Climate Change Policy and the Science of Design

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Climate change has the potential to drive transformations in natural resource access, availability, and use that will have significant, far-reaching impacts worldwide, not only for those of us living today but also for future generations. As economists we are being called upon to assess the economic impacts of alternative climate change scenarios and the costs of efforts to mitigate and adapt to the adverse consequences of climate change. I classify these professional activities as "economic analysis," and I cite John Quiggin's 2011 AAEA Fellows Address (Quiggin 2012) as one of many noteworthy contributions we have made. Equally important, we are being asked to design economic artifacts – institutions, markets, contractual relationships, measuring and monitoring procedures, and decision support systems – that will allow people to better respond to and adapt to changing circumstances. I classify these professional activities as "economic design."

In my AAEA Presidential Address (King 2012) I asserted that these two sets of activities, economic analysis and economic design, while closely related and highly complementary, are also distinct and different. I also asserted that, while we are familiar with and accustomed to the processes and methods of economic analysis, our shared understanding of economic design scholarship is less fully developed. This paper focuses on the general questions of how we do economic design and what constitutes good scholarship in economic design, with illustrations and examples related to the design of climate change policy.

Herbert Simon's *The Sciences of the Artificial* (Simon 1981) sets the stage for an exploration of the science of economic design. Simon defines an "artifact" as an object, process, symbolic system, or institution that is intentionally created to meet human needs. In the context of climate change policy, for example, cap-and-trade systems and carbon taxes are artifacts designed to provide incentives for reducing anthropogenic carbon emissions that contribute to the CO_2 concentration in the atmosphere. The science of design is a body of knowledge, methods, and procedures that serves as the conceptual foundation and basic template for the design of such artifacts. Simon's work has inspired efforts by scholars in many disciplines, including economics, to develop a deeper understanding of fundamental design processes and procedures (Baldwin and Clark 2000; Cross 1984, 2010; Hevner et al. 2004; Milgrom 2011; Norman 2002; Petroski 2003; Roth 2002).

Climate change policy offers a nearly ideal context for exploring the challenges associated with economic design. Like so many design problems, climate change is a "wicked problem" (Rittel and Webber 1973; Batie 2008). It is ill-defined, with no universally agreed upon objective, an infinite solution space, and no clear-cut way to know that a "solution" has been identified. The very nature of the problem can also be defined in many ways, depending on one's perspective, and the consequences of not adequately addressing the problem could be

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catastrophic for many people. Equally important for my purposes here, climate change policy is an area in which there are a number of exemplary economic design efforts already underway.

It would be foolish for me, a novice to work in this area, to try to propose a “solution” to the problem of climate change policy here. Rather, my aim is to use this particular problem as a focal point for examining the process of economic design and the opportunities and challenges associated with this activity. In the sections that follow, I first enumerate some of the many economic artifacts associated with a global climate change policy. I then use these artifacts to illustrate some of the aspects of the design process that I identified in my Presidential Address. I close with some thoughts on how we can advance economic design scholarship, with the ultimate goals being to accumulate and codify our knowledge and skills over time and transfer that knowledge and skill to our students.

Climate Change Policy Design Artifacts

Any global climate change policy is an artifact built upon and comprised of a collection of more narrowly focused, interlinked artifacts. At the same time, climate change policy is embedded in a broader institutional context that can also be the focus for design efforts. This reflects a fundamental design principle of hierarchical decomposition identified by Simon (1981, pp. 193-229) in his essay on “The Architecture of Complexity” and further developed by Baldwin and Clark (2000) in their work on modularity. In this section I identify and briefly describe some of these more narrowly and more broadly focused artifacts.

