POLICY Brief

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Science and innovation policy for the 21st century: Shaping the Dialogue

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Generating, developing and applying science and innovation to benefit humanity at local and global levels has never been more important and challenging for decision-makers in the public, private and civil sectors. Keeping in mind that scientific discovery may be a necessary condition for change, it is seldom sufficient for economic development. Innovation involves the application and use of both old and new science and technology in new ways. Making that system work is a challenge no country has completely solved.

Canada's federal government recently stated that innovation is "essential in shaping our future." Moreover, it recognizes that this country "needs an inclusive plan to foster a confident nation of innovators—one that is globally competitive in promoting research [and] translating ideas into new products and services" (Government of Canada 2016a). Strategies like Canada's new Innovation Agenda (2016b) will undoubtedly support the pursuit and implementation of new measures that strive to make good on the ambitious government vision "to build Canada as a global centre for innovation" (2016a). But reaching that goal involves dealing with complexities and imbalances that might render many policies, initiatives and instruments ineffective or in some cases counterproductive, leading to unequal distribution of benefits and risks for diverse communities across the innovation spectrum. Thus, new thinking is required about the drivers and tools underpinning current approaches to science and innovation policy.

Current innovation challenges

The idea that science can be put to work in solving pressing public policy challenges is embraced by think-tanks, governments, universities and industry. In many ways, the history of Canada is a story of scientific progress driving socio-economic development. Governments invested heavily in adapting, adopting and tweaking the best transportation technologies to open the country, in developing new crop varieties to grow in Western Canada's harsh climate, working with industry to address challenges in the management and use of our forests, fisheries, mineral deposits and oil fields, and driving the development of long-distance telephony, anchored on satellite systems, to link us for the 21st century. Science (and government) have been central to all of these achievements (Doern, Phillips & Castle, 2016).

Canada, more than most countries, has had a strong supply-push model of scientifically-driven technological change and economic development. This remains true even today. The OECD reports that the public sector, universities and not-for-profit foundations combined

The Johnson Shoyama Centre for the Study of Science and Innovation Policy (CSIP) is an academic research institute that draws on expertise from across the social sciences, sciences and humanities. CSIP supports understanding of the policy and governance dimensions of science and innovation through the application of robust theory, innovative method and evidence-informed discussion.

contribute about 47 per cent of the resources and undertake about half of the nation's research. While some of that money is notionally directed to specific targets, much is unfocused compared with programs in other countries. Governments in Canada direct much of their support either through the higher education sector, where the commercial application is not specified, or to firms as ex post subsidies for research expenditures (STIC 2015).

Science and innovation in the 21st century is characterized by at least three dominant trends (Phillips 2007). First, the science underlying the modern economy is far more diffuse and distributed than in the past. Small teams of motivated individuals were at the core of the waves of technological change over the past 150 years. Those teams could draw from a relatively stable stock of global scientific knowledge to solve discrete problems that constrained our national economy. Now science is both global and dynamic. Jinha (2010) estimates that between the first formalized journal article in 1665 and 2009, the world collectively published about 50 million articles and was adding approximately 1.5 million articles a year to that stock. At that rate, the stock of knowledge would approximately double by 2033. Second, global science has been amplified by global markets, where consumers and suppliers aggressively compete to be the first to exploit new innovations. The result is that those few new ideas that are introduced are often rapidly and widely adopted. Those that are adopted are often not the best or most inventive, but rather the first to match with needs in the marketplace. Third, the market—represented by consumers, governments buying on behalf of individuals, firms producing finished consumer goods and the broader social community—are becoming much more engaged and demanding. Isolated, supply-driven innovations risk missing the mark of what citizens and consumers want or will tolerate. At the extreme, consumer-led innovation is completely disconnected from the underlying scientific enterprise.

The main impact of this accelerating world is that the gains from successful technological change are concentrating in specific sectors, markets, locales and firms. Rogers (2003) characterizes the world as one where innovations go through a normalization process, with early adapters testing and validating the value of an innovation, before widespread adoption occurs. In such a world, benefits are distributed across and along the supply chain to both early and late adopters. With the acceleration and integration of the scientific and innovative system, we are seeing new distributions of impacts and outcomes, with far more of the benefit being captured by leading innovators and the average participant gaining less in total. These winner-take-all events challenge our standard assumption that investment in science will lead to widespread prosperity. The quintessential example of this is the internet, where a handful of oligopolies (i.e. Amazon, Google, Facebook, Netflix, Disney, Alibaba and Tencent) dominate the choice architecture for most online consumers, thereby earning the bulk of the online profits (Economist 2017).

