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Carbon Pricing, Innovation, and Productivity:

Implications for Canadian policy makers

By Roger Martin[1] and Alison Kemper[2]

Sustainable Prosperity is a national research and policy network, based at the University of Ottawa. SP focuses on market-based approaches to build a stronger, greener economy. It brings together business, policy and academic leaders to help innovative ideas inform policy development.

This brief provides an overview of links between carbon pricing, innovation, and productivity. It contains a summary of some of the leading research undertaken on the subject in Canada and internationally, and assesses the implications of that research for Canadian policy makers. It provides many of the leading references on the subject, and so should be considered as a foundational document on the subject rather than a definitive analysis.

Key Messages

- Canada's poor innovation and productivity performance are matters of concern, and a major challenge to our long-term prosperity
- There is evidence that increases in resource efficiency can translate into growth in productivity, addressing a persistent issue in the advancement of Canada's prosperity. Pricing carbon can help drive innovation in technologies and business models that promote resource efficiency, and so drive productivity improvements.
- Given the importance of addressing productivity as the critical driver of Canada's future prosperity, carbon pricing – and the help that it can provide – needs to be considered as part of any policy addressing Canada's long-term prosperity.

Sustainable Prosperity
c/o University of Ottawa
555 King Edward Avenue
Ottawa, ON K1N 6N5
613-562-5800 x3342
www.sustainableprosperity.ca

1 Roger Martin is Dean of the Rotman School of Management at the University of Toronto and Director of the School's Michael Lee-Chin Family Institute for Corporate Citizenship.

2 Alison Kemper is a Research Associate at the Michael Lee-Chin Family Institute for Corporate Citizenship.

The Issue

Over the past two years, there has been an increased focus in economic policies the world over on green growth. This focus has brought together agendas – on climate change, on innovation, and on public investment in response to the recent economic crisis – that were previously considered to be independent of each other. Put simply, what were once debated as environmental policies are now becoming part of broader economic policy considerations (Aghion, Hemous, & Veugelers, 2009a; Summers, 2010).

As a result of this convergence, new opportunities have emerged to examine the positive relationship that can exist between good environmental policy and good economic policy. In particular, the necessary transition to a low carbon energy system brings with it the opportunity to use environmental policy to promote long-term economic development. For Canada, where the opportunity may be greatest is in the relationship between carbon pricing, innovation, and productivity.

A simple conceptual model illustrates the relationship this paper will explore.

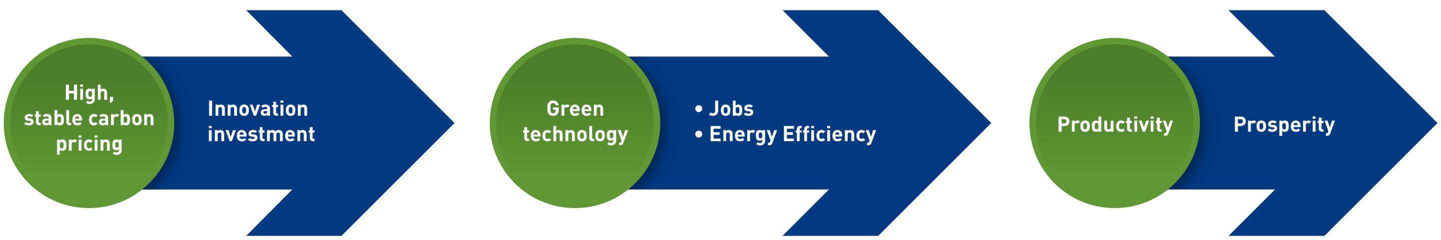

Figure 1: Conceptual model for the relationship between carbon pricing and prosperity (absent environmental impacts)

Some economists have focused on the development of models that project the impact of carbon pricing schemes on the emissions of greenhouse gases (GHGs) (Nordhaus, 1973, 2007). In recent years, they have applied their expertise on innovation policy to the problem of green technology investment (Arora & Gambardella, 2010; Cockburn, S. Stern, & Zausner, 2009; Krugman, 2010; Mowery, 2009; Newell & Henderson, 2009; Wright & Shih, 2010). There is a robust body of literature on how pollution pricing can drive innovation (Popp, 2001 and 2006). Theory and empirics which connect carbon pricing, innovation and industry growth are less developed.[1] This paper uses the model above as a framework to explore relevant work that has been done to date and to identify the gaps that remain.