The artifacts that have received the most attention from economists in recent years are markets or taxes that put a price on previously unpriced greenhouse gas emissions. Efforts to design these market-based instruments build on earlier work by Crocker (1966), Stavins (1995), and Kling and Rubin (1997). Aldy et al. (2010) provide a good, non-technical overview of more recent work focused specifically on climate change mitigation. They identify the following key issues in this design problem: choice of the fundamental mechanism (carbon tax or cap-and-trade), point of regulation, scope of regulation, allocation of policy rents, price volatility, promoting technology development and diffusion, deployment policy, and a whole host of issues related international implementation of policies.

A number of much more narrowly focused yet still important artifacts are critical for the successful adoption and implementation of carbon taxes or cap-and-trade markets. For example Antle et al. (2003) and Mooney et al. (2004) have focused on the important issues of designing contracts for carbon sequestration by agricultural producers and the measurement protocols needed to implement those contracts. These efforts address fundamental problems associated with verifying carbon offsets that can play an important role in both national and international carbon emission markets.

Another set of artifacts provide information to voters and consumers about climate change processes, mitigation and adaptation alternatives, and the greenhouse gas emissions associated with product purchase decisions. Examples range from Al Gore’s presentations that were encapsulated in the film *An Inconvenient Truth* to political discourse on all sides of the climate change policy issue in the U.S. electoral process. Here the work of economists is less apparent, but I believe behavioral economics has much to contribute in shaping the way scientific information is presented and in framing policy choices, and game theory provides valuable insights on the prospects for designing mechanisms that encourage truthful statements in political discourse.

Shifting perspective to the institutional context within which cap-and-trade systems or carbon taxes are adopted and implemented, it is useful to draw on Elinor Ostrom's (1990, pp. 50-55, 192-216) insights on the importance of the collective-choice and constitutional-choice rules that determine the process for designing the operational rules that affect day-to-day decisions made by participants in the system. In the climate change policy context, operational rules are the trading rules, offset provisions, monitoring procedures, and settlement processes that are fundamental design details of cap-and-trade or carbon tax mechanisms. Collective-choice and constitutional-choice rules determine who is eligible to make decisions about climate change policy and the processes system participants use to set operational rules. In the climate change policy context, these collective- and constitutional-choice artifacts include not only international agreements such as the Kyoto Protocol (United Nations 1998) but also international organizations such as the World Trade Organization that may be used to implement border tax adjustments. They also include much more fundamental institutional artifacts such as general voting processes for public goods provision (Maskin 2008; Bierbrauer and Sahm 2010; Finus, Altamirano-Cabrera, and van Ierland 2005) that will ultimately determine whether any comprehensive climate change policy can be adopted and implemented.

Finally, the complex models and modeling systems that experts use to forecast climate change and to assess the impacts of alternative climate change policy provisions also comprise an important set of artifacts related to climate change policy (e.g., Adams et al. 1990; Antle et al. 2003; Nordhaus and Boyer 2000; Stern 2007). These synthesize and encapsulate knowledge and expertise from many sources and allow it to be applied in a consistent fashion across a range of settings by many users. Careful design of these tools for economic analysis makes them easier to use and more reliable.

The Design Process

Simon (1981) and other design scholars such as Nigel Cross (2010) assert that the design process is fundamentally different from the process of inquiry associated with the natural sciences and with economic analysis. If we are to rigorously assess design efforts and teach design, we need to understand that process.

One of the most fundamental differences between these two modes of inquiry is in their perspective on problems and problem formulation. Economic analysis begins with careful problem formulation. In theoretical work, results are deduced from carefully crafted, parsimonious problem formulations that define their domain of applicability. In a very real sense, these analytical results are inevitable once the problem has been formulated. Careful, thorough problem formulation is also the foundation for empirical work, since conceptual models are the source of hypotheses to be tested or relationships to be modeled and the basis for interpretation of empirical evidence.

In contrast, economic design typically begins with a characterization of what a solution would look like and with the generation of multiple paths for reaching that solution. Often, understanding of the problem deepens and develops as solutions are proposed and tested.