Disconnects in the generation and utilization of new ideas is equally problematic and bringing the fruits of science to markets has never been more difficult. Canada's Science Technology and Innovation Council concluded in its *State of the Nation 2014* report that "Canada's most profound and urgent ST&I challenge lies in increasing the number of firms that embrace and effectively manage innovation as a competitiveness and growth strategy". Although "higher education institutions also play a vital role in developing and advancing knowledge and its application" there are uphill battles within the academic research environment that can stifle innovation processes (STIC 2015). Researchers in single disciplines are limited in their capacity to fully address and resolve the large-scale oft-called "wicked" problems of adaptation and adoption in this complex, dynamic world. As one recent study at four universities observed, more must be done to facilitate and enable collaboration across the sciences, social sciences and humanities if we are to bring about the sorts of comprehensive and effective solutions needed to address large-scale challenges (Schmeiser et al. 2015). Moreover, research conducted in isolation from other disciplines and modes of thinking carries the risk of generating innovations that disrupt current practices and modes of thinking, creating conflict that either mobilizes or disenfranchises divergent geographic or social populations, including northern and First Nations communities. While there may be winners from such disruptive events, the costs of transition for many are often higher than they need to be.

Towards an effective science and innovation policy research agenda

This new context of global innovation requires a more effective policy tool kit. The policy system since the end of the Second World War has aspired to evidence-based policy making, where objectively-based problems are framed through the public choice lens and adjudicated by rational (or at least 'boundedly-rational') decision makers (Simon 1991). More recently there is a move to characterize and study policy in the context of evidence-informed policy making, where causal stories frame problems subjectively in the context of the social system (Stone 1989) and decision making involves 'muddling through' (Lindbloom 1959).

Deductive, reductionist approaches that rely on argumentation and basic presuppositions evolved to contribute to evidence-based policy making but are no longer adequate. The traditional public choice framing assumes largely autonomous actors independently make rational choices yielding outcomes that deliver impacts that fit a bell-curve distribution. All our models assume this. In some ways,

the development of the risk-analysis framework and the adoption of cost-benefit analysis as core filters to assess individual projects and discrete policies reflect this model of policy making.

The emergence of complexity confounds that approach. We now can observe a range of lumpy market and policy spaces, where new integrated market structures or densely packed socio-economic subsystems make judgements in the face of profound uncertainty. Decisions from these types of systems are subject to significant asymmetries and network effects, with the potential for emergent, non-linear outcomes. Innovation is one policy space where we see profound complexity. Most transformative events, such as the internet or mobile devices, develop in unexpected ways, disrupting both the proponents themselves and government policy systems (Phillips 2007). Assuming we know where technology will take us often leads to stranded public investments and wasted effort. Where these conditions hold, our conventional modeling and analysis lead to biased and inconsistent conclusions, which would lead governments to make poor policy choices. These circumstances, along with current concerns regarding the questionable authority of science – including the so-called "reproducibility crisis" (Baker 2016) and loss of trust in "expertise" (Nichols 2017) necessitate an expanded tool kit to develop and implement policies that are seen as appropriate and palatable.

Aspects of Governance

A new policy research agenda must necessarily address three discrete but interrelated aspects of governance: strategic assessment; public engagement; and decision making.

First, we need to work to reframe how we assess and judge prospective and emergent scientific advancements and technological or organizational innovations. Assessment begins well before we know the applications. Whereas in the past the federal government used to be the lead, setting national priorities and providing the lion's share of funding, the space is increasingly occupied by other funding entities. Foundations, new arms-length granting agencies, universities and private firms are testing a set of new structures to accelerate science, technology and innovation, including conditional grants, networked multidisciplinary projects, clusters, partnerships, big science infrastructure, and institutes, centres and open innovation spaces. These systems have proliferated with little evaluation of their system effects. There is a need for new diagnostic, design and evaluation tools. There has been significant work already on the impact of different decision criteria (e.g. scientific novelty, commercial viability, economic impact, sunk costs, environmental sustainability, safety, risk, uncertainty and ethics) on both the nature and flow of selection decisions. Theory and evidence suggests that when ill-defined or nebulous criteria are added to decision systems, objective evidence is less important than the structure of the decision space and the personal views of the decision makers. This is especially true when people argue from different starting points, or when evidence is agglomerated without consideration of the respective importance for the different variables.

Given that fewer than one per cent of funded projects deliver technologies or products that find success in the market place, research design, selection and evaluation warrant more consideration. We need to test to determine whether research management decisions—including the decisions by researchers to collaborate and apply for funding, the panels to adjudicate, and funders to allocate funds to portfolios of investments—are appropriately structured, tasked and normalized to handle risk framing and uncertainty. Poorly designed systems are more likely to generate intuitive choices based on weak evidence that leads to risk aversion, anchoring on familiar or immediate opportunities and overall sub-optimal activity (Kahneman 2002). A range of new approaches, including institutional and network analysis, case studies, agent-based models, and behavioural experiments, offer ways to test for the impacts of different structures, rules, process and criteria on assessment.

