

Environmental and Resource Economics: A Canadian Retrospective*

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1. Introduction

This paper gives a brief overview of contributions to environmental and resource economics in Canada. We concentrate on work from the past 25 years, but we also highlight earlier pathbreaking work. Canadians have made fundamental contributions to many aspects of the field, especially in resource economics, non-market valuation, and international environmental economics. Our focus is on academic work by scholars in Canada,¹ but we put this in the context of the development of the field internationally. Given space constraints, we cannot be comprehensive and so the review discusses big picture trends, along with a selective overview of leading contributions. We also had to limit the scope of the article and so do not cover energy economics and mainly consider fisheries when discussing renewable resource economics.

We begin in Section 2 by discussing broad trends in the field, and review trends in Canada in section 3. We then review major Canadian contributions to various topics in the field. We discuss renewable resources in Section 4, non-renewable resources in section 5, pollution control in section 6, non-market valuation in section 7, and open economy environmental economics in section 8.² We conclude with some thoughts about future work.

2. Broad Trends in the Field

Research trends in environmental and resource economics have been reviewed in several previous papers. The *Journal of Environmental Economics and Management* looked back on the field in its 25th anniversary issue (Vol. 39, 2000). Deacon et. al (1998) reviewed trends and highlighted future opportunities for research. More recently, Auffhammer (2009) used Google Scholar citations to assess trends and identify high impact papers and books.

Deacon et. al. (1998) and Slade and Thille (2009) noted that work in nonrenewable resource economics declined in the 1990's. After an initial burst of activity in the late 1970's stimulated by oil price shocks, contributions slowed in part because concerns about looming exhaustion of resources faded in the face of relatively flat long run real resource prices. Instead, and perhaps paradoxically, the non-renewable resource literature became energized by issues connected to the abundance of resources, such as Dutch Disease, the Resource Curse, and more recently the Green Paradox. And as work on non-renewable resources waned, work on renewable resource economics tended to increase. This was in part a response to concerns about the sustainability of natural capital triggered by tropical

¹ Some scholars spent only part of their career in Canada; we focus on work they did while in Canada. In the case of co-authored papers, one co-author working in Canada was enough to meet our criterion for a "Canadian" contribution.

² Work on climate change is discussed throughout the review as it spans the various topics listed above.

deforestation, fisheries depletion, and water scarcity.

Each of the reviews found a steady volume of research on pollution control, although the focus of that work evolved over time. There was initially a great deal of work on the design and properties of incentive-based environmental policies in both first and second best worlds. More recently attention has focussed on the use of empirical methods to identify the effects of policies on pollution, productivity, and other outcomes; and to evaluate the effects of environmental factors on health, agricultural productivity and other sources of value. Regarding specific issues of concern, Aufhammer (2009) notes three trends in the study of pollution policies – increased focus on climate change; increased attention to the interaction between environmental issues and economic development; and the growth of the literature on trade and the environment. The emergence of a large literature on economic growth and the environment was stimulated by Grossman and Krueger's (1993, 1995) papers on what became known as the Environmental Kuznets Curve.

Finally a large branch of the environmental economics literature is concerned with non-market valuation – how to value the benefits and costs of changes in environmental quality. Environmental amenities are typically not traded in markets and so a variety of sophisticated techniques have been developed to measure these values. Aufhammer (2009) notes that roughly half of the top cited papers in key environmental field journals can be classified as non-market valuation papers.

3. Trends in the Field in Canada

To assess broad trends in Canada, we look at three indicators. First, since this paper is part of a special issue to celebrate the 50th anniversary of the Canadian Economics Association, we look at the mix of papers in the field published over the past 25 years in the *Canadian Journal of Economics*. The *CJE* attracts work from researchers around the world, and so is not solely an indicator of what researchers in Canada have been doing,³ but it is one of the channels via which the CEA influences the field.⁴ Second, we look at patterns in the papers presented at the annual meetings of the Canadian Resource and Environmental Economics Study Group (CREE). This annual conference was initiated in 1991 when John Livernois and Patrick Martin hosted the first meeting at the University of Guelph. Finally, we

³ Another option would have been to compile a list of high impact work done by scholars in Canada published in the top general journals, relevant field journals, and in other outlets such as books. We did not pursue this mainly because of time constraints, although the coverage of material throughout this review has been influenced by citation counts.

⁴ Another journal supported by the CEA, *Canadian Public Policy*, has had a long history of publishing papers on resource and environmental policy. It has helped to forge links between the academic community and policy-makers. In recent years there have been two special issues relevant to the field. Elgie and McCarney (2016) edited an issue on "Big Ideas for Sustainable Prosperity," and Heyes, Elgie and Rivers (2013) edited an issue on "Environmental Policy in Canada." Numerous other contributions have appeared over the years, including some that we cite later in the review: Pearse (1988), McKittrick (1997) and Carbone and McKenzie (2016).

follow Aufhammer (2009) in looking at recipients of the Association of Environmental and Resource Economists (AERE) Publication of Enduring Quality Award.

3.1. Environmental and Resource Economics in the Canadian Journal of Economics

We classified papers on Environmental and Resource Economics published in the *Canadian Journal of Economics* during 1993-2016 into various topics: Non-renewable resources (NR), renewable resources (RR), pollution control (PC), climate change (CC), international environmental and resource economics (IE), non-market valuation (NV), and miscellaneous (M).⁵ The results are summarized in Table 1.

Table 1. Environmental and Resource Economics Papers in the CJE 1993-2016

Field	Papers	Share (%)
Resources: Non renewable	12	14.3
Resources: Renewable	15	17.9
Pollution Control	13	15.5
Climate Change	11	13.1
International Environmental Economics	19	22.6
Non-market Valuation	2	2.4
<u>Misc.</u>	<u>12</u>	<u>14.3</u>
Total	84	100

Roughly one third (32%) of the papers are on resource economics, almost evenly split between renewable and non-renewable resources, but with a slight edge to renewable (18% vs. 14%). Deacon et al. (1998) in their review of papers published in JEEM from 1974-1996 found that slightly less than 30% of the papers were on resource economics. Our numbers are mostly from the two decades following theirs, but they are comparable, suggesting that the CJE has had a good record of attracting papers from that field.

Next to resource economics is a set of papers that we have classified as "International Environmental Economics."⁶ These account for almost a quarter of

⁵ We collected all of the environmental and resource economics papers in the CJE from 1993 - 2016. Based on their titles and abstracts, we manually classified them into the various topics. Energy papers are included in the "misc." category because we are not covering energy in this review. Some papers might fit into more than one topic; we chose the topic that seemed to fit best.

⁶ We include papers on international trade and natural resources in this category.

the papers (23%). In contrast, for the period 1989-96, Deacon et al. (1998) found that only 4.5% of the papers in JEEM dealt with international / global issues. The much larger presence of such papers in the CJE reflects three factors. As Aufhammer (2009) notes, this has been one of the growing areas of research within environmental economics. Second, the CJE has had a long reputation for attracting and publishing good papers in international economics. This has spilled over into international environmental economics. Finally early major contributions to the area came from scholars in Canada, and this helped to raise the profile of the CJE as an outlet for such work.

Two areas where publications in the CJE are under-represented compared to environmental and resource economics field journals are (non-trade-related) papers on pollution control, which account for only 15% of the papers in the field found in the CJE; and non-market valuation. This may in part reflect the merits of general vs. specialized field journals as outlets for this work.

Another way to measure the relative contributions from each of these areas is to employ citation counts. In Table 2 below we list the top 10 most highly cited papers in the field in the CJE during our time period. The citations are from Google Scholar (as of June 30, 2017). This list is of course biased toward older papers. It is striking that six of these papers are on international environmental and resource economics issues. Three are on non-renewable resource economics, and one is on pollution and water.

Table 2. Top 10 most cited papers in Environmental and Resource Economics Papers in the CJE 1993-2016

Authors	Title	Topic	Year	Citations
Ederington & Minier	Is Environmental Policy a Secondary Trade Barrier? An Empirical Analysis	IE	2003	382
Dean	Does Trade Liberalization Harm the Environment? A New Test	IE	2002	256
Brander & Taylor	International Trade and Open-Access Renewable Resources: The Small Open Economy Case	IE	1997	248
Tahvonen	Fossil Fuels, Stock Externalities, and Backstop Technology	NR	1997	161
Gaudet	Natural Resource Economics under the Rule of Hotelling	NR	2007	145
Hamilton & Hartwick	Investing Exhaustible Resource Rents and the Path of Consumption	NR	2005	145
Renzetti	Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions	PC	1999	144

Ludema & Wooton	Cross-Border Externalities and Trade Liberalization: The Strategic Control of Pollution	IE	1994	141
Perroni, & Wigle	International Trade and Environmental Quality: How Important Are the Linkages?	IE	1994	128
Beghin, Roland-Holst & Van Der Mensbrugge	Trade and Pollution Linkages: Piecemeal Reform and Optimal Intervention	IE	1997	117

3.2. CREE Conference

The CREE conference has been held each year since 1991. We were successful in obtaining programs for 21 of the 26 years. We classified papers presented at the conference using the same topics as in Table 1. Figure 1 shows the average composition of papers across topics over the 26 years.

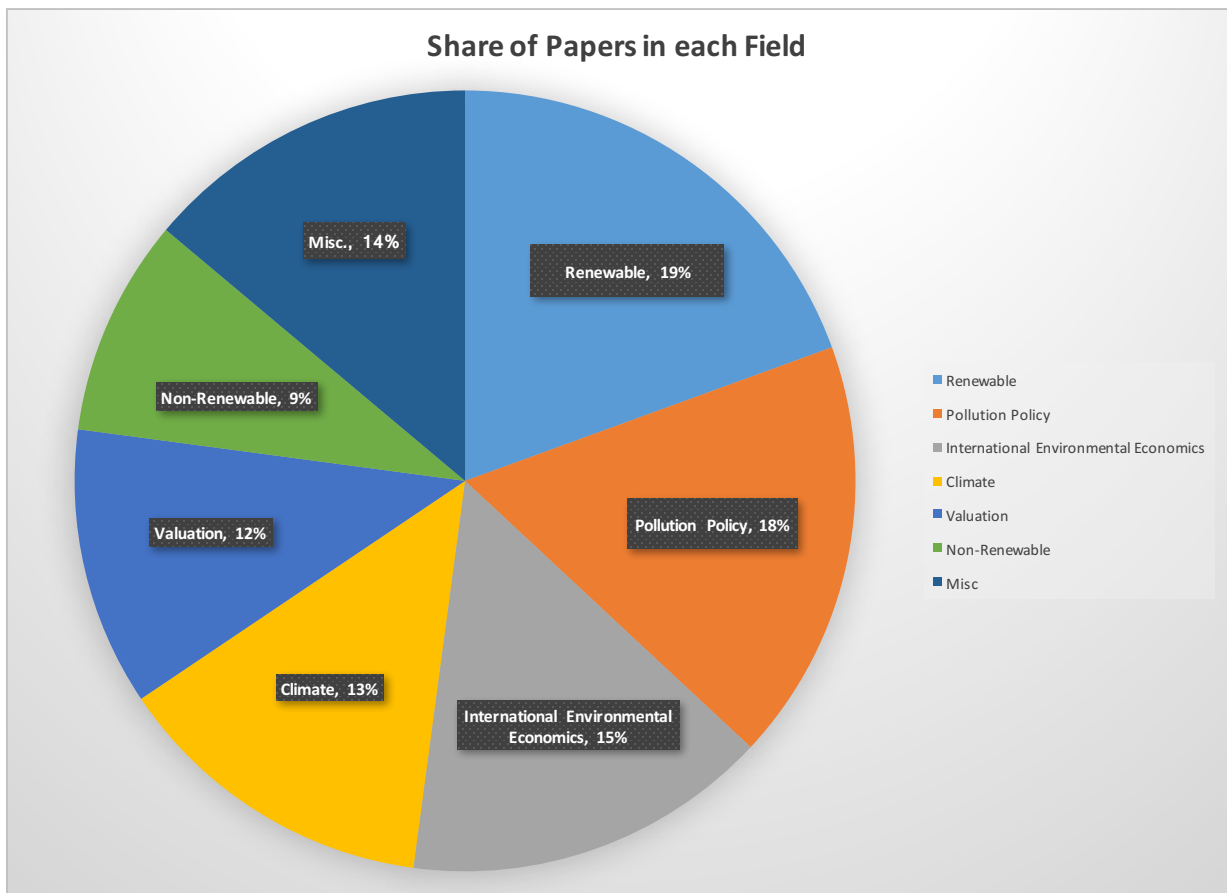


Figure 1. Share of papers on each topic at CREE Conference 1991 -2016

The topical pattern shares some striking similarities with the publication pattern we found for the CJE, with three exceptions. International environmental economics is less well represented at CREE than in the CJE, and there are more papers on valuation at CREE than in the CJE. And a larger share of the resource economics papers have been on renewable resources at CREE than in the CJE.

