outcome of the trial. The stacking is done on two counts: (a) a value that it is worse to place an innocent person in jeopardy than to free a guilty person; and (b) a judgment that it will in general be more difficult to prove innocence, even when the defendant is innocent, than to prove the guilt of a guilty defendant. By making a pre-commitment to the presumption of innocence, the legal system engages in "deck-stacking" as a matter of legal principle. In this conception of the role of precommitments, Boardman (1999) states that: "When we anticipate the making of a decision at some future time, 'pre- commitment' is something like 'stacking the deck' in the present for or against one of the choices which we might make on a future occasion." The key quality of pre-commitments is that they serve to skew the distribution of future outcomes in one way, rather than another.

Let us now try to apply the pre-commitment framework to the introduction of innovations that have unpredictable consequences for stakeholders. To see exactly how this might work, consider the following thought experiment, which draws on Sumner (1987, p. 182). Imagine a committee appointed to review entrepreneurial "experiments" in an economy, i.e., the introduction of novel products and services. Just like a review board that oversees medical experiments on human subjects, our fictitious entrepreneurial review board imposes two criteria on every experiment: (a) that it promise a satisfactory ratio of overall benefits to costs; and (b) that it provide adequate protection for its "subjects," i.e., stakeholders. This fictitious committee thus pre-commits to certain constraints on the innovative experiments entrepreneurs will be allowed to perform in an economy. In other words, new ventures that cannot meet the presumption of risk-adjusted return (psychic, not merely financial) will not be allowed to be built.

When the committee evaluates a project, it can make one of two mistakes: it can allow projects where the risk-adjusted return turns out to be negative, and it can fail to undertake projects where the risk-adjusted return would have turned out positive. The interesting cases are ones where a project appears to offer a very positive cost/benefit ratio for the entrepreneur, but imposes a negative externality on a stakeholder. These are exactly the ventures that the pre-commitment framework would preclude the entrepreneur from embarking on. A society which allows entrepreneurs to simply weigh their costs and benefits in launching new ventures is adopting what Sumner calls a direct strategy. This is like our earlier example of a judge weighing evidence and deciding the balance is in favor of conviction. The alternative is an indirect strategy, where we make a pre-commitment to observe certain constraints, the kind of constraints that would require us either to prove beyond reasonable doubt that the indicted is guilty, or persuade individual stakeholders to work with us, i.e., satisfy the constraint of free informed choice by stakeholders. With the direct strategy, all our mistakes will be false positives (Type I) where we accept projects whose results actually turn out to be negative. With the pre-commitment, all our mistakes will be false negatives (Type II) where we fail to undertake a project whose results would have turned out positive.

There are two reasons for skewing the distribution of projects using a pre-commitment not to embark on potentially harmful projects even at the cost of turning down opportunities that may have later turned out profitable. The first is a *judgment* that the decision making process itself will be beset by difficulties and mistakes. We have already described the endlessly ponderable informational problems associated with true novelties. Add to this the psychological fact that human beings are boundedly rational, and the difficulties of thinking through all possible consequences become insurmountable. The second reason for submitting to a pre-commitment is the value that it is better to lose some profitable opportunities (incur false negatives) than incur actual social costs (false positives) because the costs of false positives will actually fall on affected stakeholders, whereas the costs of the false negatives will "only" be opportunity costs. Conventional economic

theory does not distinguish between these two costs (the actual cost, or the cost of a forsaken benefit), but in real life we might think there is a considerable psychological difference between imposing actual costs and failing to capture imaginable benefits. Evidence from psychology – for example, Prospect Theory, also attests to the fact that costs weigh on the psyche more heavily than gains and that people are generally risk averse, both of which favor avoiding false positives at the cost of increasing the number of false negatives.

The basic result that emerges from our imaginary entrepreneurial innovation committee is that "The many defects of the decision context... render precommitment an attractive option" (Sumner, 1987, p. 191), i.e., that there should be a presumption in favor of constraints on the performance of entrepreneurial experiments in the economy by applying a rule that the informed free choice of stakeholders must be obtained before the "experiment" can go ahead. This means the entrepreneur would have to "front" the costs of persuading unwilling stakeholders to become willing parties to her venture. This requirement emerges straightforwardly from the Type I/II error trade-off in the context of the desire to satisfy the overall goal of maximizing the benefits of innovations.¹

This framework leaves three problems unsolved. First, the costs of persuading stakeholders to accept uncertainties fall on the entrepreneur and thus create disincentives to innovate. Second, there is the question of innovations that prospectively have very attractive societal payoffs but require some small costs to be imposed on particular stakeholders. Third, there is the problem that the success of the entrepreneur's innovation might depend on secrecy, which conflicts with the requirement to inform stakeholders about the venture. In this regard, let us consider a second framework within which we might try to resolve these issues, as well as some others.