Second, citizens and consumers are no longer content to be the compliant markets for new technologies and their products. People from all walks of life are seeking, sometimes demanding, a greater role in defining the goals and methods of research and innovation. Governments everywhere have taken up the challenge but generally have not found mechanisms that improve the 'fit' of science, technology and innovation into the social space.

Governments have constructed a wide range of processes to engage people (Rowe and Frewer 2005), but there is limited evidence these efforts have improved public acceptance or government decisions (Phillips 2012). Ultimately, engagement, uptake and use of new technologies is an individual choice. Perceptions of costs, benefits, tolerances for risk or uncertainties, and values and interests, in particular, are factors in our personal choices, but are fundamentally influenced by the communities and social networks in which we live and work (Thaler and Sunstein 2008). Most citizen and consumer assessments interrogate the individual to discover the personal calculus one goes through in making a decision related to adopting new production technologies or consuming novel products. There is *prima facie* evidence that communities, citizens and consumers are less influenced by objective evidence of personal cost and benefit and are more driven by causal stories and the opinions of others. When people are challenged to deal with conflicting opinions, especially about fundamentally uncertain phenomena, they often revert to biases, heuristics and conventions. We need to delve further into the cognitive and social foundations that drive citizen and consumer opinions (e.g. by region, socio-economic type or psychographic attitudes/beliefs) and to examine the structures designed to aggregate and target their preferences.

Third, we need a new tool kit to design, structure and audit decision making itself. There are a number of opportunities to populate the research toolkit. We could examine the role of key organizations that frame decision sets (Guston, 2001, calls them boundary organizations). Using behavioural experiments we can assess how the number and types of variables affect choice. Finally, we can test to see how people made decisions that involve sunk costs and uncertain future costs and benefits. Applying these approaches to real decisions in the science and innovation policy space will enable

us to assess how to ensure evidence is appropriately considered and used in complex decisions.

There is significant work already done describing and critiquing the goals, structures and outputs of regulatory and policy systems, but little that critically models or assesses the internal decision-making structures and processes and their impact on choices. The rising cost and increased time for review for some classes of technology is unambiguously altering investment strategies and priorities (Phillips 2016). Specific policies and mechanisms have become flashpoints about the benefits and risks of developing disruptive technologies. New crop varieties, pipelines, energy developments, new mines and new drugs have all faced long, uncertain and costly reviews and significant social conflict. Decisions can be and are skewed by ideological positions and political wrangling in legislative processes, by precedent-setting interpretations of rules during administrative and judicial proceedings, and by inadequately supported and complex government review processes. Risk analysis, in particular, has framed risk as hazard mitigation, which often truncates consideration of benefits and tends to skew risk dialogues and decisions to discussions of harm avoidance. This approach has arguably minimized errors of commission, but at the expense of errors of omission, as safe and efficacious innovations may be delayed or erroneously rejected. A range of therapeutic drugs, genetically modified crops, energy production technologies and industrial chemicals have passed all the objective tests for safety in many OECD countries yet await final approval to be used. Understanding how perceptions about risks, benefits and uncertainties are shaped and how specific decision events are structured offers an opportunity to contribute to science-based, evidence-informed policy and regulation.

There is a real opportunity to use, build and advance a set of theories and methods to assess the relative role of ideas, decision architecture and human cognitive capacity in regulatory and policy decisions arenas that make decisions about which science, technologies and innovations we will pursue and utilize. Understanding the roles of stakeholders, what they view as evidence and how they use evidence to frame problems, assemble options and make choices within decision-making structures, is fundamental to identifying opportunities for improving governance.

The policy imperative

The emergence of a knowledge-driven, scientifically-based global innovation system fundamentally challenges the Canadian and global policy system. Complex systems operate differently and deliver profoundly different outputs. The policy and regulatory system can no longer solely rely on our old models, methods and metrics. The basic task for policy scholars and practitioners is to develop and adapt a set of tools that will assist society to optimize the use of the full suite of technologies our research community is generating. Our long-term health and prosperity depend on this mission. Science and innovation policy in Canada offer a unique opportunity to develop and test a range of new models and methods of strategic assessment, meaningful citizen engagement and thoughtful decision making in order to strengthen our evidence-informed policy system.

References

Visit www.schoolofpublipolicy.sk.ca for detailed references.

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People who are passionate about public policy know that the Province of Saskatchewan has pioneered some of Canada's major policy innovations. The two distinguished public servants after whom the school is named, Albert W. Johnson and Thomas K. Shoyama, used their practical and theoretical knowledge to challenge existing policies and practices, as well as to explore new policies and organizational forms. Earning the label, "the Greatest Generation," they and their colleagues became part of a group of modernizers who saw government as a positive catalyst of change in post-war Canada. They created a legacy of achievement in public administration and professionalism in public service that remains a continuing inspiration for public servants in Saskatchewan and across the country. The Johnson Shoyama Graduate School of Public Policy is proud to carry on the tradition by educating students interested in and devoted to advancing public value.

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