Next we looked at trends in paper topics selected for presentation at CREE. There is a lot of yearly fluctuation in topics, as would be expected given the relatively small numbers of papers on the program each year.⁷ To get a clearer picture of long run trends, we therefore plot 5 year averages to the extent possible given that we have a few missing programs.⁸ The results are illustrated in Figures 2a and 2b. Since the latter half of the 1990's there has been an increase in the fraction of papers on climate and international environmental economics, with a corresponding decline in the share of papers on other topics.

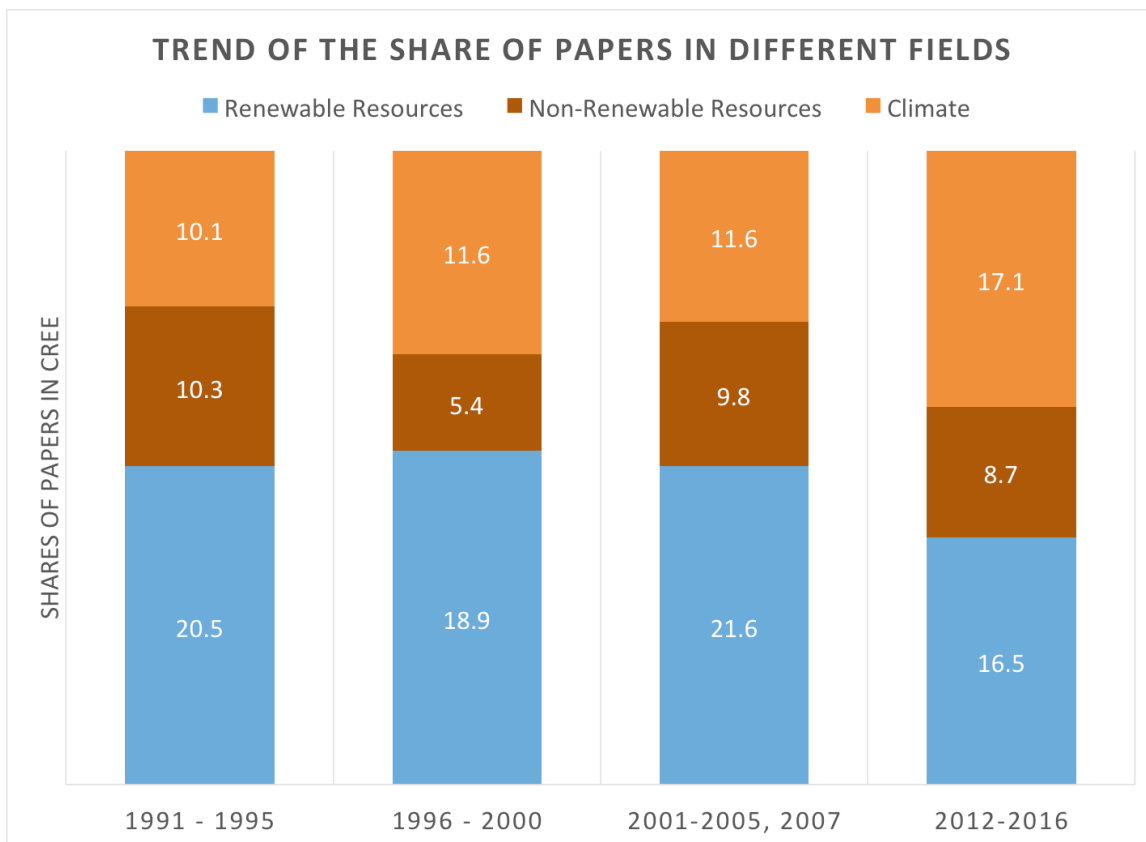


Figure 2a. Trends in Natural Resources and Climate Papers at CREE

⁷ There were about 20 papers per year until parallel sessions were introduced a few years ago, increasing the number of papers to 30-35 per year. The conference attracts many participants from Canada, Europe and the US and occasional participants from other countries such as Japan.

⁸ The programs we have from 2001-2007 are grouped together and we are missing 2008-2011.

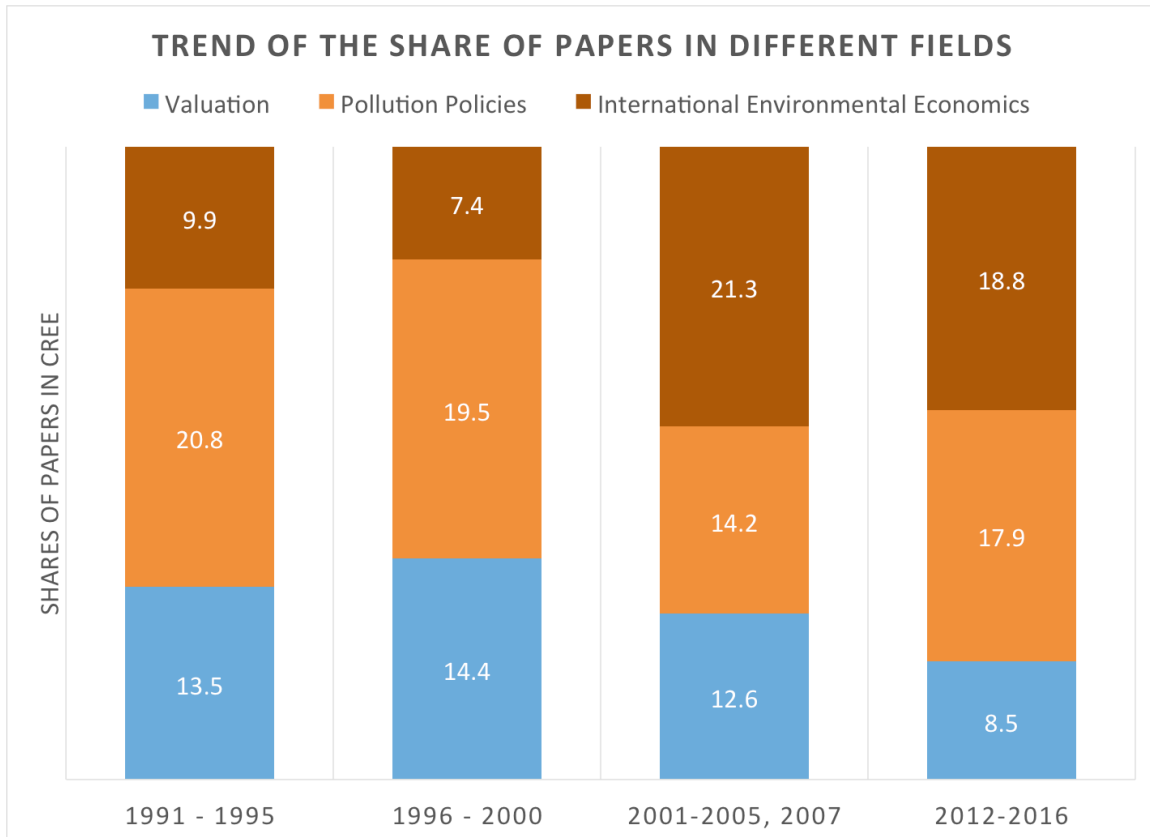


Figure 2b. Trends in Valuation, Pollution, and International Papers at CREE.

3.3. Publication of Enduring Quality Award

The Association of Environmental and Resource Economists (AERE) Publication of Enduring Quality Award has been presented annually since 1989 to recognize work that has had lasting impact in the field. The first award went to Harold Hotelling for his classic paper on exhaustible resources.⁹ Table 3 lists recipients working in Canada. Although all of the publications except one are from before our 25-year window, they highlight areas where Canadians have made fundamental contributions to the field that continue to have impact both in Canada and in the rest of the world today.

Three of the publications are in renewable resource economics. Gordon (1954) and Scott (1955) are the two seminal papers in fisheries economics that created the field. Clark's (1976) book was very influential in developing the dynamic approach to renewable resource economics. These works stimulated much work in renewable resources economics in Canada and around the world that continues today.

⁹ The rules were subsequently changed to require that the author be living at the time the award was selected.

Hartwick (1977) is a contribution to non-renewable resource economics, and is an early paper on sustainability. Its key result is that if resource rents are invested in human-made capital, a constant level of per capita consumption can be sustainable in a world with no technical change or population growth and Cobb-Douglas technology (as long as the share of resources in production is not too high). This became known as Hartwick's Rule. This work has a wide range of implications, ranging from the merits of creating sovereign wealth funds in resource-extracting countries, to the prescription that national accounts should measure net investment in natural as well as produced capital. Hartwick's contribution is an important precursor to "Green Accounting," which we discuss in section 5.2.

Antweiler et al. (2001) is a contribution to international environmental economics. It employs a combination of theory and empirical evidence to disentangle the effects of openness to trade, scale of production, and per capita income on sulphur dioxide pollution using a panel of air quality data from cities across the world. It found no evidence that increased openness to trade systematically shifted polluting industry to low income countries; that is, the evidence did not support the pollution haven hypothesis. And when the combined effects of changes in scale, composition of production, and production techniques are added up, freer trade led to lower levels of pollution for the average country in the sample. These findings stimulated a large literature on the effects of trade on environmental outcomes.

Table 3. AERE Publication of Enduring Quality Award: Recipients in Canada

Award Year	Publication	Topic
2000	Colin W. Clark (1976; 1990), <i>Mathematical Bioeconomics: The Optimal Management of Renewable Resources</i>	RR
2006	H. Scott Gordon (1954). "The Economic Theory of a Common-Property Resource: The Fishery" ¹⁰	RR
	Anthony Scott (1955). "The Fishery: The Objectives of Sole Ownership"	RR
2012	Werner Antweiler, Brian R. Copeland, and M. Scott Taylor (2001). "Is Free Trade Good for the Environment?" ¹¹	IE
2014	John M. Hartwick (1977). "Intergenerational Equity and the Investing of Rents from Exhaustible Resources."	NR

¹⁰ Scott Gordon did this work while at Carleton University. He moved to Indiana University in 1966

¹¹ In 2012 the prize was awarded jointly to two papers; the other was Grossman and Krueger's (1995) paper on the Environmental Kuznets curve.