1 This reflects a conclusion arrived at in Sustainable Prosperity's recent Policy Brief, *Carbon Pricing, Investment, and the Low Carbon Economy*, (http://www.sustainableprosperity.ca/papers/sp-policy-brief-carbon-pricing-investment-and-low-carbon-economy) that more research on the links between emissions reductions and investment is required.

Carbon pricing and innovation

The literature on the relationship between carbon pricing and the development of green technology is relatively recent. Traditional views of energy policy link technology development to research subsidy policies (Nordhaus, 2002). In that context, carbon pricing mechanisms are framed as disincentives to the use of oil, gas, and coal and not as incentives for low carbon technology innovation. However, because the development of green technology often requires ongoing investment, some economists are starting to consider the potential for carbon pricing to help "kick start" cleaner energy industries (Aghion, Hemous, & Veugelers, 2009b).

At the same time, research indicates that low carbon prices provide little incentive for consumers to shift their preference away from existing technologies (Rivers & Jaccard, 2006) or build enough demand for alternative energy sources. A low, slowly escalating carbon tax on a stochastically priced commodity will not provide adequate incentives to shift consumption to non-carbon energy sources in the near term. Induced technological change requires large and persistent shifts in demand (Henderson & Newell, 2010).

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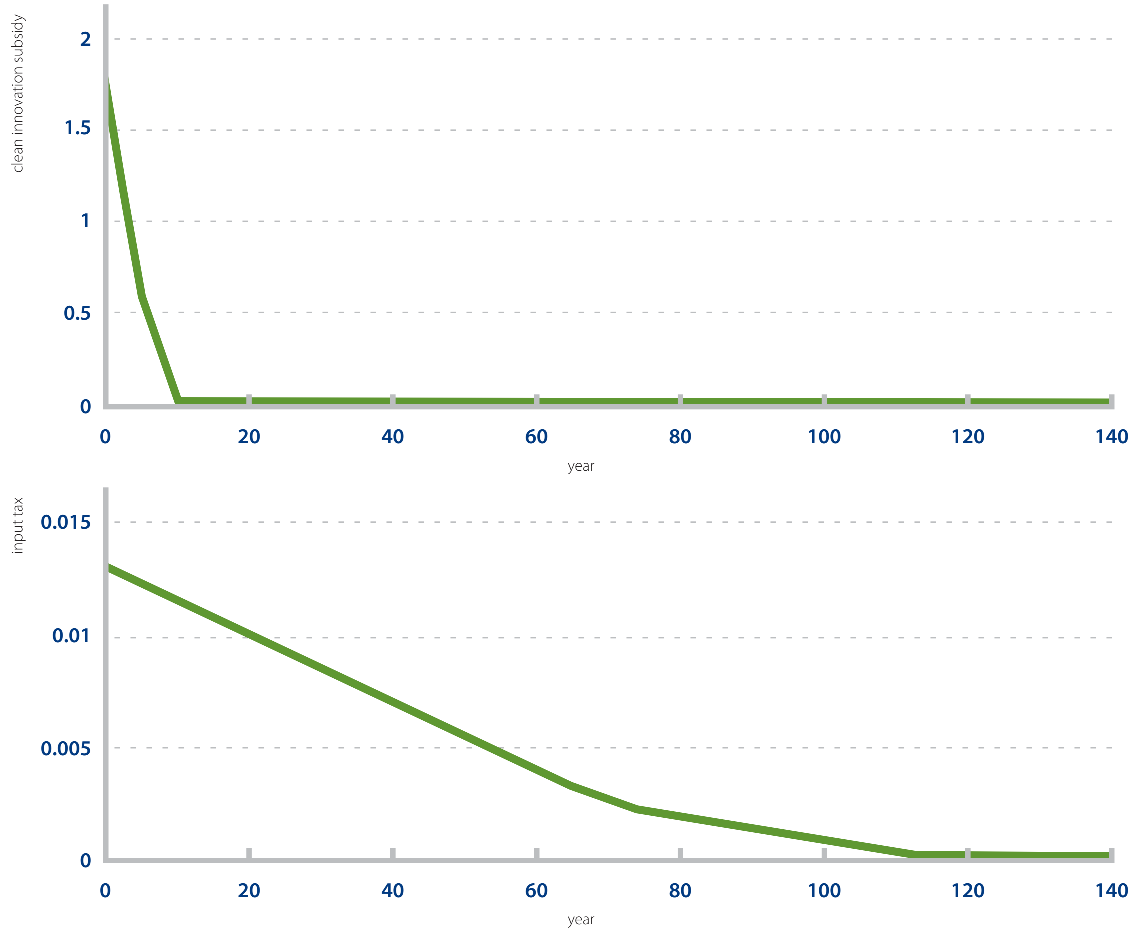
Hence, a high price for carbon is required to shift demand to low carbon energy sources (Anderson, 2006). High prices create large incentives for firms and governments to invest in R&D: this has also been true in the case of agriculture and food (Wright & Shih, 2010) and synthetic fuels (Arora & Gambardella, 2010). Experience shows, however, that such investments collapse with downturns in price, implying that a carbon price should be stable or steadily rising to be effective.