A contractarian framework

One frequently useful way of thinking through economic and social issues that will be familiar to most readers of this paper is the contractarian paradigm (Buchanan, 1975). Contractarian thinking has a very long history in political economy, stretching at least back to Locke. It has been used both within the stakeholder literature (Freeman, 1994) as well as within the literature on the economics of innovation (Witt, 1996), so there are some precedents in the literature for approaching issues around innovation, stakeholders, and entrepreneurship using a contractarian framework. The basic idea of such an approach is that it might be possible to reason through the positive and negative impacts of an innovation from the perspective of any and all individuals with a possible stake in an innovation, i.e., all of the citizens that could be party to a social contract that specifies how innovation is to be handled in their society.

Of course, in the recent past this contractarian paradigm is associated especially with the work of John Rawls (1971) and by far and away the most striking feature of Rawl's contractarianism is the idea of the veil of ignorance. Rawls' concern was with the very basic principles of justice in society, which would be chosen by free and rational persons who are concerned with furthering their own interests. In order to ensure impartiality in the choice of principles, Rawls invoked the idea of putting people behind a veil of ignorance as to their place in society, i.e., their wealth, abilities, etc. The idea is that if these personal differences are unknown then everyone is similarly situated; given that each individual is assumed to be able to veto any social contract option, this enables a choice of those principles for a social contract that are fair to everyone. In the situation we are considering in this paper, from behind the veil of ignorance no one would know what kind of stake they have in an innovation: they might be an investor making a fortune from the innovation; a worker being invisibly poisoned by their exposure to the innovation; an entrepreneur being bankrupted through unforeseen liabilities created by the innovation; or a consumer benefiting from using the innovation. Due to of its impartiality, the veil of ignorance therefore seems like a useful tool for considering what kind of social contract might make sense to govern innovations.

As identified by Witt (1996) the central issue addressed by the contractarian framework is how to balance the entrepreneur's incentives to innovate (because innovations increase societal welfare) with externalities potentially created by these efforts (because negative externalities risk lowering the welfare of some stakeholders).

In order to make the analysis of this hypothetical contracting situation tractable with standard decision theory, economists often tacitly introduce an important simplifying assumption: novelty is conceptualized as something that is in principle knowable but has not been considered before (Witt, 1996, p. 115). Therefore, novelty involves adding new possibilities to the choice set being considered by decision makers, and these new options are assumed to instantaneously reveal their full consequences to decision makers. Within this framework, decision makers are assumed to be able to assign probabilities to the likelihood of good and bad things happening as a result of an innovation.

Based on these assumptions we can evaluate alternative hypothetical social contracts for dealing with innovation in general. Witt (1996) proposes that from behind the veil of ignorance stakeholders might consider the merits of two alternative institutional regimes governing the introduction of innovations by entrepreneurs: a "laissez faire" regime and a "pareto progress" regime. In the laissez faire regime the entrepreneur has complete freedom of contract, the success of the innovation depends only on its competitive advantage in the marketplace and negative externalities inevitably fall on whom they fall. In this regime, there are strong incentives for entrepreneurship because entrepreneurs are protected from stakeholders who might otherwise pressure them to curtail or absorb the externalities they create. Given this favorable incentive structure, this regime promises to produce higher overall levels of innovations and therefore higher overall welfare increases than the pareto progress regime, and would depend on the "rising tide (of wealth) raising all boats," i.e., that temporary losses experienced by some stakeholders would be erased over the long term by the benefits of growth. Laws that offset fraud, negligence and establish unlimited liability would be part of this regime (Witt, 1996).