4. Renewable Resources

Canadian contributions to the economics of renewable resources have been both deep and broad. The early work of Scott Gordon (1954), deepened by the capital theoretic insights of Tony Scott (1955) essentially launched the field of renewable resource economics, highlighting both the fundamental market failures in open access fisheries and laying the groundwork for the analysis of alternative management regimes. By the 1970's techniques from the optimal control literature were harnessed to analyze the intrinsically dynamic aspects of resource management highlighted by Scott (1955). Clark and Munro (1975) and Clark (1976) are two of the classic contributions to the field.

Canadians also had a major impact in advocating the use of individual transferable quotas (ITQs) for fisheries, arguably the most important example of an idea from the economics literature having a significant impact on resource management policy. The idea of using individual tradable rights to deal with environmental problems originated with Thomas Crocker (1966) and the University of Toronto's John Dales (1968) who proposed it as a way to manage pollution. Two of the strongest advocates for the use of ITQs in fisheries were Tony Scott (Scott et al., 1981) and Peter Pearce (1982).¹² Pearce (1988) provides a good discussion of the role of property rights more generally in strategies for the effective management of natural resources.

Since the 1990's Canadians have continued to make significant contributions to the fishery management literature. The fiction of an omniscient social planner adopted in many early renewable resource models was at odds with reality (Beddington et al., 2007). There is now considerable emphasis on incentive-based management where the motives and capacities of all actors are accounted for (Grafton et al., 2006). Clark, Munro and Sumaila (2005) showed that subsidies to reduce fishing capacity can have negative effects on resource conservation. Turner (1997) studied a negative side effect of ITQs – the problem of quota-induced discarding of unwanted fish. Several papers have argued for the establishment of marine protected areas to deal with the fundamental uncertainty present in many natural reproductive systems (Lauck et al., 1998). Many fish stocks are shared by multiple countries, which leads to complex management issues that have been studied extensively by Gordon Munro (see for example Munro et al., 2004).

One of the paradoxes of fisheries management is that despite evidence of declining fish stocks, fisheries are nevertheless heavily subsidized. In important work Sumaila et al. (2010) quantify these subsidies, estimating that they total in excess of US\$25 billion per year. Recent work by Sakai (2017) finds that the impact of these subsidies varies by both their ultimate purpose (whether they are for management

¹² For a good review of early contributions to the fishery economics literature that underscores the significant contributions of Canadians, see Wilen (2000).

improvement or go to subsidize costs), and the management regime in place (input management vs. ITQs). Some subsidies have little effect on stock depletion, while others do. In other work, Sumaila (2006) has highlighted the importance of illegal fishing as an impediment to management.

Other renewable resources have received attention. There have been numerous contributions to the water literature, notably Renzetti's (2002) book on water demand and Dupont and Renzetti (2001) on the role of water in manufacturing in Canada. Daniel Rondeau has several papers on wildlife management, including Rondeau (2001) on managing deer populations. Concern about climate change has led to research on the role of forests as carbon sinks (Wilman and Mahendrarajah, 2002; van Kooten et al. 2004) as well as the role of carbon services in influencing optimal forest rotations (van Kooten et al., 1995).

While much Canadian work in the renewable resource literature has focussed on management and policy issues, there has also been some empirical work on aspects of markets associated with resources. Dan Gordon has studied linkages between geographically separated fish markets and tested the law of one price (Gordon et al., 1993; Asche et al., 2004). Harry Paarsch used data from the forest industry to make significant contributions to the empirical auction literature. Paarsch (1992) used data on tree planting contracts in British Columbia to test whether the common or private value paradigm best characterized bidding behaviour. Researchers would often assume a priori that one or the other paradigm was operative; the attempt to distinguish between the two empirically was highly innovative. Paarsch (1997) used a structural empirical auction approach to recover the underlying valuations of bidders in timber auctions in B.C. using the empirical distribution of bids. He then showed how this can be used to calculate the optimal reserve price to maximize revenue for the seller. Paarsch and Shearer (1999, 2000) went on to use data from tree planting industry to study incentive effects of piece rates to pay workers and to compare piece rate compensation systems with fixed wages.

Finally, although much work on resource economics is narrowly focussed on management of particular stocks, the renewable resource paradigm is also fruitful for studying sustainability more broadly. For example, Brander and Taylor (1998) develop a simple general equilibrium model where human and environment interaction determines both population growth rates and environmental change. They use the model to examine the collapse of the Easter Island society, concluding that the uniqueness of its environment, relative to other islands colonized by Polynesians, led to its collapse. Brander and Taylor then argue that a similar pattern of environmental overshoot and collapse is evident in the histories of the Mayans, the Chaco Anasazi, and several Mesopotamian societies, a theme taken up and amplified by Jared Diamond's (2005) best-selling book *Collapse*.

5. Non-renewable Resources

Much work in environmental and resource economics is at root driven by a fundamental market failure arising from negative externalities. A key result of Hotelling's classic 1931 paper that laid the foundation for the theory of non-renewable resources is that markets can do a good job of allocating the extraction of exhaustible resources over time.¹³ The research agenda has therefore differed from that in other areas in resource and environmental economics, which is often dominated by the design and analysis of policies to deal with externalities. Market failures (arising from issues such as market power and pollution) play a role in the non-renewable resource literature, but they do not typically arise from the potential for resource exhaustion. Concerns about sustainability loom large, but they are mostly a problem of intergenerational distribution, rather than a narrow issue of economic efficiency.

5.1. *The Hotelling Model*

Hotelling's work had little impact until the 1970's when oil price shocks triggered concerns about the scarcity of resources. Throughout the 1970's and into the 1980's there were numerous refinements and extensions of Hotelling's model, especially to take into account strategic exploitation of market power, but also to allow for exploration, uncertainty, and interactions between resource stocks and economic growth. However as Slade and Thille (2009) in their review note, "By the 1990's ... interest in the subject began to wane, and by 2000, the flow of new theories and tests had been reduced to a trickle."¹⁴ In part this is because the set of research questions, motivated by evolving policy concerns, changed over time. Below we briefly discuss a few of the key research areas in which Canadians made contributions over this time.

The Hotelling model treats nonrenewable resource stocks as an asset, and the allocation of resource extraction over time is determined by intertemporal arbitrage. Expected future returns are weighed against present returns, and in the simplest version of the model this implies that expected resource rents will rise over time at the rate of interest. And this typically will imply that prices will rise over time as the resource stock is depleted.

While the logic and elegance of the model is appealing, finding empirical support for it has been challenging. Long run data on real prices for various non-renewable resources show a lot of volatility, but there is no obvious sustained upward trend

¹³ The other classic early contribution to non-renewable resource economics was by Gray (1914) who, using numerical examples and verbal analysis, studied the depletion path for a mine owner in a competitive market. Gray was at the University of Saskatchewan when this paper was published. See Crabbé (1983) for an extensive discussion of Gray's contributions to the field.

¹⁴ Notable extensions of the Hotelling model after 2000 include Gaudet et al. (2001) who consider spatially distributed deposits and consumers and Cairns (2001) who considers endogenous investment in the capacity of the mine.

(Gaudet, 2007). This has stimulated both theoretical and empirical work.

Slade (1982) showed that if technical change led to declining extraction costs over time, then prices may first exhibit long run declines before eventually rising. A number of studies, including Livernois and Uhler (1987) allowed for exploration and the discovery of new resource deposits; this also can lead to long run U-shaped price paths. However, evidence for U-shaped price paths is mixed at best. In recent work, Boyce and Nøstbakken (2011) have studied exploration and development of U.S. oil and gas fields and find support for the hypothesis of Hotelling scarcity effects.

Another line of work considered resource deposits as a risky asset, and linked the Hotelling model to the Capital Asset Pricing Model (Gaudet and Howitt, 1989; Gaudet and Khadr, 1991; Gaudet, 2007). The key insight is that resource asset prices should reflect risk (taking into account the covariance of the risk with other assets) as well as scarcity. Slade and Thille (1997) and Young and Ryan (1996) used data from Canadian mining firms and found evidence that taking into account risk premiums improves the empirical performance of the model, but nevertheless leaves much of the behaviour of resource prices unexplained.

The predictions of the Hotelling model can be used to value a mine: the value of reserves depends only on current spot price less marginal extraction cost. In a well-known paper, Miller and Upton (1985) used stock market data for oil and gas companies in the US and found support for this hypothesis. However subsequent tests were less supportive. Among these is Cairns and Davis (1998), who use data from gold mines and do not find support for the Hotelling valuation principle.

Ironically, one of the few studies that finds support for the Hotelling model is Livernois et al. (2006), who use data from old growth timber. While forests are usually considered a renewable resource, they argue that old growth timber can be treated as essentially non-renewable. They obtained data on the shadow prices of the resource from timber auctions, modify the model to take into account the opportunity cost of forest land, and find some support for the Hotelling predictions.

Finally, the Hotelling model has seen a revival recently because of the role of nonrenewable fossil fuel resources in contributing to climate change. The Green Paradox (Sinn, 2012) posits that policies aimed at reducing carbon emissions may ultimately fail or backfire because of the intertemporal substitution channel of the Hotelling model. In a Hotelling world, agents conserve nonrenewable resources because markets ensure that holding on to resource deposits will generate a return in the future. But if agents expect future carbon taxes, green innovations or other policies to reduce the expected future returns from extracting fossil fuels, then there is an incentive to shift production to the present, pushing up current levels of carbon emissions. This has been the subject of a growing literature focussing both on the robustness of this prediction and the design of supply side policies aimed at shutting down this channel. Recent contributions from people working in Canada

include Chakravorty, Leach and Moreaux (2011), Winter (2014), and Long (2015).

5.2. Sustainability and Green Accounting

Much of the interest in the Hotelling model during the 1970's and 1980's was driven by concerns that we might run out of exhaustible resources. The larger question behind this is the sustainability of well-being. The notion that humanity cannot survive by consuming its inheritance of capital (both natural and human-made) was well-known, but John Hartwick's (1977) paper was a key contribution in showing how sustainability might be achieved in a world with exhaustible resources. Hartwick's Rule (as his main result came to be known) was that under some conditions constant consumption can be sustained if resource rents are invested into another asset that can be used to generate a flow of consumption. The result is perhaps most compelling (when adjusted to account for terms of trade effects) in the case of a small open economy (see Vincent et al., 1995) because the premise is that countries can always buy whatever they need from the rest of the world if they run out of resources. Once we consider planet-wide sustainability, investment in human-made capital is not sufficient for survival; we also need natural and human made capital to be sufficiently good substitutes.

This work highlighted the importance of natural capital when thinking about sustainability and has led to a large literature aimed at improving national accounting to take into account natural capital when measuring net national product (this sometimes known as the Green GDP, or genuine savings literature). Hartwick has been a major contributor to this literature (see among others Hartwick, 1990; and Hamilton and Hartwick, 2005).

5.3. Taxation and Auctions

Whether or not a government attempts to follow a sustainable path or live off its resource endowment, strategies for raising public revenue from non-renewable resources are critical. Boadway and Keen (2010) and Gaudet and Lasserre (2015) synthesize, review and extend the resource taxation literature. Auctioning rights to extract resources is another important potential source of revenue. Early and influential work on empirical auctions using data on oil and gas leases was carried out by Ken Hendricks (see for example Hendricks and Porter, 1988 and Hendricks et. al, 1994).