The model developed by Acemoglu, Aghion, Bursztyn and Hemous (2009b) calls for immediate high prices for carbon in order to generate cheap green technology that can be used universally, prices that can decline over time as the installed base of energy generation and consumption shifts. The high initial cost of green technology shift can be financed through revenues from a pricing instrument.

Figure 2: Acemoglu, Aghion, Bursztyn, Hemous (AABH) model of carbon tax and investment timelines.



Source(s): Calibrations from the Acemoglu, Aghion, Bursztyn and Hemous (2009) model.
Results are for a discount rate of 1.5%. Taxes and subsidies are proportional. Scales should be read as follows: for input taxes 0.015 reflects a tax of 1.5% on the price of the dirty input; for subsidies 1.5 reflects a 150% subsidy to profits derived from clean technologies.

A carbon tax increases the cost for carbon-intensive energy, but that proportional cost to the end user of the pricing policy diminishes over time as the user switches to low-carbon energy. At the same time, the public subsidy required for the low carbon alternative declines as greater demand for it leads to improvement in the experience curve, learning-by-doing, and economies of scale. So, both the economic impact on the end user and the public cost (in the form of subsidies) diminish over time, as a result of innovation and greater market share.[2, 3]

One policy implication of this research is the need to consider a transitional strategy for green technology and carbon pricing. A high initial carbon price creates the possibility of inducing rapid technological development and an earlier switch to alternative fuels or efficient technologies. But with high carbon pricing in the near term being a difficult political sell, public investment may be required to promote technology and related industrial development.

2 The amount of and duration of the public subsidies needed will depend on how quickly the carbon price ramps up. If this happens slowly, public subsidies may require a longer phase-out period that is depicted in figure 2.

3 It should be noted that the theoretical model presented by AABH differs from the practical application of a carbon tax. The most obvious example is present in British Columbia, where the gradual phase-in of the carbon tax is done to give emitters time to respond, and addresses the political realities of the difficulty of introducing a high carbon tax at the outset. It also creates an escalating carbon tax rate, and assumes an increasing carbon tax-based revenue stream. The BC approach also does not subsidize the emitters, and so the marginal effective tax rate will vary by emitter because BC uses the tax revenue to reduce personal and corporate income tax rates.