The alternative pareto progress regime that stakeholders behind the veil might consider comprises a very different clutch of rules. In this regime an innovation would have to meet the criterion that it creates wealth for some stakeholders without reducing wealth for others, i.e., it is pareto improving. Therefore, entrepreneurs would have to compensate stakeholders for the negative externalities they incur, i.e., make side-payments to these afflicted stakeholders. As this would lower the expected gains from innovation, the overall level of entrepreneurial activity in this Pareto progress scenario would be lower and overall welfare increases therefore slower. The historical record shows that institutional regimes of this type have certainly existed and as a result suffered slow rates of innovation (Mokyr, 1996). For this reason, Witt concludes that if stakeholders were negotiating a social contract behind a veil of ignorance they would choose the laissez faire regime rather than the Pareto progress regime.

However, the assumptions we have made, while traditionally being valued for their tractability, do not square very well with the true novelty created by innovations. Naive applications of the contractarian framework to innovations assume novelties instantaneously reveal their full consequences to decision makers, at least probabilistically. Yet our analysis of the epistemological implications of true novelty in section *Conceptions of innovation and uncertainty* shows that this is far from a realistic assumption. True novelties are inherently more problematic. Witt reached the following conclusions in his work on the topic:

In such a view, novelty is better interpreted as something who's meaning and implications *cannot* instantaneously be revealed ... The yet unknown implications may turn out to be good or evil ... *Deliberately ignoring the unknowability condition would appear to be an irrational attitude* ... Whether liable or not, the innovator may not be able to anticipate the damages and social costs that result from her/his innovative efforts ... (Witt, 1996, pp. 124–125; italics original)

In these circumstances, imposing either unlimited liability for externalities or compensatory payments for stakeholders is implausible because either one destroys the entrepreneur's incentive to innovate. Instead, some form of limited liability would be necessary, so that the incalculable consequences of an innovation for a broad swathe of stakeholders are not concentrated on the entrepreneur. This uncertainty sharing has the effect of establishing the entrepreneur's right to cause externalities – some uninsurable risks will always be borne by some stakeholders as long as a society does not want to establish massive disincentives for entrepreneurship.

The basic result that emerges from the contractarian framework is therefore somewhat different from the pre-commitment logic we examined earlier. Both frameworks pivot around the trade-off between the potential wellbeing created by innovation (which requires incentives that encourage entrepreneurial experimentation) and the potential wellbeing destroyed by it (the potential costs of negative externalities incurred by some stakeholders). However, the contractarian framework draws our attention to the institutional mechanisms that govern how the uncertainties surrounding innovations are spread around society: limited liability, for instance. The lack of informed consent among stakeholders - which is highlighted in the precommitment model - is just one of the prices of progress. Moreover, the exact extent of limited liability is opaque in the framework and ultimately left as an open question.

So far, the solutions we have explored have a normative flavor and arise from the deliberations of concerned philosophers and others. Next we turn to the actual practice of entrepreneurs in building new firms and markets to examine how they introduce innovations.

An entrepreneurial framework

In this section of the paper we present an entrepreneurial framework, induced from empirical observations of expert entrepreneurs (Sarasvathy, 1998, 2006) and their role in creating new markets based on new technologies (Dew, 2003). Interestingly enough, this framework provides a stakeholder-dependent solution to the isotropy problem that incorporates a pre-commitment.

The key features of the framework are laid out in the dynamic model in Figure 1, at the heart of which is the concept of commitments made by selfselected stakeholders (Sarasvathy and Dew, 2005a). The central intuition behind this framework is that every entrepreneurial venture can be thought of as a network of stakeholders engaged in an ongoing process of (re)negotiating the design of innovations, a process which continually shapes and alters the consequences of innovations (and thus their externalities). Stakeholders in this process are conceptualized as self-selecting into the entrepreneurial process by making specific commitments to an entrepreneurial venture in return for a voice in the (re)design of innovations (Hirschman, 1970). All stakeholders participate in the ventures under assumptions of varying degrees of uncertainty (which is inescapable in the worldview of grue/isotropy). However, all parties are assumed to use an "effectual" logic (Sarasvathy, 2001, 2006) - i.e., a logic of non-predictive control (Wiltbank et al., 2006). Traditional decision theories emphasize the probabilities and values of possible outcomes as if they are exogenously given, outside the control of the decision makers. Effectual logic takes perceived control as a fundamental criterion of decision making, where control is defined as probability alterability (Goodie, 2003). Ergo, in effectual logic, to the extent that you can control the future, you do not need to predict it. Voice in the (re)design of innovations gives stakeholders some control over the uncertain consequences (of innovations) that get introduced in the world and is



Figure 1. A dynamic model of the effectual stakeholder network (Sarasvathy and Dew, 2005a, p. 543).

therefore valuable, particularly *before* the consequences are clear and predictable. Before we get into how this framework feeds into our discussion of isotropy, pre-commitment and contractarianism, let us examine its basic structure and components.