While the problem-focused strategy of economic analysis is an efficient one for well-structured "tame" problems, the solution-focused strategy is likely to be superior for the ill-structured "wicked" problems like that of designing policies to deal with climate change. Interestingly, the improved understanding – and sometimes redefinition – of an ill-structured design problem as multiple solutions are proposed and tested sometimes yields a more structured problem formulation that is amenable to progress toward a solution through economic analysis. A recent paper by Tirole (2012) offers an interesting illustration of this kind of thinking. He lays out a design agenda for climate change policy by describing the attributes of the overall policy framework that would be the product of that process.

Decomposition of complex design problems into more manageable sub-problems is another characteristic of the design process. Baldwin and Clark (2000) assert that modularity – identification of independent modules linked by simple interfaces – is a key to the design of complex artifacts like computers and is reflected in the structure of the economy that supports the design and development of those artifacts. Modularity makes it possible to change one component without changing everything and thereby fosters innovation and competition. For example, the protocols for measuring carbon sequestration developed by Mooney et al. (2004) can be tested and refined without knowing all the details of a cap-and-trade system in which they would be embedded. Shifting to a more comprehensive perspective, Metcalf and Weisbach (2012) note that modularity will be critical in the implementation of regional and global cap-and-trade systems that link together diverse, conceptually disparate national systems.

Creativity plays a critical role in the generation of solutions for design problems. Cross (2010, pp. 54-58) highlights the importance of sketching in this creative process. He notes that sketching, with drawings from multiple perspectives and thumbnail sketches of details often appearing on the same sheet of paper, permits simultaneous consideration of different levels of abstraction. For complex design problems, the broad conception of overall solutions is essential, but attention to details is also important. Sketches need not be pictorial. For example, a recent article by Olmstead and Stavins (2012) provides a verbal "picture" of a comprehensive international climate policy architecture. Sections on three important features of the architecture – expanded participation, an extended time path for emission targets, and market-based policy instruments –can be likened to thumbnail sketches. Similarly, Tirole (2012, pp. 129-130) even uses the term "sketch" in the roadmap offered at the end of his paper.

What nineteenth century philosopher C.S. Peirce called abductive reasoning – logical leaps that develop ideas that *may* be true – also plays a central role in the creative process. As Cross (2010, p. 78) observes:

> … designing seems to proceed by oscillating between sub-solution and sub-problem areas, as well as by decomposing the problem and combining sub-solutions … partial models of the problem and solution are constructed side-by-side … But the crucial factor, the 'creative leap', is the bridging of these two partial models by the articulation of the concept … which enables the partial models to be mapped into each other.

We rarely see descriptions of this in our literature, so I will offer a personal example that occurred for me as I did background reading for this paper.

Elinor Ostrom's remarkable book *Governing the Commons* focuses on the processes of self-organization and self-governance in small-scale, clearly bounded common pool resource systems where individuals need to develop mechanisms to alleviate or eliminate the adverse collective outcomes that stem from independent actions. The global climate has many of the characteristics of the common pool resource systems that have been the focus for Ostrom's work, but it is hardly small-scale or clearly bounded. Furthermore, while the successful cases Ostrom examines are confined to small populations living in a single country, climate change has the potential to affect the entire world population. Also, while individual appropriators are the participants in the institutional innovation processes described by Ostrom, countries are the key participants in the development of international climate change policy. Despite these differences, however, the insights embodied in Ostrom's (1990, p. 90) eight design principles illustrated by long-enduring common pool resource institutions are remarkably applicable in the climate change context:

1. Clearly defined boundaries
2. Congruence between appropriation and provision rules and local conditions
3. Collective-choice arrangements
4. Monitoring
5. Graduated sanctions
6. Conflict-resolution mechanisms
7. Minimal recognition of rights to organize
8. Nested enterprises (when common pool resources are parts of larger systems)

Clearly the context for climate change policy design is different from that studied by Ostrom, but by likening nations to people and recognizing that fewer than 200 nations participated in the recent climate conference in Durban, South Africa, the descriptions of successful negotiation processes presented in Ostrom's work become relevant and revealing. The agreement in Durban broadens participation and lays the foundation for setting meaningful long-term emission targets, but success in the negotiations to come will depend on progress related to many of the design principles identified by Ostrom.