5.4. Effects of Resource Extraction on the Rest of the Economy

Finally, there is a large and diverse literature that studies various spillover effects of resource abundance and extraction on the rest of the economy. A large literature focusses on the so-called "Resource Curse": many countries well-endowed with

natural resources are poor or embroiled in ongoing conflict (van der Ploeg, 2010). Some resource abundant countries have prospered, and so the question is why natural resources are good for some countries and not others. One channel that has been the subject of much attention is the role of institutions and how they interact with resource abundance. Baland and Francois (2000) was an influential contribution to that work. Much of this literature has not been explicitly linked to the Hotelling model. Boyce and Emery (2011) show that the Hotelling model predicts a negative correlation between resource abundance and income growth but a positive correlation between resource abundance and income levels. They find support for these predictions using a panel of U.S. state-level data.

A milder version of the "Resource Curse" is the "Dutch Disease," the hypothesis that real exchange rate appreciations and factor market reallocations caused by a resource boom lead to a contraction of the manufacturing sector. Two channels can generate a Dutch Disease (Corden and Neary, 1982). One is the spending effect: the wealth generated by the resource sector pushes up the demand for nontradables and this squeezes the manufacturing sector. Drelichman (2005) finds support for this in his study of the effect on Spain of its exploitation of silver mines in its American colonies. The other channel is a factor market reallocation effect, as the booming resource sector pushes up wages and pulls labour out of the manufacturing sector. Beine et al. (2012) find evidence in support of this for Canada using data from the 2002-2008 period of high oil prices. Beine et al. (2015) study the role of immigration and inter-provincial migration in mitigating Dutch Disease effects in Canada. Carbone and McKenzie (2016) use a computable general equilibrium model to assess the effects of an oil price shock on different sectors and provinces in Canada.

Another question is how the benefits and costs of resource extraction trickle down into the rest of the economy. This is a particularly important issue in developing countries. Recent work exploits micro data to assess the incidence of resource booms. Aragon and Rud (2013) find evidence that real income rose in communities near a large gold mine in Peru. On the other hand, in their study of gold mining in Ghana, Aragon and Rud (2016) find that pollution from mining lowered agricultural productivity, thus reducing rural income.

The spillover and trickle down effects are also important for developed countries. Fortin and Lemieux (2015) found that resource booms in extractive industries in Newfoundland, Saskatchewan and Alberta increased wages for young and less educated workers and reduced wage dispersion in those provinces. The costs of pollution from resource extraction however can potentially undermine real income gains. Muehlenbachs et al. (2015) study the effects of shale gas developments on water quality and housing markets in Pennsylvania and quantify the costs of pollution.

6. Pollution Control

6.1. Policy Instruments

Canadian contributions to the pollution control literature have been eclectic; it is difficult to point to a core area where there have been sustained contributions.

Perhaps the key policy innovation in environmental regulation over the past 30 years has been the use of tradable emission permits. Most accounts credit John Dales (Dales, 1968) and Thomas Crocker (1966) for independently developing the idea.¹⁵ Until very recently, much of the academic focus on transferable permits in Canada was in the fisheries literature, where the system is known as Individual Transferable Quotas (ITQs). There has however been some work in Canada on tradable emission permits. Muller and Mestleman (1998) used lab experiments to study cap and trade systems, van Egteren and Weber (1996) study the link between permit allocations and non-compliance, Insley (2003) studied a firm's incentive to invest in pollution control, and Bruneau (2004) considered incentives to innovate.

There have also been various contributions to theoretical aspects of the design and potential impact of environmental policy. The role of politics in the design of environmental policy was studied by Boyer and Laffont (1999) and Yu (2005), while enforcement issues were considered by Livernois and McKenna (1999). Boyer and Laffont (1997) consider the implications of making banks that finance polluting firms liable for pollution damages. Dewees et al. (1996) study the role of tort law in dealing with environmental problems in their book on accident law. Benckekroun and Long (1998) study the interaction between pollution policy and firm-level market power. Another form of strategic interaction arises when neighbouring countries pollute. This has generated a literature using dynamic games. Dockner and Long (1993) is an early contribution. Long (2011) provides a good survey of applications of dynamic games to all aspects of environmental and resource economics.

Much of the work on pollution regulation assumes that abatement occurs via a black box in the firm's production technology. In practice, specialized firms provide technologies and services to help polluters achieve cleaner production. In a series of papers Bernard Sinclair-Desgagné and colleagues have studied the role of the environmental service industry under various assumptions about market structure and pollution policy instruments (see David and Sinclair-Desgagné, 2005).

A large literature, mostly developed outside Canada (although see McKittrick, 1997) considered the interaction between environmental policy and labour market distortions (see Goulder, 2013). This is often referred to as the "double dividend" literature. The idea is that the revenue collected from pollution taxes can be used to reduce other distortions in the economy – a cleaner environment is the first

¹⁵ See for example Stavins (2003).

dividend; a more efficient tax system is potentially the second dividend. The British Columbia carbon tax is one of the few cases where this idea has been more or less put in place – the tax was sold as being revenue neutral and some individual and business marginal tax rates were reduced when the carbon tax was enacted. Work assessing the efficacy of the BC carbon tax has recently begun to emerge – see Rivers and Schaufele (2015), Antweiler and Gulati (2016) and Yamazaki (2016).

6.2. Growth and the Environment

The last twenty-five years have seen a debate on aggregate pollution outcomes stimulated by Grossman and Krueger's (1995) finding of a pattern of first rising and then falling pollution levels with per capita income. This finding, dubbed the Environmental Kuznets Curve (EKC), created a large and voluminous literature using both theory and empirics to understand more deeply the connections between economic growth and the environment.¹⁶ Copeland and Taylor (2003, chapter 3) examine in detail several theories giving rise to an EKC pattern. Antweiler et al. (2001) isolate the scale effect of economic growth (which tends to raise pollution) from the effects of increased per capita income (which tends to reduce pollution via increased policy stringency). Several papers have shown that the empirical finding of an EKC pattern is sensitive to pollutant type, country selection, etc. What is unclear even today is whether these sensitivities arise because of improper aggregation across countries, each of which is following its own environment development path.¹⁷ Equally uncertain is how this finding should impact on environmental policy more generally. It has been interpreted by some as suggesting economic growth is a panacea for improved environmental quality, when in fact growth – at best – provides us with the means to make better environmental choices. To this day, the EKC literature and debate remains contentious.

6.3. Climate Change

Climate change has stimulated a great deal of research on pollution control and mitigation. One vehicle for assessing potential outcomes and different policy scenarios is the use of large scale quantitative models. John Whalley and Randy Wigle were early contributors to this literature; Whalley and Wigle (1991) considered the international incidence of carbon taxes and in Abrego et al. (2001) they consider the implications of linking global trade and environmental policy. Mark Jaccard and his colleagues have developed quantitative models for Canada explicitly aimed at assessing various climate change policy options (see for example Jaccard et al., 2003). Jared Carbone used computable general equilibrium models to explore various aspects of climate change policy. See for example Carbone et al.

¹⁶ For a review of the growth and environment literature see Brock and Taylor (2005).

¹⁷ An inspection of raw emission data will in many cases reveal an EKC pattern across time for many of the currently developed countries of the world, and this would seem to suggest a common mechanism behind the data. See Brock and Taylor (2010) and Cherniwchan (2012) for an alternative empirical approach to study the growth and environment relationship.

(2009) who consider the potential benefits of global trade in emission permits. Small scale analytical general equilibrium models have also been used to study climate change policy. Copeland and Taylor (2005) use a simple general equilibrium model to show how some of the classic results in environmental economics need modification in a general equilibrium context with international trade. For example, allowing global trade in emission permits can make some countries worse off because of induced terms of trade effects in goods markets.

There has also been much debate arising from the uncertainties associated with the process of climate change. One such debate was initiated by early reconstructions of historic temperature records showing a relatively flat pattern from the 11th-19th century followed by a sharp increase in the 20th century (Mann et al. 1998, 1999). This hockey stick pattern was featured in the 2001 IPCC Third Assessment Report. Ross McKittrick together with co-author Stephen McIntyre (2003, 2005) played a leading role in questioning the methods and results of this work.¹⁸ In other work related to climate change uncertainty, Leach (2007) studies the implications of gradual learning about the long term causes of climate change.

6.4. Identification and Policy Evaluation

Finally perhaps the most significant trend in the environmental literature in the past 15 years has been the use of empirical techniques from the labour, public and empirical IO literatures to evaluate policy outcomes and / or to use counterfactuals to evaluate policy alternatives. Another branch of the literature seeks to identify the effects of pollution and other environmental factors on health, agricultural productivity and other factors that can be used to value the benefits of improvements in environmental quality. To date there has been relatively little work of this type in Canada. A recent contribution is Muehlenbachs et al. (2015), who estimate the effects of shale gas developments in Pennsylvania on housing markets. Other Canadian examples of empirical work evaluating policy outcomes include Chandra et al (2010), who assess the effects of tax rebates on hybrid vehicles; Harrison and Antweiler (2003), who use data from Canada's national Pollution Release Inventory to distinguish between the role of voluntary reductions in emissions from the effects of direct regulation (they find that direct regulation is the primary driver); Renzetti (1999), who finds that marginal prices for water and sewage charged to firms and residential users are well below marginal costs; and Eckert (2004) and Muehlenbachs et al. (2016) on the role of inspections in enforcement of environmental regulations.

¹⁸ The interested reader is directed to the National Oceanic and Atmospheric Administration's very user-friendly interface (<https://www.ncdc.noaa.gov/cag/time-series/global>) to plot their own temperature record. Of particular relevance to Canada is the shrinking Arctic sea ice. See <https://www.climate.gov/news-features/videos/old-ice-arctic-vanishingly-rare>.

7. Non-market Valuation

There are two main ways to estimate the value that consumers place on environmental amenities - the revealed preference approach, and the stated preference approach. The revealed preference approach uses market transactions and actual behaviour, while the stated preference approach relies on survey methods. Canadians have made fundamental contributions to both.

The challenge in valuing environmental amenities such as air and water quality, wilderness preservation, recreation benefits, etc. is that the amenities are not traded in markets. Consequently the revealed preference approach needs to use indirect methods to estimate consumer demand. The travel cost method is one of the cornerstone valuation techniques. Pioneering work in developing the method was carried out by Jack Knetsch (Clawson and Knetsch, 1966). The idea is that even though consumers may not directly pay for their consumption of wilderness recreation services, they incur costs to travel to and use the sites. These costs vary with distance from the site, opportunity cost of time, etc. Travel costs can serve as proxies for prices and can be used to estimate demands for recreational services that will vary with the quality of the environmental amenities at the various sites. Time costs play an important role in the travel cost method and Wilman (1980) contributed a theoretical model incorporating time constraints.

Knetsch also made fundamental contributions to the interpretation of the stated preference approach to valuation and his work also forms an early contribution to the growing field of behavioural economics. In a series of papers, he and his co-authors used experiments to point out the importance and persistence of gaps between what individuals are willing to pay for a good and what they are willing to accept in compensation for giving up the good (Knetsch and Sinden, 1984; Kahneman, Knetsch and Thaler, 1990). These gaps were much larger than could be accounted for by income and wealth effects. In other work Kahneman and Knetsch (1992) demonstrated the importance of "embedding effects". The values obtained from surveys depend on whether consumers are asked to value goods on their own or as part of a larger package. For example, reported willingness to pay to protect a particular endangered bird may not differ much from reported willingness to pay to protect all endangered birds. They also provided evidence that it can be difficult to separate the intrinsic economic valuation of a good from the moral satisfaction association with contribution to a public good. All of this work raised important questions relevant to the design and interpretation of surveys that aim to elicit consumer demands for environmental amenities. It also stimulated refinements and innovations in the design of stated preference methods. For example, Rollins and Lyke (1998) showed how the presence of diminishing marginal existence values has implications for the sensitivity of willingness to pay measures to the scope of the goods in question (such as protecting the first national park versus protecting the 50th park).