Figure 1 illustrates the key components of the entrepreneurial process, viewed through the lens of effectuation. Entrepreneurs can be theorized to start the process with three resources, which vary according to the individual/s in question: (a) who they are - their identity; (b) what they know - their knowledge base; and (c) whom they know - their social networks. Research in entrepreneurship has already shown the importance of prior knowledge (Dew et al., 2004), social networks (Uzzi, 1997) and identity (Sarasvathy and Dew, 2005b) for entrepreneurs. Given these means-at-hand, they begin acting upon whatever they can afford to do (Sarasvathy, 2001). This involves interacting and negotiating with potential stakeholders they already know or happen to meet. A key aspect of these initial interactions is that the entrepreneur may or may not start with some particular idea for an innovation, and either way the idea does not determine with which stakeholders he/she negotiates. Rather the inverse, in fact. The nature of the innovation is determined by which stakeholders self-select in to the venture by negotiating some kind of deal with the entrepreneur. This series of deals - together with other contingencies that occur along the way - determines which innovation actually comes to be. This self-selection process sets in motion a cycle of increasing resources available to the venture while at the same time imposing constraints on the innovation being developed by the venture. Of course the innovation developed in this process is inherently unpredictable at the beginning of the process because the process is actor-centric: it depends on which stakeholders selfselect into the venture, and on their order of arrival (Hellmann, 2000).

If we are to effectively grapple with the consequences of this process for addressing the issue at hand, namely, the differential impact of innovations on stakeholders, we need to put the framework under the microscope. With a view to much closer scrutiny, we reproduce below a complete conceptualization of the stakeholder interaction, taken verbatim from Sarasvathy and Dew (2005a, pp. 544–546): Consider an innovation, widget X, which might be any type of artifact - a technology, a natural artifact, an idea, etc. -

Let us assume Entrepreneur E brings widget X to Customer C to make a sale. [Later in the analysis, we will show that C can be *any* kind of a potential stakeholder, such as an investor, a supplier, a strategic partner, etc.] Also, for the moment, it does not matter whether we assume that E is proceeding causally (i.e., has found C through predictive approaches such as market research) or effectually (i.e., has found C through non-predictive mechanisms such as through her existing social network or some kind of a chance encounter or as part of her routine interactions with other people in her daily life).

Let us further assume that she wants to sell 1,000 units of X to C at \$100 a piece. Let us now imagine that C says the following:

I will gladly buy X if only it were blue instead of green. (Of course, the very first C may or may not say this, but we assume E keeps talking to people she knows or meets until she finds the first C who is interested)

Now E has a decision to make. Should she go ahead and invest in making the widget blue (cost \$10 K, say)? There are several criteria she may consider in making this decision. First, she may or may not have the \$10 K needed to make the modification. Second, if she does make the modification, C may or may not buy. Third, there may or may not be other possible customers (say, D) who may be willing to pay >\$100 (say, \$120) per unit for a green X – i.e., for the widget as is, without any modification.

Assuming that E has the money to make the modification, E needs a mechanism that will decide whether C is indeed a customer (T = True) or is actually a non-customer (F = False) who will not buy the modified blue X. This mechanism, like any other mechanism we can devise will of course be prone to two types of errors. It may either classify C as a non-customer (F) when C is in fact a customer (T) [Type I error]; or, it might classify C as (T) when C is actually not a customer (F) [Type II error]. Again, assuming E has the money to make the modification, there are 3 possible solutions to this problem:

Solution 1: E goes in search of other possible customers D first. If no D exists, then E gets C to sign a contract that penalizes C if he decides not to buy the modified widget. [Note: This is psychologically highly unlikely unless E and C have an ongoing relationship of trust. In the case of an emerging new network, C faces two types of uncertainties leading to contractual hazards here. (a) E may not be able to deliver the modified widget as per contracted specifications (unknown competence); or (b) it might not be possible to specify very clearly in advance what exactly C wants modified and C could find himself in trouble by signing an incomplete contract].