Once new technologies are established and energy consumption has shifted, carbon taxes will no longer impose significant costs on consumers. Continued technological development may no longer require public support once the market has shifted, as the demand and carbon price will continue to drive innovation. As the ultimate policy prescription, the carbon price has the added advantage of being policy-direct (meaning it directly targets carbon emissions, which are the policy priority), technology neutral by definition, and fiscally neutral (and even fiscally positive under some scenarios).[4]

The use of the revenues from a carbon tax is also a significant issue. McGill researchers Isabel Galiana and Christopher Green highlight the difficulties with using carbon pricing alone as a stimulus for R&D (2009). They go on to claim that unless significant portions of such revenues are invested in green technology, the development of low carbon technology will be too slow to achieve the emission targets currently in place, and will make tougher ones impossible to reach (2009). The stochastic nature of markets for oil and gas has therefore been a major deterrent to innovation. Three options to provide predictable pricing can address this problem.

Price collars

Price collars provide both an upper and lower boundary to carbon-based energy (McKibbin, Morris, & Wilcoxen, 2009). Governments set price ranges for oil and gas, and they collect tax revenues on the difference between the spot market price and the range they have set. The decreased variability allows firms to calculate the risks and returns on capital investments. Consumers make better informed purchases of large appliance, homes and automobiles. Investment in new energy efficient capital stock is made less risky (McKibbin et al., 2009).[5]

There is a quickly developing theoretical literature on reducing the price risk in energy innovation. Aldy, Krupnick, Newell, Parry and Pizer review a wide variety of mechanisms in their discussion paper, *Designing Climate Mitigation Policy* (2009). Burtraw, Palmer and Kahn focus specifically on symmetrical safety valves, their term for a defined price range that reduces risk (2009) in a paper that also includes an exhaustive literature review.

4 Sustainable Prosperity 2010.

5 Under that specific scenario (a price range for fossil fuel energy, within which the fossil fuel input price and carbon price move against each other to provide overall stability in the price of the energy output) the incentive might however be lessened for producers, who face the possibility of a variable carbon price. This explains why most carbon pricing "collars" focus on only the carbon price itself (typically in the cost of a carbon allowance in a cap-and-trade system).

Publicly set qualities, quantities, and prices

Recent work published by the World Bank has looked to the field of public health for solutions. For many years, authorities have specified qualities, quantities and prices for vaccines in advance of the demand. They see that similar mechanisms can be used in energy markets (Avato & Coony, 2008). The emergence of feed-in-tariffs for hydro electric power is one instance of a similar program, a mechanism cited by both Deutsche Bank and Ernst and Young as determinative of opportunities for innovation (Creating Jobs and Growth: The German Green Experience, 2009; Renewable energy country attractiveness indices, 2010).

Public investment

For many governments, the preferred policy up until now – as seen in the U.S. American Reconstruction and Recovery Act and other stimulus packages around the world – has been to provide sizable public investment for low-carbon technology development. This is driven by the logic, suggested above, that the development of low carbon technology will be too slow to achieve the emission targets currently in place, and will make tougher ones impossible to reach. However, Richard Nordhaus has indicated that flooding the landscape with green R&D money will create considerable likelihood of misallocation of scarce resources (2002), a concerned shared by others (Rivers & Jaccard, 2006). It is critical to allocate revenues prudently or risk public support for a carbon price. It is important to understand that the disagreement is not over the role of carbon pricing *per se,* but over whether it acts as a sufficient incentive to green innovation – particularly in the short term. The core problem is that, while a sufficiently high carbon price could go a long way to driving the needed innovation, most assume that governments are unlikely to set a price at that level in the near term.

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For many other economists, the risk of misallocation appears much smaller than that of inaction. The most influential work in this area is the 2006 *Stern Review on the Economics of Climate Change,* which advocated immediate and preemptive constraint on carbon emissions to avoid massive future adaptation and mitigation costs.