While revealed and stated preference methods are often viewed as substitutes, it is

possible to combine them. Adamowicz et al. (1994) is an early and very influential paper developing techniques for combining the two approaches. Their methods have been used in numerous applications.

Vic Adamowicz, Peter Boxall, Michael Williams and their colleagues have also made numerous fundamental contributions to the development of stated preference methods. One important aspect of their work has been the development of techniques using choice experiments where the environmental attributes survey respondents choose are varied in an experimental design. Boxall et al. (1996) compares this approach with alternative stated preference approaches. Adamowicz et al. (1998) developed methods for using stated preference approaches for passive use valuation - cases where a change in environmental quality is not reflected in changes in observable behaviour. These methods have been widely applied in both academic and consulting contexts. Boxall and Adamowicz (2002) develop a method to identify preference heterogeneity across consumers and use this to value different policies that affect wilderness park attributes.

Another strand of the valuation literature focuses on the value of preserving the option to make a future choice (Arrow and Fisher, 1974). Kassar and Lasserre (2004) find there is an option value to preserving multiple similar species if there is uncertainty about which species will best fulfill future needs. Margaret Insley (formerly Forsyth) has applied option value to a number of different environmental and resource questions, including whether or not to preserve a forested wilderness preserve when its amenity value follows a stochastic process (Forsyth, 2000).

There are numerous applications of valuation techniques; we mention only a couple here. Adamowicz et al. (2011) use multiple valuation methods to estimate and compare the value of reducing microbial illness and cancer risks in the context of drinking water quality. Dupont (2004) studies gender differences in environmental valuations. Parents of either gender are willing to pay more for environmental quality than those without children, and there is some evidence that men have higher valuations than women.

8. International Environmental Economics

Work on trade and the environment has expanded significantly since the early 1990's. This was a time of increasing globalization and a proliferation of trade agreements. Key questions are how the design and stringency of environmental policy is affected by openness to trade and investment, whether more stringent environmental policy affects international competitiveness, and whether globalization exacerbates environmental problems.

8.1. *Environmental Policy in an Open Economy*

Although there was work in the 1970's on potential conflicts between a free trade agenda and the environment, the debates over the merits of free trade agreements

throughout the 1990's stimulated a great deal of work on the interaction between trade and environmental policy (see Copeland, 2011 for a review). In the absence of effective environmental policy, trade liberalization can exacerbate environmental problems and reduce welfare if the costs of environmental harm exceed the efficiency gains from freer trade. Copeland (1994) examined trade and pollution policy reform in an economy with both trade and environmental policy distortions. One lesson from that work is that reforms of trade policy need to be accompanied by environmental policy reforms. Another lesson is that trade policy can act as a substitute for weak environmental policy. If countries lack an effective environmental policy regime, trade restrictions that reduce production or consumption of pollution intensive goods and activities can yield gains.

A different concern is that governments may sacrifice environmental interests to promote or protect polluting industries. In public policy discussions, this is the fear of a "race to the bottom" in environmental policy. A large literature uses the Brander and Spencer (1985) export subsidy model to explore this issue. Brander and Spencer showed that when domestic and foreign firms have market power, governments can have an incentive to subsidize domestic firms. This gives firms a strategic advantage over their foreign rivals and shifts profits from foreign to domestic firms. Peter Kennedy's (1994) paper was one of three papers that appeared around the same time applying this idea to environmental policy.¹⁹ In addition to clarifying conditions under which governments might want to use weak environmental policy as a disguised subsidy, these papers provided a work-horse model that has been used to explore many questions on the interaction between trade and environmental policy.

Markusen, Morey, and Olewiler (1993, 1995) also consider firms with market power. They show that small changes in pollution policy can yield large discrete changes in pollution and welfare as firms decide to relocate. And, depending on the severity of the harm from pollution, governments may engage in either a race to the top (as environmental policy is aimed at driving away polluting firms) or a race to the bottom (as weak environmental policy is used to attract domestic production).

In recent years, there has been a much interest in linkages between trade and climate change. One issue is the effect of trade on the incentives to regulate emissions of global pollutants. When pollution spills over international borders, the trade regime affects the strategic interaction between governments in their choice of environmental policy. Copeland and Taylor (1995) show that a free trade agreement ends up acting like a credible commitment by dirty good exporters to pollute more and gives them a strategic advantage in the non-cooperative game in emissions. This has implications for issues such as the sequencing of trade and environmental negotiations (dirty good exporters would like to secure a free trade agreement prior to negotiating an emissions agreement).

¹⁹ The others were Barrett (1994) and Conrad (1993).

Trade can potentially undermine subglobal agreements to reduce carbon emissions via carbon leakage – a commitment to emission cuts by a coalition of countries can create incentives for pollution-intensive production to shift to countries outside the coalition. This has generated a debate over the role for border adjustment taxes to combat carbon leakage. Markusen (1975) laid the foundation for this work - he showed how trade policy can be used to target pollution from foreign countries that affects Home. Whereas Markusen analyzed a simple import tax, Copeland (1996) considered the merits of a pollution content tax on imports. Recent contributions from people working in Canada include Böhringer, Carbone and Rutherford (2016) who use computable general equilibrium scenarios to investigate the effects of border taxes on carbon leakage, and McAusland and Najjar (2015) who study the potential for carbon footprint taxes to mitigate leakage concerns.

The key premise of much work on the interaction between environmental policy and trade is that environmental policy affects trade and investment flows. The existence and magnitude of this effect is the subject of a large empirical literature.²⁰ Early work found little or no effect of environmental policy on trade flows. However, subsequent work from the last 15 years using panel data and taking endogeneity seriously has found that more stringent environmental policy does tend to reduce net exports and incoming foreign direct investment. There has been relatively little work on these issues in Canada. One exception is Levinson and Taylor (2008) , who use a panel instrumental variables approach and finds that US environmental regulations have a relatively large and significant effect on US imports from Canada and Mexico.

This work is related to the larger issue of how environmental policy affects competitiveness. Porter (1991) famously proposed that more stringent environmental policy (if properly designed) could increase competitiveness. This became known as the Porter Hypothesis and generated much theoretical and empirical work. See Ambec et al. (2013) for a recent review.

8.2. *Effects of Trade on the Environment*

Much of the concern about the effects of trade on the environment revolves around the Pollution Haven Hypothesis according to which trade causes polluting industry to concentrate in relatively poor countries with weak environmental policy. Copeland and Taylor (1994) developed a simple pollution haven model with endogenous environmental policy. Because environmental quality is a normal good, richer countries have more stringent environmental policy and hence a comparative advantage in clean goods. Trade shifts polluting production to countries with weak environmental policy and this increases global pollution. Many refinements of this model exist. In Antweiler et al. (2001) and Copeland and Taylor (2003) environmental policy interacts with other sources of comparative advantage (such as relative capital abundance) to determine trade patterns. If other factors matter

²⁰ For reviews of this literature see Copeland and Taylor (2004) and Levinson (2010).

more than environmental policy, richer countries could have a comparative advantage in the polluting industry and the pollution haven hypothesis would fail. Other work such as Benarroch and Weder (2006) and McAusland and Millimet (2013) considers the effects of trade on pollution when there is intra-industry trade.

A large empirical literature seeks to identify the effects of trade liberalization on environmental outcomes. A simple decomposition is useful to think about this (Grossman and Krueger, 1993; Copeland and Taylor, 1994). Holding all else constant, an increase in the scale of production will raise pollution. Pollution can fall if production techniques become cleaner. And the composition of economic activity matters – pollution tends to rise if the mix goods produced becomes dirtier.

In models where trade is driven by comparative advantage, a key prediction is that trade-induced composition effects will contribute to increases or decreases in pollution depending on whether a country has a comparative advantage in dirty or clean production. One of the surprising empirical findings is that composition effects of trade on pollution tend to be small. This is found in computable general equilibrium models (Perroni and Wigle, 1994), studies that try to estimate the composition effects of trade (Antweiler et al, 2001; Cole and Elliott, 2003), and in studies that directly measure the composition effect using a decomposition approach (Levinson, 2009; Shapiro and Walker, 2015). Controlling for scale and income, the pure effects of trade tend to have little effect on environmental outcomes. This is surprising in part because the empirical work noted above studying the effects of environmental policy on trade patterns has found that environmental policy does affect trade flows, although the magnitude of the effect varies across studies.

With little measured change in the composition of production, both Levinson (2009) and Shapiro and Walker (2015) attribute the significant declines in pollution from US manufacturing over the past 25 years to large reductions in emission intensities. However, the changes in composition of production are measured at the sectoral or product level. One possibility is that trade may induce significant changes in the composition of output across firms within sectors. Measured sectoral emission intensities would fall if trade causes a decline in production from less efficient dirtier firms and expands production from more efficient and cleaner firms. Over the past 10 to 15 years, a large empirical international trade literature has documented significant firm-level adjustments to trade liberalization. This research agenda is just beginning to be exploited in the trade and environment literature. Cherniwchan et al. (forthcoming) review and synthesize this work, using a framework that decomposes changes in sectoral emission intensities into changes in the composition of output across firms within a sector, and changes in the composition of tasks within firms, as well as actual changes in emission intensities at the task level.

Recent work has employed other methods to estimate the effects of trade. Bombardini and Li (2016) find significant effects of pollution-induced increases in

infant mortality in prefectures in China that experienced positive export shocks in pollution intensive industries due to WTO tariff changes in the rest of the world. Cherniwchan (2017) finds that NAFTA reduced emissions from US firms and finds evidence that this was due to offshoring of pollution intensive tasks.

8.3. *Effects of Trade on Natural Capital*

Much work on trade and pollution has at its root a trade-off between income and environmental quality. However, the natural environment is an important input into production and human health, and so income and environmental quality can be complements. The literature on trade and renewable resources takes this linkage seriously.

Brander and Taylor (1997) combine the classic Schaeffer open access fisheries model with a Ricardian trade model to study the effects of trade liberalization on renewable resources and real income. Countries with a comparative advantage in renewable resource harvesting experience short run income gains, but long run stock depletion. In their benchmark case, trade lowers long run real income.

This work has been extended in various ways; here we highlight work done in Canada. A key implication of the Brander/Taylor model is that the effects of trade on renewable resources depend on the property rights regime. If externalities are fully internalized then trade leads to the usual gains. In practice there exists a wide range of property rights / regulatory regimes, and so we expect that the effectiveness of regulations will be endogenous. One line of enquiry links overuse of resources to poaching by those without harvesting rights. Another focuses on the monitoring and enforcement of activity by those with harvesting rights. Bulte and van Kooten (1999) examine the impact of an ivory trade ban on elephant populations in the presence of poaching taking into account the tourism benefits of elephants but also the damage they cause to local agriculture. While a trade ban has an ambiguous effect on optimal stocks, their empirics suggest a lower population may be optimal in the case of Zambia. Hotte, Long and Tian (2003) consider a model with endogenous poaching. An export boom leads to an increase in resources allocated to protecting the resource stock, but nevertheless can still lead to welfare losses. Copeland and Taylor (2009) develop a model with imperfect monitoring of those with harvesting rights, so that resource regulators face an incentive constraint when implementing regulations. Trade can lead to transitions in the management regime. Management and real income improve with trade in some resources, but trade can lead to resource collapse in other cases.