Solution 2: E invests (or goes out and raises) \$10 K in expectation of the net profit due to the order from C. Without an enforceable contract, this expectation is unreliable at best as a decision criterion. But E could also do this effectually, using the affordable loss principle – i.e., not with the expectation of any net profit from a potential transaction with C, but merely as an investment that she could afford to undertake (and lose) with imagined possibilities of other uses for the blue widget in case C chooses not to buy. In this weakly effectual case too, this investment is not a reliable one for market creation except in its potential for exaptation (Dew et al., 2004).

Solution 3: The final solution to the problem is the strongly effectual one consisting of any mechanism that reduces Type I errors at the cost of incurring Type II errors. In other words, the effectual commitment always favors the error of letting possible customers go as opposed to letting noncustomers drive the decision process. In our current thought experiment, the strongly effectual solution takes the form of the following counter-offer to C:

It will cost me \$10 K to make the modification you suggest. I will make the modification if you will put up the \$10 K up front. In fact, if you will pay for the modification, I will even supply you the modified widget at \$80 per unit, so ultimately you will end up saving money on this purchase.

[Note that this solution does not require E to search for all possible D's before making the counter-offer. And this explicit ignoring of alternatives is what makes it the process different from causal processes].

Let's now examine C's decision as to whether he wants to commit \$10 K for transforming green X into blue. Again, (1) C may or may not have the

\$10 K; (2) E may or may not deliver the modified widget; and, (3) C may be able to find someone else to make the blue X for <\$80 a piece. Assuming that C has the money, while in the causal case it is obvious that he will invest it with E only of there is no one who can supply blue X at <\$80, effectuation suggests he make a counter-offer to E as follows:

I will invest \$10 K to transform your green widget into blue X. But, instead of a discount on the price, I would like to take equity in the product and share future returns on it.

The two effectual counter-offers together transform the relationship into a partnership that commits both to a blue widget world. Furthermore, under this partnership, both C and E need to specify blue X only to the extent possible at this time, leaving it up for re-negotiation as they together develop the innovation. E's contractual commitment to undertake the modification signals her private estimation of her own competence, and C's investment of \$10 K identifies him as an actual customer (T).

Self-selected stakeholders transforming an innovation

Based on our microscopic examination of the stakeholder negotiation described above, we can make several important observations that are relevant to the purposes of the current paper.

Observation 1: X may be sui generis

When the entrepreneur and a stakeholder negotiate a commitment, they are both behaving (de facto) as if the innovation is grue: they are transforming the original widget X into some different X. Since this includes types of Xs that none of the parties may have imagined before sitting down together at the negotiating table, it involves a transformation process that does not rely on pre-existing knowledge alone. The particular widget X that is the outcome of the negotiation did not have to pre-exist the deal. Instead, its reality in the world may be sui generis something of its own kind, unanticipated and unpremeditated - at the actual moment of commitment. And we can see how, as the venture grows, an entrepreneurial network of stakeholders may embody several such transformations in the "life" of an innovation.

Observation 2: E and C need not have clear goals or well-ordered preferences

The description of the effectual commitment quoted above made certain assumptions – e.g., that E knows he/she is a supplier, and that C knows he/she is a customer. Yet even if we reversed these assumptions the effectual commitment would still work – i.e., we can replace the assumption of known goals for E and C with the assumption that E and C have ambiguous goals. Imagine E being a little unsure whether he/she wants to make green or blue X, and C being a little unsure whether he/she actually wants X. Yet in negotiating with each other and actually committing to terms that each is able to fulfill within individual constraints, we can see how an unexpected transformation of widget X may be effected.

Observation 3: E and C themselves are transformed

It is not only X, but also E and C that are transformed through this negotiation process. Referring back to quoted description above, one can see that E becomes a *de facto* supplier to C when he/ she makes a commitment to C; and that C becomes a *de facto* customer by committing to E. Therefore the status of stakeholders is also transformed in the negotiating and commitment-making process.

Observation 4: Focus on what X will be and not on what X will be worth

Since the process described here engenders uncertainty about what exactly widget X will eventually be, it creates a fog of uncertainty about what X might be worth in the future. As a result, the negotiating parties are less concerned with the potential for payoffs from X since none of the parties can be sure whether X might end up blue or green or some other color widget that is yet to be imagined, let alone what X might therefore be worth down the road. The focal point of the negotiation process is what each stakeholder is willing to commit to have X transformed into a different X rather than any calculated/predicted evaluations of X down the road or negotiated agreements to appropriate payoffs from X.