Boland and Collopy (2004a, 2004b) note the importance of "vocabulary" in the creative process. They (2004b, p, 276) define this as "… a set of images, concepts, sensibilities, preferences, and logic that have been developed through time and experience." In effect, a designer's vocabulary is a set of solution components that can be pieced together in new ways that are dictated by a particular problem situation. As a key component in a designer's style, it can be an enabling factor that makes it possible to rapidly fill in the details for a proposed problem solution. A designer's vocabulary can be likened to a tool-box of design elements. The discussion by Aldy et al. (2010) of key issues in the design of market mechanisms for mitigating climate change illustrates a design vocabulary that has developed in the economics literature over the years. Similarly, the discussion of voting mechanisms for the provision of public goods offered by Bierbrauer and Sahm (2010), while it is highly abstract, provides useful insights on possibilities for and problems in the design of democratic mechanisms for decision making in an international organization for climate change policy.

Ongoing evaluation for the workability of designs is another important distinguishing feature of economic design. Designers repeatedly ask, "Will it work?" or "Will it work better than what we have now?" Roth (2002, p. 1342) observes that, while game theory and mechanism design are the conceptual foundation for market design, these theories necessarily abstract from complications that may be of great importance in particular design efforts. Dealing with the details of these complications requires tools that complement theory, most notably experiments and computational models. The model-based experimental results presented by Antle et al. (2003) are a good example of this kind of evaluation. They use a crop ecosystem model and an econometric-process simulation model to explore the marginal costs of carbon sequestration in a spatially heterogeneous cropping region under per-hectare and per-tonne contracting regimes and conclude that efficiency gains under per-tonne contracts more than offset higher measurement costs. Bosetti and Frankel (2012) offer another example of this aspect of the design process as they search for long term, country-specific emission targets that could be both effective in limiting CO_2 concentrations and politically feasible.

Finally, a distinguishing feature of design problems is that they almost always have clients, who commission the design and establish the design specifications, and users, who actually use the artifacts that are the product of the design process. Norman (2002) emphasizes that clients may not be users, and he goes on to note that it can be a challenge to satisfy the client while creating a design that truly meets the needs of users. Norman also notes that a designer's mental model of an artifact may be quite different from that of a user. An effective design is not only a synthesis of these two points of view but also a vehicle for communication between the designer and the user. Gehry (2004) observes that the design process is one of mutual discovery whereby the designer not only learns about the client's values but also helps the client discover those values.

Clients and users are often evident in the design work of economists. Roth (2002) highlights the important role of clients in the FCC spectrum auctions, noting:

> A more careful historian than I will have to see if the economists lined up on each side of the package bidding question were representing firms with predictable interests in the matter. (In addition, designers can have professional incentives to see their designs adopted, and these needn't always be perfectly aligned with their client's interests.) But politics is part of design, and we're going to have to learn to deal with the politics of design.
>
> (Roth 2002, p. 1368)

Politics and private interests both play a significant role in debates on climate change policy and in policy design efforts. This has led to questions about the objectivity of scientific results and may underlie important differences in policy proposals. For example, the choice of the discount rate used in evaluating long-term benefits and costs associated with mitigation and adaptation dramatically shifts weights placed on the interests of current and future generations.

Advancing Economic Design Scholarship

Science is a cumulative endeavor, with new research building on existing knowledge. Roth (2002, p. 1342) observes that:

> Whether economists will often be in a position to give highly practical advice on design depends on whether we report what we learn, and what we do, in sufficient detail to allow scientific knowledge about design to accumulate. … for this purpose *we need to foster a still unfamiliar kind of design literature in economics, whose focus will be different than traditional game theory and theoretical mechanism design* [Roth's italics].