Green innovation, employment, and productivity

There remains the question of the relationship between energy technology innovation and increased levels of employment and productivity. Studies on the employment benefits of green innovation predominate. Work for the United Nations Environment Program by Renner, Sweeney, & Kubit, (2008) identified the potential economic benefits – in the form of employment and investment – of action on climate change Further, Deutsche Bank has outlined the results of major studies of employment in the green economy:

Figure 3: Deutsche Bank's summary of green employment studies

SOURCE	NO. OF JOBS ACTUALLY/ POTENTIALLY CREATED	REGION EXAMINED	TIMEFRAME	OTHER CONSIDERATIONS
UNEP, 2008. "Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World."	470,000	Worldwide	2006	Wind and solar for countries where data was available
	624,000+	Worldwide	2006	Solar thermal for countries where data was available
	1,174,000	Worldwide	2006	Biomass for countries where data was available
	64,000+	Worldwide	2006	Geothermal and hydro for countries where data was available
	145,000	Germany	2006	Energy efficient retrofit jobs based on €19 billion public and private investment
	18,000	India	2009	Construction of natural gas buses
University of California, 2008. "Energy Efficiency, Innovation, and Job Creation in California."	1,500,000	California	1977-2007	Resulting from energy efficiency policies
	403,000	California	2008-2020	Efficiency and climate-action driven jobs taken into account the potential for innovation
US Metro Economics, 2008. "Current and Potential Green Jobs in the US Economy."	750,000	US	2006	By increasing renewable use and implementing efficiency measures
	2,500,000	US	2008-2018	By increasing renewable use and implementing efficiency measures
	4,200,000	US	2008-2038	By increasing renewable use and implementing efficiency measures
Political Economy Research, 2008. "A Program to Create Good Jobs & Start Building a Low-Carbon Economy."	2,000,000	US	Present potential	Based on spending $100 billion in public funds in a 'green' recovery program
Barack Obama, 2008. Energy and Economic Policies.	5,000,000	US	2008-2018	Based on $150 billion stimulus
Gordon Brown, 2008. UK Renewable Program.	160,000	UK	2008-2020	Based on £100 billion stimulus
	25,000,000	Worldwide	2050	

(Creating Jobs and Growth: The German Green Experience, 2009)

More scientific studies largely concur. In Kammen, Kapadia, and Fripp's metastudy of 13 articles (2004), they find that "transitioning from a fossil fuel–based economy to a renewably powered one will spur economic growth and provide considerable employment." A similar study conducted on U.S. data concluded that there was potential for four million jobs in alternative energy in the U.S. (Wei, Patadia, & Daniel M. Kammen, 2010). The ILO has published a report that indicates that "Within current policy frameworks, only a fraction of the potential benefits for jobs and development is forthcoming (Renner et al., 2008)."

It is clear that green technology can increase employment in the period in which innovation and production of new technologies are in demand. However, since *total productivity = output quantity/input quantity,* productivity and employment can increase simultaneously only when output increases. Such an increase in output might occur if there were significant increases in the production of goods and services which use less costly green technologies, a possibility that has not yet been examined extensively.

… skepticism may not be supported by the evidence available: efficiency and productivity may be related in a virtuous cycle.