Observation 5: Magnitude of novelty tied to room for stakeholders

The level of novelty generated in this entrepreneurial process depends critically on two factors: first, the extent to which the entrepreneur's initial widget X is unformed and negotiable; and second, the extent to which stakeholders negotiate constraints on the innovation. The more malleable the entrepreneur's initial idea is and the more constraints stakeholders negotiate into the innovation, the more the process that results in the transformation of the artifact X embodies the interests of the stakeholders involved in its transformation. In other words, the more novel the venture idea, the more room for stakeholders to shape it; and the more stakeholders have room to shape the idea, the more unexpected the ultimate widget X will turn out to be.

Observation 6: Generalizable to a wide variety of innovations and stakeholders

It is possible to generalize the effectual process to a wide range of innovation contexts and stakeholders. For example, the identities of C and E can be varied: C might be an investor stakeholder instead of a customer, and E might be an organizational department instead of an individual entrepreneur. The problem and solution components that the players bring to the negotiating table can also be varied: the entrepreneur can start with either problem recognition (demand-side driven) or a solution concept (supply-side driven). In general, X can be any potential component (broadly conceived) of an innovation that a stakeholder brings to the negotiating table, including a list of constraints such as a negative externality that the stakeholder and entrepreneur negotiate over.

To summarize, the process of negotiating mutual commitments (a) transforms an extant idea into something new (an innovation), and (b) forges a network of stakeholders in a venture, each of whom have a say in what that innovation will be. In essence, C and E negotiate the grue widget X into a blue one – not by induction, but by actual commitment to a blue widget world and by beginning to make, sell and use blue widgets. In sum,

The point of disjunction for the predicate 'grue' in the case of X is not some arbitrary point t in the future, but the act of commitment by two stakeholders to a particular future X.

Implications for the differential impacts of innovations

So what has our minute examination of the effectual commitment under the microscope shown us? What

do all these observations add up to in terms of our problem at hand – namely, the differential impact of innovations on stakeholders? What difference does it make that an entrepreneur builds innovations effectually with *self-selected* stakeholders rather than reasoning *globally* about the consequences for all possible stakeholders of the innovation – whether from behind a veil of ignorance or through a precommitment not to introduce deleterious innovations? The key to the difference lies in letting the growing network of *local and contingent* stakeholder commitments determine what the new artifact will be. Let us examine this locality and contingency in greater detail.

Each commitment involves a dualism: (i) a commitment to the artifact, X and (ii) a commitment to the stakeholder, C. A key difference between the effectual conception of the entrepreneurial process and "causal" conceptions is that in the effectual formulation the stakeholder C trumps the artifact X. Instead of treating the stakeholder network as a flexible input into the innovation commercialization process, the entrepreneur considers the innovation as flexible outcome of the stakeholder negotiation process. As such, the artifact X is better conceptualized as a series of transformations x_i , rather than as any one X. The effectual process, therefore, has embedded in it a pre-commitment to the stakeholder as opposed to the innovation.

The commitment to C, moreover, is substantial and very real, as C will have a real voice in future stakeholder interactions. By having a voice at the table where the innovation is itself re-designed, the effectual process maximizes the opportunity for stakeholders to negotiate over both the positive and negative consequences resulting from the (changing) innovation. In other words, in the contractarian (Veil of Ignorance) and pre-commitment frameworks, the entrepreneur pre-conceives an innovation, predicts its probable consequences and then evaluates the pros and cons of its commercialization from a stakeholder-neutral viewpoint, considering negative and positive externalities as part of that process. In contrast, in the effectual process, stakeholders self-select into the process by making some kind of actual commitment to the venture (we will deal with the nature of these commitments below). They negotiate over what the innovation

will become rather than try to pre-determine what it *shouldn*'t.

This process provides a mechanism to internalize externalities caused by the innovation, thus creating an opportunity for the transformed artifact to meet the needs, goals and aspirations of all the stakeholders who make commitments to the network. This includes new stakeholders "turning up," making a commitment of some kind, and negotiating over the nature of the artifact in order to get "externalities" incorporated into a redesign of the artifact. Thus, in the effectual solution concept, there is no once-andfor-all innovation, with given externalities, positive or negative. Instead, innovations are conceived as being continually remolded based on an ongoing process of stakeholder (re)negotiations which enable externalities to be internalized by adjusting the design of the innovation on an ongoing basis.