Despite the importance of economic design, we will only have a rich literature on economic design if we have widely recognized examples of excellent design research.

One key component of the economic design literature that Roth calls for would be studies that introduce new or newly adapted economic artifacts. Hevner et al. (2004, p. 82) present seven guidelines for understanding, doing, and evaluating information systems design research:

1. Creation of an innovative, purposeful artifact.
2. The artifact must contribute to the solution of an important, relevant problem.
3. The utility or efficacy of the design must be rigorously demonstrated.
4. The contribution must be new and interesting.
5. Rigorous methods must be used in both construction and evaluation of the design.
6. The artifact needs to work and the environments in which it works need to be understood.
7. The research needs to be communicated effectively.

I believe these are a good starting point for guidelines on economic design studies. I also believe that the design-oriented climate change policy studies I have cited here illustrate what it means to meet these criteria.

As I searched for examples of publications describing the design of specific economic artifacts, I was struck by how rare these are in our literature relative to studies that analyze the performance of alternative artifacts or explain the conditions under which they would be adopted. On the one hand, this may be due to a lack of shared understanding within our profession on what constitutes a "good" economic design study. On the other hand, it may stem from the fact that the design process often involves a client, who may consider the product of design efforts to be proprietary. If this is the case, our profession may need to design and share mechanisms, such as suggested consulting contract templates, that allow for and promote scholarly reporting of design research results. At the same time, we need to ensure that relationships with clients are disclosed in such studies in order to avoid concerns about conflict of interest. Another explanation for the relative lack of design studies in our literature is that the creative contribution of design efforts diminishes rapidly as designs are adapted for new settings. Over time, the innovative activity of design research transforms into more routine activity of design practice as new artifacts are adapted to solve new problems.

In addition to publications that describe specific artifacts, a literature on economic design should also include studies that summarize design experience and that help to build the "vocabulary" of economic design in specific contexts. As already noted, Ostrom's (1991) design principles for common property resource institutions are an example of such contributions to the literature. In depth comparisons of policy alternatives, such as those provided by Aldy et al. (2010) for climate change also contribute to the shared vocabulary on policy design.

Finally, a literature on economic design should include new theoretical work that is motivated by the need to explain irregularities in design outcomes. Repeated efforts to solve ill-structured problems sometimes lead to insights on how those problems can be structured and addressed analytically to yield results that can be generalized.

Teaching Design

Cross (2010, pp. 38-47) asserts that everyone has design ability. He then goes on to say that design ability can be destroyed or lost, or it can be nurtured. If we are to nurture design ability, we need to understand the design process and we need a shared, evolving body of knowledge about design. Even when these preconditions are met, translating design understanding and knowledge into teaching strategies remains a challenge.

Simon (1981, pp. 155-156) addresses this challenge in *The Sciences of the Artificial*, proposing key components of a curriculum on design that reflect his own unique perspective on human problem solving. These include utility theory and statistical decision theory, formal logic, optimization techniques, heuristic strategies for identifying and choosing satisfactory alternatives when optimization is not possible, and strategies for problem formulation that rely on decomposition of hierarchic systems.

Writing thirty years after Simon, Cross (2010, pp. 29 and 38) suggests that design teaching should focus on developing the following abilities, which I paraphrase:

- Characterize and resolve ill-defined problems
- Employ solution-focused problem solving strategies
- Use abductive, appositional thinking
- Use non-verbal graphic and modeling media that help translate abstract requirements into concrete objects
- Communicate design effectively

These represent an evolution from the curriculum components proposed by Simon. For me, the interesting question is that of how attention to these would reshape undergraduate and graduate education in agricultural and applied economics. In both educational settings, we face limits on the time we have available to add new topics and experiences. In effect, if we agree that design should be part of our students' experiences, we face the design problem of finding a way to add design to the curriculum subject to resource and institutional constraints. I will briefly discuss four types of design learning activities that I believe we can build into educational programs at both of these levels.