Trade can also have direct effects on natural capital via the introduction of invasive species. In a series of papers Carol McAusland has studied how the risk of invasive species varies with trading partners (Costello et al., 2007), and possible trade-related policy remedies (McAusland and Costello, 2004).

In contrast to the work on trade and pollution, there has been relatively little

empirical work that seeks to identify the effects of trade on the sustainability of renewable resources. In Canada, most of this work has come from economic history. Carlos and Lewis (1993, 2010) have studied the role of competition between the Hudson's Bay Company and Northwest Company and interaction with North American indigenous people in the depletion of beaver populations in the export trade in beaver pelts in early Canada. Allen and Keay (2001) study the near extinction of the Bowhead whales off Greenland in the late 17th and early 19th century. They identify various factors contributing to the collapse, among them being international competition among whalers. Taylor (2011) finds that the interaction between international trade, innovations in tanning technology and booming demand from European countries led to the rapid collapse of bison populations in the United States in the period 1870-1880.

An important finding from economic history is that international markets can be very destructive to natural resource stocks, and this destruction can occur in a very short time window. Opening up to trade can concentrate global demand on harvests from individual resource stocks. Without effective regulations or institutions to prevent overexploitation, collapse can happen relatively quickly. This realization, together with the recognition that property rights regimes and regulation are slow to develop suggests that we should be vigilant when considering the effects of increased globalization on natural capital.

9. Conclusion

Canada is a resource abundant country heavily reliant on international trade, and with large expanses of wilderness. It is not a coincidence that those areas where Canadians have played a leading role in the development of the field – resource economics, international environmental economics, and valuation of environmental amenities – reflect Canada's place in the world. But although the motivations for research may have been influenced by the Canadian experience, researchers in Canada have been fully engaged internationally, with contributions from Canada advancing the field around the world and techniques from elsewhere influencing work in Canada.

We conclude with a few thoughts on future research in Canada and abroad.

Economics has increasingly become an empirically grounded discipline over the past couple of decades and much of the most recent innovative work in environmental and resource economics has used careful and creative empirical strategies to identify the effects of policies and other factors in determining outcomes. Although data limitations are always a constraint, there is much potential for more work of this type in Canada. And in some areas, there are many opportunities for the interaction between theory and empirical work. The underwhelming empirical performance of the Hotelling model is one example where the development of new theory, disciplined by empirics, would seem to have potential.

There has been much attention to climate change in recent years. It is one of the great challenges of our time and combines interesting issues of measurement, governance, interaction between the economy and the environment, and issues of global and intergenerational equity. Work on climate change should and will continue to attract a great deal of attention. However one of the lessons from recent empirical work on pollution and health is that local air and water pollution continue to have serious and large negative effects on human health. This is especially the case in developing and newly industrializing countries. These are cases where finding ways to address environmental problems can have large benefits in the near term as well as in the long run. The literature on linkages between the environment and development is growing but there is much scope for more work examining the health consequences of environmental policy.

Environmental and resource economics is concerned with connections between the economy and the natural environment. One of the hallmarks of work on renewable resource economics is that it takes seriously the interaction between the biology of the resource and economic incentives. There is also much work on climate change that follows this path.²¹ Interdisciplinarity works better in some contexts than others, but this is a field where linkage between different disciplines has been critical in understanding outcomes and developing good policy.

Another important channel of linkages is between different markets in the economy. Much work in environmental economics is partial equilibrium, and in many cases that is appropriate. However in recent years we have seen increased use of general equilibrium models. The double dividend literature studied the interaction between environmental policy and the labour market; the trade and environment literature exploits the effects of environmental policy on comparative advantage; and the climate change literature focusses on the long run effects of the interaction between the economic system globally and the natural environment. In each of these cases, the use of general equilibrium approaches has been essential in developing new insights. This trend is likely to continue and become more important in the future because interactions between countries (and hence general equilibrium effects) are fundamental in the climate change problem and inevitable in many local environmental problems because of linkages across countries and markets via trade and technology flows. Canadians (and the *Canadian Journal of Economics*) are in an ideal position to lead the world in producing and publishing this much needed research, given our long history of significant contributions to international, resource, and environmental economics.

²¹ See for example Moreno-Cruz (2015) and Moreno-Cruz and Keith (2013).

References

- Abrego, L., Perroni, C., Whalley, J. and Wigle, R. M. (2001) "Trade and environment: bargaining outcomes from linked negotiations," *Review of International Economics* 9(3), 414-28
- Adamowicz, W.L., J.J. Louviere and M. Williams (1994) "Combining revealed and stated preference methods for valuing environmental amenities," *Journal of Environmental Economics and Management* 26(3), 271-92
- Adamowicz, W.L., P. Boxall, M. Williams and J. J. Louviere (1998) "Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation," *American Journal of Agricultural Economics* 80(1), 64-75
- Adamowicz, W.L., D. Dupont, A. Krupnick and J. Zhang (2011) "Valuation of Cancer and Microbial Disease Risk Reductions in Municipal Drinking Water: An Analysis of Risk Context Using Multiple Valuation Methods," *Journal of Environmental Economics and Management* 61(2), 213-26
- Allen, R.C. and I. Keay (2001) "The First Great Whale Extinction: The End of the Bowhead Whale in the Eastern Arctic," *Explorations in Economic History* 38(4), 448-77
- Ambec, S., M. Cohen, S. Elgie and P. Lanoie (2013) "The Porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness?" *Review of Environmental Economics and Policy* 7(1):2-22.
- Antweiler, W., B. R. Copeland, and M. Scott Taylor (2001) "Is free trade good for the environment?" *American Economic Review* 91(4), 877-908
- Antweiler, W. and S. Gulati (2015) "Scrapping for Clean Air: Emissions Savings from the BC SCRAP-IT Program," *Journal of Environmental Economics and Management* 71, 198-214
- Antweiler, W. and S. Gulati (2016) "Frugal Cars or Frugal Drivers? How carbon and fuel taxes influence the choice and use of cars." *SSRN Working Paper 2778868*
- Arrow, K. and A. C. Fisher (1974) "Environmental preservation, uncertainty, and irreversibility," *Quarterly Journal of Economics* 88:312-319.
- Asche, F., Gordon, D. V. and Hannesson, R. (2004) "Tests for market integration and the law of one price: the market for whitefish in France," *Marine Resource Economics* 19(2), 195-210
- Aragon, F.M. and J. P. Rud (2013) "Natural Resources and Local Communities: Evidence from a Peruvian Gold Mine," *American Economic Journal: Economic Policy* 5(2), 1-25
- Aragon, F.M. and J. P. Rud (2016) "Polluting Industries and Agricultural Productivity: Evidence from Mining in Ghana," *Economic Journal* 126(527), 1980-2011
- Aufhammer, M. (2009) "The Field of Environmental and Resource Economics: A Google

- Scholar Perspective," *Review of Environmental Economics and Policy* 3(2), 251–69
- Baland, J.M. and P. Francois (2000) "Rent-seeking and resource booms," *Journal of Development Economics* 61(2), 527–42
- Barrett, S. (1994) "Strategic environmental policy and international trade," *Journal of Public Economics* 54(3), 325–38
- Beddington, J.R., Agnew, D. J. and Clark, C. W. (2007) "Current problems in the management of marine fisheries." *Science*, 316(5832), 1713–16
- Beine, M., C. Bos, and S. Coulombe (2012) "Does the Canadian Economy Suffer from Dutch Disease?" *Resource and Energy Economics* 34(4):468–92.
- Beine, M., S. Coulombe, and W. Vermeulen (2015) "Dutch Disease and the Mitigation Effect of Migration: Evidence from Canadian Provinces." *Economic Journal* 125(589):1574– 1615
- Benarroch, M. and R. Weder (2006) "Intra-industry trade in intermediate products, pollution and internationally increasing returns," *Journal of Environmental Economics and Management*, 52(3): 675–89
- Benckroun, H. and N.V. Long (1998) "Efficiency inducing taxation for polluting oligopolists," *Journal of Public Economics* 70 (2): 325-42.
- Boadway, R., and M. Keen (2010) "Theoretical perspectives on resource tax design," *The Taxation of Petroleum and Minerals: Principles, Problems and Practice* 24, 13–74
- Böhringer, Christoph, Jared C. Carbone and Thomas F. Rutherford (2016) "The Strategic Value of Carbon Tariffs," *American Economic Journal: Economic Policy*, 8(1), 28–51
- Bombardini, M. and B. Li (2016) "Trade, Pollution and Mortality in China," *NBER Working Paper No. 22804*
- Boxall, P.W. Adamowicz, M. Williams, J. Swait and J. Louviere. (1996) "A comparison of stated preference approaches to the measurement of environmental values." *Ecological Economics* 18(3), 243–53
- Boxall, P.C. and W. Adamowicz. (2002) "Understanding heterogeneous preferences in random utility models: the use of Latent Class Analysis." *Environmental and Resource Economics* 23(4), 421–46
- Boyce, J.R. and L. Nostbakken (2011), "Exploration and Development of U.S. Oil and Gas Fields, 1955-2002." *Journal of Economic Dynamics and Control*, 35 (June): 891-908.
- Boyce, J.R. and J. C. Herbert Emery (2011), "Is a Negative Correlation Between Resource Abundance and Growth Sufficient Evidence that There Is a 'Resource Curse'?" *Resources Policy*, 36 (March 2011): 1-13.
- Boyer, M. and J. J. Laffont (1997) "Environmental Risks and Bank Liability," *European Economic Review* 41(8), 1427–59

- Boyer, M. and J. J. Laffont (1999) "Toward a Political Theory of the Emergence of Environmental Incentive Regulation," *Rand Journal of Economics* 30(1), 137–157
- Brander, J. A. and B. J. Spencer (1985) "Export Subsidies and International Market Share Rivalry," *Journal of International Economics* 17(1–2), 83–100
- Brander, J. A., and M. S. Taylor (1997) "International Trade and Open-Access Renewable Resources: The Small Open Economy Case." *Canadian Journal of Economics* 30(3), 526–552
- Brander, J. A., and Taylor, M. S. (1998) "The simple economics of Easter Island: A Ricardo-Malthus model of renewable resource use." *American economic review* 88(1), 119–38
- Brock, W.A. and M.S. Taylor, (2005) "Economic Growth and the Environment: A Review of Theory and Empirics," in P. Aghion and S. N. Durlauf, eds., *Handbook of economic growth*, Volume 1, Pages 1749-1821, Elsevier
- Brock, W.A. and M.S. Taylor, (2010) "The Green Solow Model," *Journal of Economic Growth*, 15 (2), 127-153.
- Bruneau, J.F. (2004) "A Note on Permits, Standards, and Technological Innovation" *Journal of Environmental Economics and Management* 48(3), 1192–99
- Bulte, E. H., & Van Kooten, G. C. (1999) "Economics of antipoaching enforcement and the ivory trade ban." *American Journal of Agricultural Economics*, 81(2), 453-466.
- Cairns, R. D. (2001) "Capacity choice and the theory of the mine," *Environmental and Resource Economics*, 18(1), 129-148.
- Cairns, R. D. and G. A. Davis. (1998) "On Using Current Information to Value Hard Rock Mineral Properties." *The Review of Economics and Statistics* 80(4), 658–63
- Carbone, Jared C., C. Helm and T. F. Rutherford (2009) "The Case for International Emission Trade in the Absence of Cooperative Climate Policy," *Journal of Environmental Economics and Management*, 58(3), 266–280
- Carbone, J.C. and K. J. McKenzie, (2016) "Going Dutch?: The Impact of Falling Oil Prices on the Canadian Economy," *Canadian Public Policy*, 42(2): 68-180
- Carlos, A.M. and F. D. Lewis (1993) "Indians, the Beaver, and the Bay: The Economics of Depletion in the Lands of the Hudson's Bay Company, 1700–1763," *Journal of Economic History*, 53(3), 465–94
- Carlos, A.M. and F.D. Lewis (2011) "*Commerce by a Frozen Sea: Native Americans and the European Fur Trade*," University of Pennsylvania Press
- Chakravorty, U., A. J. Leach and M. Moreaux (2011) "Would Hotelling kill the electric car?" *Journal of Environmental Economics and Management* 61(3), 281–96
- Chandra, A., S. Gulati and M. Kandlikar (2010) "Green Drivers or Free Riders? An Analysis of

Tax Rebates for Hybrid Vehicles," *Journal of Environmental Economics and management* 60(2), 78–93

Cherniwchan, J. (2012) "Economic growth, industrialization, and the environment," *Resource and Energy Economics* 34: 442-67

Cherniwchan, J. (2017) "Trade Liberalization and the Environment: Evidence from NAFTA and U.S. Manufacturing" *Journal of International Economics* 105: 130-149.