The key to the effectual commitment - i.e., the reduction of Type I errors even at the cost of Type II errors - is that it sorts prospective stakeholders into stakeholders and non-stakeholders. Looked at from the entrepreneur's perspective, the Type I/II tradeoffs stacks the deck towards letting bona fide stakeholders drive the innovation process. By reducing Type I errors, the entrepreneur prefers to let prospective stakeholders go (instead of incorporating them into the venture, and thus the innovation design process) rather than letting non-stakeholders drive the innovation process. This point is worth a little explanation because, intuitively, it might seem that the entrepreneur would want to do the opposite, i.e., bring in all prospective stakeholders and listen to the entire cacophony of voices, given the uncertainties attendant in the consequences of true novelties. In fact, the opposite is true. What is needed most in such very uncertain scenarios is some mechanism for sorting between relevant and irrelevant stakeholders (per Fodor and Goodman). The effectual commitment mechanism accomplishes this sorting. Stakeholders that pass the commitment "test" are given a voice in the (re)design of the innovation; those that do not commit are not. The key idea here is that this sorting process leads to innovations that are actually workable for the specific stakeholder network that constitutes an entrepreneurial venture, i.e., the process produces locally workable solutions to the problem of differential stakeholder impact of innovations.

At first glance, a local solution might seem unsatisfactory. But there are good reasons, ecological as well as statistical, not to dismiss it out of hand or accept it with only a sense of resignation. As robotics found out in overcoming isotropy, human beings have evolved to "tune out" irrelevant information. This has resulted in their cognitive capacities being "limited" to processing local and contingent information better than carrying out global calculations. But this "limitation" has also resulted in their inherent creativity - making novelty possible in the first place (Joas, 1996). Omniscient solutions in the face of innovative possibilities are therefore, not only impossible, but also unnecessary and ineffective in most cases. Several results from psychology, robotics and ecological conceptions of behavior and rationality attest to this (Todd and Gigerenzer, 2003).

These results are consistent with sound statistical reasons for this artificial bounding of the stakeholder set. Consider for example, the cases in which smaller samples entail better solutions. As Todd and Gigerenzer (2003) and Kareev (1995) have explained, there is a robust psychological/statistical basis for this decision bias: "[L]imitations in human cognitive capacity may actually lay the groundwork for inferences of causality in terms of the early detection of co variation." (Todd and Gigerenzer, 2003, p. 160). The reason for this is that cognitive limits force people to reason from small samples; because small samples have a greater likelihood than large samples of exhibiting a magnified estimate of correlation. This is an advantage - small samples increase the chance of detecting correlations in a population (Kareev, 1995).

In the face of isotropy, the effectual process leverages this evolutionarily sensible and statistically sound bias for considering fewer strong signals rather than a larger number of weak signals. Using selfselection through actual commitments to limit the stakeholder set enhances the likelihood that the entrepreneur will detect *relevant* stakeholders and key contingencies in potential consequences early. So, on the one hand, the entrepreneur increases the likelihood and number of innovations she introduces by allowing stakeholder self-selection to drive the new venture creation process. On the other hand, stakeholders get a voice in - and therefore some control over - the design of innovations, and therefore some control over the consequences generated by the entrepreneurial injection of true novelties in the world.

Limitations and future research

It is important to note that the effectual entrepreneurial solution to the differential stakeholder impact of innovations problem is not a panacea. For a start, there is no guarantee in our framework that all ex-post relevant stakeholders will indeed get an adequate ex-ante voice in the process. The following example serves to highlight this limitation.² Assume an entrepreneurial physician develops a new medical device that can extend the life of terminally ill patients with a certain type of heart disease. The device sells well, but is very expensive. As the results of using the device are so good, research dollars for this certain type of heart disease decline. This reduction in research funding is a negative externality of the device being in the market. The stakeholder group most affected ex-post is the group of patients that cannot afford the device because of lower income, lack of insurance, or some combination of both. But one could argue that the same group for the same reason - low income and lack of insurance could also not afford to self-select into the development of the innovation ex-ante, and hence could not shape the artifact to be inexpensive in the first place.