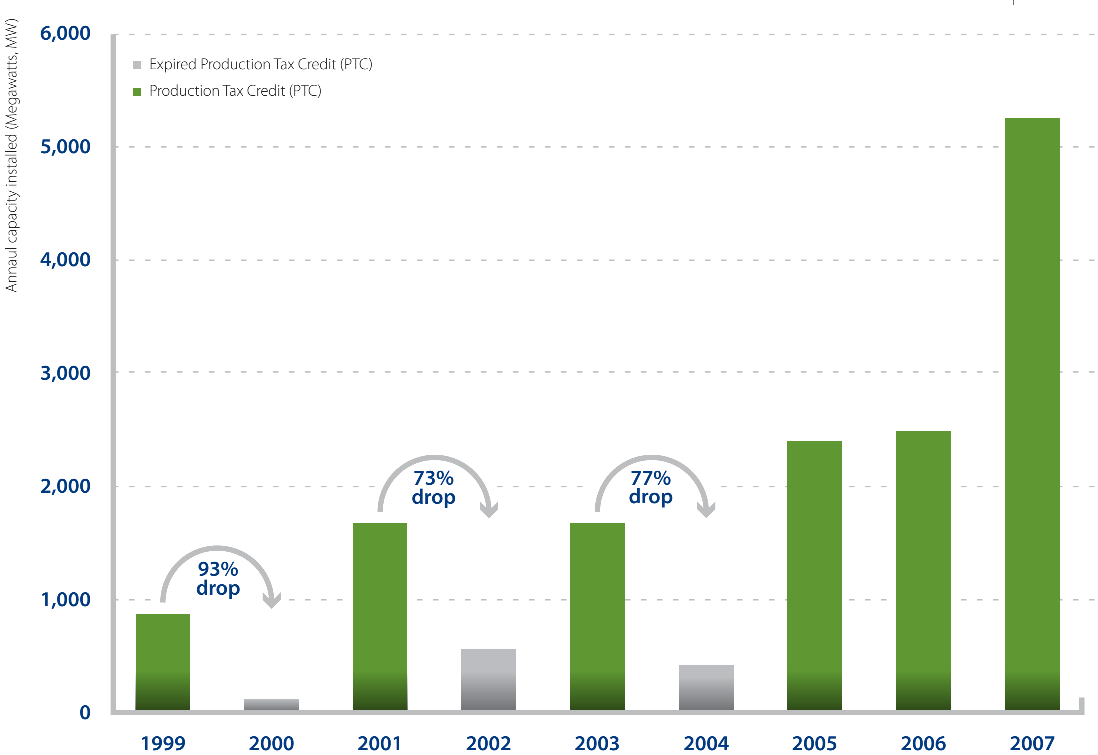
Recent studies show that energy efficiency gains can drive increased productivity, although Jaffe, Newell, & Stavins (2002) state: "Generally, economists have been skeptical of the win-win theory." Boyd and Pang see a decline in productivity from reducing energy inputs in glass manufacturers (2000). Chien and Hu look at "the effects of renewable energy on the technical efficiency of 45 economies… Increasing the use of renewable energy improves an economy's technical efficiency. Conversely, increasing the input of traditional energy decreases technical efficiency (2007)." Pilat finds that low productivity can result from inefficient use of resources (1996). Perhaps most convincingly, Worrell, Laitner, Ruth and Finman's metastudy of 70 industrial case studies indicates that energy efficiency improvements can positively influence productivity (2003). If they are correct, skepticism may not be supported by the evidence available: efficiency and productivity may be related in a virtuous cycle.

Finally, recent news reports from Germany indicate that the installation of significant numbers of wind turbines has shifted the price of electricity to new lows (van Loon, 2010). Perhaps this is early evidence of Aghion's innovation revolution (Aghion, 2009). It will be critically important to identify the conditions under which the shift to new, carbon free technology can shift energy costs below the baseline for conventional energy technology.

Creating the conditions for innovation and productivity

In North America, there has not been a stable demand for alternative energy or a stable price on carbon. As a result, businesses have abandoned the development of large scale energy efficiency projects and alternative energy production when prices for oil and gas dropped and consumers abandoned alternative fuels. Larry Summers, head of the U.S. Council of Economic Advisors, recently said: "Clarity brings certainty, certainty brings confidence, and that is what moves the economy forward" (Summers, 2010). At the end of the day, this boils down to being about investment, and the necessary policy framework to promote investment in low carbon innovation.