Cherniwchan, J., B. R. Copeland and M. S. Taylor (2017) "Trade and the Environment: New Methods, Measurements, and Results," *Forthcoming Annual Review of Economics*

Clark, C. W. and G. Munro (1975) "Economics of Fishing and Modern Capital Theory: A Simplified Approach," *Journal of Environmental Economics and Management* 2(2), 92–106

Clark, C. W. (1976) "Mathematical Bioeconomics: The Optimal Management of Renewable Resources," *Wiley, New York*

Clark, C. W., Munro, G. R. and Sumaila, U. R. (2005) "Subsidies, buybacks, and sustainable fisheries," *Journal of Environmental Economics and Management*, 50(1), 47–58

Clawson, M., and J. L. Knetsch (1967) "*Economics of Outdoor Recreation*," John Hopkins Press, Baltimore

Cole, M.A. and R. J. R. Elliott (2003) "Determining the trade–environment composition effect: the role of capital, labor and environmental regulations," *Journal of Environmental Economics and Management*, 46(3), 363–383

Conrad K. (1993) "Taxes and Subsidies for Pollution-Intensive Industries," *Journal of Environmental Economics and Management* 25(2), 121–35

Copeland, B.R. (1994) "International Trade and the Environment: Policy Reform in a Polluted Small Open Economy," *Journal of Environmental Economics and Management* 26(1), 44–65

Copeland, B.R. (1996) "Pollution Content Tariffs, Environmental Rent Shifting and the Control of Foreign Pollution." *Journal of International Economics*, 40(3), 459–76

Copeland, B.R. (2011) "Trade and the Environment," *Palgrave Handbook of International Trade*. Palgrave MacMillan, 423–96

Copeland, B.R., and M. S. Taylor (1994) "North-South Trade and the Environment," *Quarterly Journal of Economics* 109(3), 755–87

Copeland, B. R. and M.S. Taylor, (1995) "Trade and Transboundary Pollution," *American Economic Review*, 85, 716-737.

Copeland, B.R. and M.S. Taylor (2003), *Trade and the Environment: Theory and Evidence*, Princeton University Press.

- Copeland, B. R., and M.S. Taylor (2004) "Trade, growth, and the environment," *Journal of Economic Literature*, 42(1), 7–71
- Copeland, B.R., and M. S. Taylor (2005) "Free trade and global warming: A trade theory view of the Kyoto Protocol," *Journal of Environmental Economics and Management*, 49(2), 205–34
- Copeland, B.R., and M. S. Taylor (2009) "Trade, Tragedy and the Commons," *American Economic Review* 99(3), 725–49
- Corden, W., and J.P. Neary (1982) "Booming Sector and De-Industrialization in a Small Open Economy." *Economic Journal* 92(368):825–48.
- Costello, C., M. Springborn, C. McAusland and A. Solow (2007) "Unintended biological invasions: Does risk vary by trading partner?" *Journal of Environmental Economics and Management* 54(3), 262–76
- Crabbé, P.J. (1983) "The contribution of L.C. Gray to the Economic Theory of Exhaustible Natural Resources and its Roots in the History of Economic Thought," *Journal of Environmental Economics and Management* 10 (3): 195-220
- Crocker, T. D. (1966) "The structuring of atmospheric pollution control systems," *The Economics of Air Pollution (H. Wolozin, Ed.)*, Norton, New York
- Dales, J. H. (1968) "Pollution, Property, and Prices," *University of Toronto Press, Toronto*
- David, M., and B. Sinclair-Desgagné (2005) "Environmental Regulation and the Eco-Industry," *Journal of Regulatory Economics* 28(2), 141–55
- Deacon, R.T., C. D. Kolstad, A. V. Kneese, D. S. Brookshire, D. Scrogin, A. C. Fisher, M. Ward, K. Smith and J. Wilen (1998) "Research Trends and Opportunities in Environmental and Natural Resource Economics," *Environmental and Resource Economics* 11(3–4), 383–97
- Deweese, D.N., D. Duff, and M. J. Trebilcock (1996), *Exploring the Domain of Accident Law: Taking the Facts Seriously*. Oxford University Press
- Diamond, J. (2005), *Collapse*, Penguin, New York.
- Dockner, E., and N.V. Long (1993) "International Pollution Control: Cooperative versus Non-cooperative Strategies," *Journal of Environmental Economics and Management*, 25(1), 13–29
- Drelichman, M. (2005) "The Curse of Moctezuma: American Silver and the Dutch Disease." *Explorations in Economic History* 42 (3): 349-380.
- Dupont, D. P. (2004) "Do children matter? An examination of gender differences in environmental valuation," *Ecological Economics*, 49(3), 273–86
- Dupont, D.P. and S. Renzetti (2001) "The role of water in manufacturing," *Environmental and Resource Economics* 18(4), 411–32
- Eckert, H. (2004) "Inspections, Warnings and Compliance: The Case of Petroleum Storage

- Regulation," *Journal of Environmental Economics and Management*, 47(2), 232–259
- Elgie, S. and G.R. McCarney (2016) "Big Ideas for Sustainable Prosperity: Policy Innovation for Greening Growth," *Canadian Public Policy Supplement* 1, November pp. 1-78.
- Forsyth, M. (2000) "On estimating the option value of preserving a wilderness area," *Canadian Journal of Economics* 33 (2):413-434.
- Fortin, N. and T. Lemieux (2015) "Changes in Wage Inequality in Canada: An Interprovincial Perspective," *Canadian Journal of Economics*, 48(2), 682–713
- Gaudet, G. (2007) "Natural Resource Economics under the Rule of Hotelling," *Canadian Journal of Economics* 40(4), 1033–59
- Gaudet, G. and P. Howitt (1989) "A Note on Uncertainty and the Hotelling Rule," *Journal of Environmental Economics and Management* 16(1), 80–86
- Gaudet, G. and A. Khadr (1991) "The Evolution of Natural Resource Prices under Stochastic Investment Opportunities: An Intertemporal Asset-Pricing Approach", *International Economic Review* 32(2), 441–455
- Gaudet, G. and P. Lasserre (2015) "The Taxation of Nonrenewable Natural Resources," in *Handbook on the Economics of Natural Resources*, eds R. Halvorsen and D. Layton, Cheltenham, U.K.: Edward Elgar, p. 66-96.
- Gaudet, G., M. Moreaux and S. Salant (2001) "Intertemporal Depletion of Resource Sites by Spatially Distributed Users," *American Economic Review*, 91(4), 1149-1159.
- Gordon, D.V., Salvanes, K. G. and Atkins, F. (1993) "A fish is a fish is a fish? Testing for market linkages on the Paris fish market." *Marine Resource Economics* 8(4), 331–343
- Gordon, H.S. (1954) "The economic theory of a common property resource: The fishery," *Journal of Political Economy* 62(2), 124–42
- Goulder, L. H. (2013) "Fiscal Interactions and Climate Change Policy." *Energy Economics* 35(2), S3–S11
- Grafton, R. Q., R. Arnason, T. Bjørndal, D. Campbell, H. F. Campbell, C. W. Clark, R. Connor, D. P. Dupont, R. Hannesson, R. Hilborn, J. E. Kirkley, T. Kompas, D. E. Lane, G. R. Munro, S. Pascoe, D. Squires, S. I. Steinshamn, B. R. Turriss and Q. Weninger (2006). "Incentive-based approaches to sustainable fisheries." *Canadian Journal of Fisheries and Aquatic Sciences* 63(3), 699–710
- Gray, L.C. (1914) "Rent under the assumption of exhaustibility," *Quarterly Journal of Economics* 28 (3), 466-489.
- Grossman, G.M., and A. B. Krueger (1993) "Environmental impacts of a North American free trade agreement," *The Mexico–U.S. free trade agreement*, ed. Peter M. Garber. Cambridge, MA: MIT Press

- Grossman, G.M. and Krueger, A. B. (1995) "Economic growth and the environment," *Quarterly Journal of Economics* 110(2), 353-377
- Hamilton, K. and J.M. Hartwick (2005) "Investing Exhaustible Resource Rents and the Path of Consumption," *Canadian Journal of Economics*, 38(2), 615-621
- Harrison, K. and W. Antweiler (2003) "Incentives for Pollution Abatement: Regulation, Regulatory Threats, and Non-Governmental Pressures." *Journal of Policy Analysis and Management* 22(3), 361-382
- Hartwick, J.M. (1977) "Intergenerational Equity and the investing of rents from exhaustible resources," *American Economic Review*, 67(5), 972-74
- Hartwick, J.M. (1990) "Natural Resources, National Accounting and Economic Depreciation," *Journal of Public Economics* 43(3), 291-304
- Hendricks, K. and R. Porter (1988) "An Empirical Study of an Auction with Asymmetric Information," *American Economic Review* 78(5), 865-883
- Hendricks, K., R. Porter and C. A. Wilson (1994) "Auctions for Oil and Gas Leases with an Informed Bidder and a Random Reservation Price," *Econometrica*, 62(6), 1415-44
- Heyes, A., S. Elgie and N. Rivers (2013) "Special Supplement on Environmental Policy in Canada," *Canadian Public Policy*, Supplement, pp. S1-S175
- Hotelling, H. (1931) "The Economics of Exhaustible Resources," *Journal of Political Economy* 39(2), 137-75
- Hotte L., N. Van Long, H. Tian (2000) "International trade with Endogenous Enforcement of Property Rights," *Journal of Development Economics* 62(1), 25-54
- Insley, M. (2003) "On the option to invest in pollution control under a regime of tradable emissions allowances," *Canadian Journal of Economics*, 36(4), 860-83
- Jaccard, M., J. Nyboer, C. Bataille, and B. Sadownik (2003). "Modeling the cost of climate policy: distinguishing between alternative cost definitions and long-run cost dynamics." *The Energy Journal* 24(1), 49-73
- Kahneman, D., J. L Knetsch and R.H. Thaler (1990) "Experimental Tests of the Endowment Effect and the Coase Theorem," *Journal of Political Economy* 98(6), 1325-48
- Kahneman, D., and J. L Knetsch (1992) "Valuing Public Goods: The Purchase of Moral Satisfaction," *Journal of Environmental Economics and Management*, 22(1), 57-70
- Kassar, I. and P. Lasserre (2004, "Species preservation and biodiversity value: a real options approach," *Journal of environmental economics and management* 48 (2): 857-879.
- Kennedy, P.W. (1994) "Equilibrium Pollution Taxes in Open Economies with Imperfect Competition," *Journal of Environmental Economics and Management* 27(1), 49-63

Knetsch, J.L. and J.A. Sinden (1984) "Willingness to Pay and Compensation Demanded: Experimental Evidence of Unexpected Disparity in Measures of Value," *The Quarterly Journal of Economics* 99(3), 507–21

Lauck, T., Clark, C. W., Mangel, M. and Munro, G. R. (1998) "Implementing the precautionary principle in fisheries management through marine reserves." *Ecological applications* 8(sp1), S72–S78.