While the framework we have described here cannot completely handle this limitation, we would like to point out that it provides usable mechanisms for those stakeholders who do wish to actively participate in innovations they care about. In this connection, should the poorer stakeholders in the example above choose to develop a low cost invention, they in turn could create a new network of self-selected effectual commitments to do so.

The broader issue in stakeholder theory regarding who counts as a stakeholder and what constitutes a stake - i.e., who gets a voice and why - naturally ought to be a central issue in researching and evaluating any entrepreneurial framework for the commercialization of inventions. And no framework can get away from the driving force of the moral imagination of the stakeholders, including that of entrepreneurs (Werhane, 1999). In fact, in different ways, all three frameworks examined in this paper rely on the application of the moral

imagination of the actors involved. For instance, Sandel (1982) critiqued the Rawlsian veil based on arguments about the constitution of the actors behind the veil; similar arguments could be made for the actors who populate the "entrepreneurial innovation committee" in the pre-commitment framework. One might also point out that significant negotiation costs might be involved in reaching certain solutions (Coase, 1960). The empirically observed entrepreneurial process that we have described here merely allows us to show how stakeholders can and do form an intrinsic part of the shaping of innovations as well as some of the consequences of those innovations. In the effectual framework the shape and history of the innovative venture embodies a variety of stakeholder inputs. Moreover, this third solution, like the contractarian framework, increases entrepreneurial activity in society, yet incorporates a pre-commitment, albeit within a local and contingent set of self-selected stakeholders. And the self-selection mechanism allows room and provides a voice for potential stakeholders to participate without being exclusively dependent on the entrepreneur's moral imagination.

Several research possibilities might emerge from the frameworks we have attempted to articulate in this paper. Two of these strike us as especially fertile. First, our own work has been motivated in large part by empirical observation, which has led us to conclude that theory in innovation and entrepreneurship does not fully account for the role of stakeholders. We believe that empirical studies documenting and exploring the impact of a variety of stakeholders on the development of innovations would contribute significantly to the literature. While research has investigated how stakeholders affect firm behavior, we believe the opportunity for research into how stakeholders affect firm formation, particularly in relation to the genesis and evolution of innovations is wide open.

Second, we believe that the concept of self-selected stakeholders represents a significant research opportunity. Self-selection seems to us to be a useful way of reorienting the stakeholder lens away from managers' (or, in our case, entrepreneurs') actions, perceptions and frameworks, and onto the activities of stakeholders. We believe such a reorientation is well overdue, and that it carries several significant implications that await fuller investigation. For a start, it conceptualizes stakeholders as active participants who can "buy" a voice (merely with what they can afford) into the innovation process, and does not treat them as passive "patients" waiting to be impacted by events outside their control (Sen, 1999; Freeman, 1984). Under what circumstances can and should stakeholders self-select into this process and when not would also open up several avenues for fruitful research – both empirical and normative.

Conclusion

We conclude on an optimistic note. Both the precommitment framework due to Elster and others and the contractarian framework due to Rawls and others seek global solutions. There has been some cause for serious pessimism in the pursuit of global solutions. Take for example Arrow's Impossibility Theorem in the social choice literature (Arrow, 1951). There is a wistful melancholy in the quest for global solutions, a feeling as it were of "if only" - if only we could enumerate all possible consequences in advance, if only our computing powers were large enough, if only human nature were more benevolent, if only we would all get on the same page, and so on. The entrepreneurial framework, however, provides a cheerful contrast, a Possibility Theorem if you will, even as it incorporates some of the techniques identified by the philosophers. Goodman (1983) captures the essence of this contrast rather eloquently:

We have come to think of the actual as one among many possible worlds. We need to repaint that picture. All possible worlds lie within the actual one.

The entrepreneurial solution to the differential stakeholder impact of innovations may not help us to find the best possible world, but it provides useful design principles for making better worlds *even if* we may not know and cannot predict what those would be.

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Notes

¹ Many readers will notice some similarity between the conclusions derived in a pre-commitment framework and the "precautionary principle" which has been widely discussed (and criticized – see Adler and Simmons, 2003) particularly in relation to environmental matters such as global warming (Freeman et al., 2000) and species extinction (Arrow and Fisher, 1974 who use an options logic to derive a precaution).

² We are grateful to an anonymous reviewer for suggesting this example.

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