Developing Understanding of the Conceptual Foundations for Design

Game theory and mechanism design are part of the mainstream economic theory and are covered in many popular intermediate and advanced microeconomics texts. I know from experience that undergraduate students are ready to be exposed to key concepts in these areas and that this material can be of great interest to them. Our graduate students need to go beyond the introduction to these topics that is standard in M.S. and Ph.D. level microeconomics courses, with methods or field coursework focusing on applications that illustrate how game theory and related mechanism design concepts can be the starting point for designing markets, organizations, contracts, and public policies. At the graduate level, I believe we also need to develop students' skills in the experimental economics and computational economic modeling tools, such as agent-based modeling, that are often required to evaluate economic designs. Coursework in this area can be an effective complement to courses in econometrics and optimization.

Building an Economic Design Vocabulary
For applied work, students need to build a context-specific design vocabulary along with understanding of conceptual foundations. Undergraduate students in subject-matter courses can be introduced to broad classes of economic design questions by examining examples of economic artifacts designed and implemented to address those questions. This is closely related to the institutional knowledge that has long been included in many of our courses. Graduate students also need to build their institutional knowledge, but this needs to be supplemented by a toolkit of skills for modeling economic designs such as alternative contract structures or regulatory policies. The challenges created by climate change are complex, far-reaching, and persistent. As such, they offer an ideal topical focus for disciplinary and interdisciplinary courses at the undergraduate and graduate levels.

Design Cases
Many of our undergraduate programs have capstone courses that give students an opportunity to apply and integrate concepts and methods introduced throughout their course of study. For agribusiness students, this is often a business strategy course, but there are also examples of capstone courses that focus on natural resource, development, or public policy issues. Often these courses are built around decision cases. In truth, many of these cases focus on design issues, but they emphasize decision rather than design – i.e., choice between alternatives rather than the development of alternatives. In some instances, the shift to a design focus may only require a change in emphasis rather than a significant change in course content. Design cases can also be an effective learning tool for graduate students, especially in M.S. programs. They can be especially useful for developing students' skills in communicating design ideas. There are many opportunities for the development of climate change policy design cases.

Design Projects
Design cases introduce students to design challenges in a controlled setting where the case author decides what information and data resources to provide. Real design problems are ill-structured and messy. They require clarification of design objectives, creative generation of solutions, iteration with the client, and continuous refinement of design proposals. Often, they can only be addressed by a team of individuals, and there are almost always significant constraints that simultaneously limit possible solutions and encourage creativity. Design projects can be included in courses on all topics and at all levels, and asking a student to design an improved business process or managerial report can be an important learning objective for an internship. Students can be challenged to: write the rules for a new market, design a contract from the perspective of each party and from the perspective of a social planner, adapt

an existing organizational structure for a new competitive or institutional setting, or write a law or regulation. Design projects are common in other fields. They require time and careful attention to limiting scope, ensuring client participation, and establishing sequences of deliverables and checkpoints throughout the process for providing feedback and advice to students. Often they are most effective when they bring together students from different disciplines who have complementary skills and comparable levels of expertise. Finally, design projects offer students at all levels a chance to encounter some of the ethical dilemmas that are often inherent in the design process. Again, climate change policy artifacts – be they intended for implementation at the local, national, or international level – can be an engaging focus for such projects.

Concluding Remarks

Design contributes in fundamental ways to human well-being, and design economics is an area of work through which applied economists can have significant impacts at all levels of economic activity. I believe we need to strengthen our shared understanding of what constitutes a science of design that is cumulative, transparent, and teachable. Economic design and economic analysis are highly complementary activities, and as agricultural and applied economists we need to move easily between the two. My remarks here are intended to motivate and encourage a continuing, lively discussion on the science of economic design. I also hope they will stimulate some new, creative thinking about climate change policy, one of the most important economic design challenges humankind has ever faced.

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