Leach, A. J. (2007) "The climate change learning curve." *Journal of Economic Dynamics and Control* 31(5), 1728–52.

Levinson, A. (2009) "Technology, International Trade, and Pollution from US Manufacturing." *American Economic Review* 99(5), 2177–92

Levinson A. (2010) "Offshoring pollution: Is the US increasingly importing polluting goods?" *Review of Environmental Economics and Policy* 4(1), 63–83

Levinson, A. and M. Scott Taylor (2008) "Unmasking the pollution haven effect," *International Economic Review* 49(1), 223–54

Livernois, J.R. and R.S. Uhler (1987) "Extraction costs and the economics of nonrenewable resources," *Journal of Political Economy* 95 (1), 195–203

Livernois, J.R. and C.J. McKenna (1999) "Truth or Consequences: Enforcing Pollution Standards with Self-Reporting," *Journal of Public Economics* 73(3), 415–40

Livernois, J.R., H. Thille, X. Zhang (2006) "A test of the Hotelling rule using old-growth timber data," *Canadian Journal of Economics* 39(1), 163–86

Long, N. V. (2011) "Dynamic games in the economics of natural resources: a survey," *Dynamic Games and Applications* 1 (1): 115-148

Long, N. V. (2015) "The Green Paradox in Open Economies: Lessons from static and dynamic models." *Review of Environmental Economics and Policies* 9(2), 266–85

Mann, M. E., Bradley, R. S., & Hughes, M. K. (1998). Global-scale temperature patterns and climate forcing over the past six centuries. *Nature*, 392(6678), 779-787.

Mann, M. E., Bradley, R. S., & Hughes, M. K. (1999). Northern hemisphere temperatures during the past millennium: inferences, uncertainties, and limitations. *Geophysical research letters*, 26(6), 759-762.

Markusen, J.R. (1976) "International Externalities and Optimal Tax Structures," *Journal of International Economics* 5(1), 15–29

Markusen, J.R., E. Morey and N. Olewiler (1993) "Environmental Policy when Market Structure and Plant Locations are Endogenous," *Journal of Environmental Economics and Management* 24(1), 69–86

Markusen, J.R., E. Morey and N. Olewiler (1995) "Competition in Regional Environmental

Policies with Endogenous Plant Location Decisions," *Journal of Public Economics* 56(1), 55–77

McAusland, C. and C. Costello (2004) "Avoiding invasives: trade-related policies for controlling unintentional exotic species introductions," *Journal of Environmental Economics and Management*, 48(2), 954–97

McAusland, C., and D.L. Millimet (2013) "Do national borders matter? Intranational trade, international trade, and the environment," *Journal of Environmental Economics and Management* 65(3), 411–37

McAusland, C., and N. Najjar (2014) "Carbon Footprint Taxes." *Environmental and Resource Economics* 61(1), 37–70

McIntyre, S., and R. R. McKittrick (2003) "Corrections to the Mann et. al. (1998) proxy data base and northern hemispheric average temperature series." *Energy & environment*, 14(6), 751–71.

McIntyre, S., and R. R. McKittrick (2005) "Hockey Sticks, Principal Components and Spurious Significance." *Geophysical Research Letters* 32 (3), L03710.

McKittrick, R. (1997) "Double-Dividend Environmental Taxation and Canadian Carbon Emissions Control," *Canadian Public Policy*, 23(4), 417–34

Miller, M.H., and C. W. Upton (1985) "A test of the Hotelling Valuation Principle." *Journal of Political Economy* 93(1), 1–25

Moreno-Cruz, J. (2015) "Mitigation and the Geoengineering Threat," *Resource and Energy Economics* 41, 248-263

Moreno-Cruz, J. and D. Keith (2013) "Climate Policy under Uncertainty: A Case for Solar Geoengineering." *Climatic Change* 121(3), 431-444.

Muehlenbachs, L., E. Spiller and C. Timmins (2015) "The Housing Market Impacts of Shale Gas Development," *American Economic Review* 105(12), 3633–59

Muehlenbachs, L., Staubli, S. and M.A. Cohen (2016) "The Effect of Inspector Group Size and Familiarity on Enforcement and Deterrence," *Journal of the Association of Environmental and Resource Economists* 3(1), 159–204

Muller, R.A., and S. Mestelman (1998) "What Have We Learned From Emissions Trading Experiments?" *Managerial and Decision Economics* 19(4–5), 225–38

Munro, G.R., A. Van Houtte and R. Willmann (2004) "The conservation and management of shared fish stocks: legal and economic aspects," *FAO Fisheries Technical Paper* 465

Paarsch, H.J. (1992) "Deciding between the common and private value paradigms in empirical models of auctions," *Journal of econometrics* 51(1–2), 191–215

Paarsch, H.J., and B. S. Shearer (1999) "The response of worker effort to piece rates:

evidence from the British Columbia tree-planting industry." *Journal of Human Resources* 34(4), 643–67

Paarsch, H.J. (1997) "Deriving an estimate of the optimal reserve price: an application to British Columbian timber sales." *Journal of Econometrics* 78(1), 333–57

Paarsch, H. J., and B. Shearer (2000) "Piece rates, fixed wages, and incentive effects: Statistical evidence from payroll records." *International Economic Review* 41(1), 59–92

Pauly, D., V. Christensen, S. Guénette, T. J. Pitcher, U. R. Sumaila, C. J. Walters, R. Watson and D. Zeller (2002) "Towards sustainability in world fisheries." *Nature* 418(6898), 689–95

Pearse, P. (1982) "Turning the tide: A new policy for Canada's Pacific fisheries," *Final Report, Commission of Pacific Fisheries Policy*

Pearse, P. (1988) "Property rights and the development of natural resource policy in Canada," *Canadian Public Policy*. 14(3): 307-320.

Perroni, C., and R. M. Wigle (1994) "International trade and environmental quality: How important are the linkages?" *Canadian Journal of Economics* 27(3), 551–67

Porter, M. (1991), "America's Green Strategy," *Scientific American*, 264(4), 168.

Renzetti, S. (1999) "Municipal Water Supply and Sewage Treatment: Costs, Prices and Distortions" *Canadian Journal of Economics* 32(3), 688–704

Renzetti, S. (2002) "The economics of water demands," *Kluwer Academic Press*

Rivers, N., and B. Schaufele (2015) "Salience of Carbon Taxes in the Gasoline Market," *Journal of Environmental Economics and Management* 74, 23–36

Rollins, Kimberly, and Audrey Lyke. 1998. The case for diminishing marginal existence values. *Journal of Environmental Economics and Management* 36:324-44

Rondeau, D. (2001) "Along the way back from the brink," *Journal of Environmental Economics and Management* 42(2), 156–82

Sakai, Y. (2017), "Subsidies, Fisheries management and Stock Depletion," *Land Economics*, 93 (1), 165-178.

Scott, A.D. (1955) "The fishery: The objectives of sole ownership," *Journal of Political Economy* 63(2), 116–24

Scott, A.D., J. A. Crutchfield, P. H. Pearse, G. R. Munro and M. Tugwell (1981) "The Public Regulation of Commercial Fisheries in Canada," *Economic Council of Canada, Queens Printer, Ottawa, Canada*

Shapiro J.S., and R. Walker (2015) "Why is pollution from U.S. manufacturing declining? The roles of trade, regulation, productivity, and preferences," *NBER Working Paper 20879*

- Sinn, H.W. (2012) "The Green Paradox: A Supply-side Approach to Global warming," *MIT Press*
- Slade, M.E. (1982) "Trends in Natural-Resource Commodity Prices: An Analysis of the Time Domain," *Journal of Environmental Economics and Management* 9(2), 122–37
- Slade, M.E. and H. Thille (2009) "Whither Hotelling: Tests of the Theory of Exhaustible Resources," *Annual Review of Resource Economics* 1(1), 239–60
- Stavins, R.N. (2003) "Experience with market-based environmental policy instruments," *Handbook of Environmental Economics* 1, 355–435
- Sumaila, U.R., A. S. Khan, A. J. Dyck, R. Watson, G. Munro, P. Tydemers and D. Pauly (2010) "A bottom-up re-estimation of global fisheries subsidies." *Journal of Bioeconomics* 12(3), 201–25.
- Sumaila, U.R., J. Alder and H. Keith (2006) "Global scope and economics of illegal fishing," *Marine Policy* 30(6), 696–703
- Taylor, M.S. (2011) "Buffalo Hunt: International trade and the virtual extinction of the North American bison." *American Economic Review* 101(7), 3162–95
- Turner, M.A. (1997) "Quota induced Discarding in Heterogeneous Fisheries," *Journal of Environmental Economics and Management* 3(2), 186–95
- Van der Ploeg, F. (2011) "Natural Resources: Curse or Blessing?" *Journal of Economic Literature* 49(2), 366–420
- Van Egteren, H., and M. Weber (1996) "Marketable Permits, Market Power, and Cheating," *Journal of Environmental Economics and Management* 30(2), 161–73
- Van Kooten, G. C., C. S. Binkley, and G. Delcourt (1995) "Effect of carbon taxes and subsidies on optimal forest rotation age and supply of carbon services." *American Journal of Agricultural Economics* 77(2), 365–74
- Van Kooten, G. C., A. J. Eagle, J. Manley, and T. Smolak (2004) "How costly are carbon offsets? A meta-analysis of carbon forest sinks." *Environmental science & policy* 7(4), 239–51
- Vincent, J.R., T. Panayotou and J. M. Hartwick (1997) "Resource Depletion and Sustainability in Small Open Economies," *Journal of Environmental Economics and Management* 33(3), 274–86
- Young, D., and D. L. Ryan (1996) "Empirical Testing of a Risk-Adjusted Hotelling Model," *Resource and Energy Economics* 18(3), 265–89
- Whalley, J., and R. Wigle (1991) "The International Incidence of Carbon Taxes," *Global Warming: Economic Policy Responses* 233, 263
- Wilén, J.E. (2000) "Renewable Resource Economists and Policy: What Differences Have We Made?" *Journal of Environmental Economics and Management* 39(3), 306–27

Wilman, E. A. (1980) "The value of time in recreation benefit studies," *Journal of Environmental Economics and Management* 7:272-286.

Wilman, E. A. and M. S. Mahendrarajah (2002) "Carbon offsets," *Land Economics* 78:405-416.

Winter, R.A. (2014) "Innovation and the Dynamics of Global Warming," *Journal of Environmental and Economic Management* 68(1), 124-40

Yamazaki, A. (2016) "Jobs and Climate Policy: Evidence from British Columbia's Revenue-Neutral Carbon Tax," Discussion Paper, University of Calgary

Yu, Z. (2005) "Environmental Protection: A Theory of Direct and Indirect Competition for Political Influence," *Review of Economic Studies* 72(1), 269-86