It is clear that business interests seek much greater clarity in energy policy. Investors require energy policies with the following key characteristics: transparency, longevity and certainty and consistency (Kahn, 2009). The American Wind Energy Association has published research which indicates that sporadic government tax credit programs produce highly variable private sector investment. When the US government allowed the Production Tax Credit to expire, less wind generation was installed.



Source: American Wind Energy Association

Figure 4: Historic impact of Production Tax Credit (PTC) expiration on annual installation of wind capacity

In their forthcoming book, **Accelerating Innovation in Energy: Insights from Multiple Sectors,** Henderson and Newell document a wide variety of means by which the US was able to stimulate innovation and the development of new industries. David Mowery's section on software, hardware and the Internet reveals that by being the first and largest customer for a range of large systems, the US government was able to create dominant industries in computer-related goods and services (Mowery, 2009).

Moreno and Sunding (2001) have examined the relationship between price volatility in water and the diffusion of irrigation devices, and find that price volatility slows the diffusion of water conservation technology. The variability of prices for oil and gas might therefore be a major deterrent to innovation.

The gaps that remain: research directions

The evidence base of a positive relationship between carbon pricing, innovation, and productivity is increasing. It suggests that carbon pricing may have a role to play in helping Canada address its innovation and productivity challenges.

At the same time, much remains to be done. There is a need to explore fully the role of multiple policies in promoting innovation and productivity. Canada has had relatively weak technology stimulation policies and few examples of carbon pricing at a level that stimulates significant substitution. More direct research on either one is important, but even more necessary is the need to understand the potential synergistic impacts of multiple policies.

The pursuit of green economic development also needs to be better understood, particularly in light of international developments. While it is clear that there are more future opportunities for employment in the green economy than in the brown economy, it is not clear how they will be apportioned. Does Germany have a substantial first mover advantage? What jobs and what new industries remain? Will China's massive investment in turbines and photovoltaics provide them with a sustainable comparative advantage? Is there plenty of work to go around? How will it be financed? What are Canada's best opportunities? In what sectors is there the greatest potential for Canada's brown jobs to be replaced by green ones? What policies can best advance these changes?

Perhaps least clear is the relationship between efficiency and productivity. Can each Canadian worker produce more output as a result of using fewer fossil fuel inputs? How might that be possible?

Sustainable Prosperity and the Michael Lee-Chin Family Institute for Corporate Citizenship plan to continue working together on some of these issues in the months ahead.

Implications for policy makers

1. Policy makers at all levels of government face an increasingly complex set of challenges, including three that are the subject of this document: climate change, innovation, and productivity.

2. The bringing together of these issues is not incidental. They are intimately related. Climate change is in part caused by a pervasive inefficiency in our production and use of energy, which is itself caused by our inability to properly reflect the full cost of producing and using that energy in our market economy. Our woeful productivity performance is rooted in the same dynamic: we don't value efficiency enough, and don't invest in addressing it through innovation.

3. The emerging evidence base presented in this brief suggests that there can be a positive relationship between carbon pricing and innovation. That innovation, in turn, has in some cases led to increases in productivity.

4. The evidence base also suggests that certain conditions need to exist for that positive relationship to emerge, centred on the need for a multi-layered, predictable, and transparent carbon pricing policy regime. It also suggests that carbon pricing should be part of a transitional strategy that begins with public support of green technology (assuming that a carbon price may not in the short-term be enough of an incentive) that gets replaced over time by an escalating carbon price that "steps in" to create the incentive for low carbon innovation.

5. Outstanding questions remain – some detailed above – on the exact causality between specific policies, how they interact, and how to maximize their positive impacts. Sustainable Prosperity and the Rotman School of Management will continue to work on these, and will engage with other potential partners with similar interests.

6. The most significant implication of this work, though, is that carbon pricing is an important part of the policy toolkit relevant to addressing innovation and productivity issues in Canada. It needs to be considered as such, and be made a part of the ongoing national discussion on our economic future.

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