Economic Instruments and Canadian Industrial Water Use

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Abstract: Water is an important input for many industrial sectors including manufacturing, mining and energy generation. Industrial water use differs from other sectors in its high reliance on self-supplied water, the potential for internal water recycling and the possibility of use leading to diminished water quality. Furthermore, industrial water use has a number of interrelated components including intake, internal recirculation, treatment prior to and following use and discharge. In principle, each of these activities can be expected to depend upon the economic and regulatory environment facing the firm. This paper examines the economic characteristics of Canadian industrial water use and considers the experiences of other jurisdictions in employing economic instruments to promote industrial water conservation. The paper then assesses the potential efficacy of economic instruments as a means of promoting integrated water resources management in the Canadian industrial sector. The paper concludes by identifying the opportunities and barriers for enhanced reliance on economic instruments.

Résumé : L'eau est un important facteur de production pour de nombreux secteurs industriels, dont les secteurs manufacturier, minier et de la production d'énergie. L'utilisation de l'eau en milieu industriel diffère de celle d'autres secteurs si l'on considère la dépendance élevée de ce secteur face à l'auto-approvisionnement en eau de même que les possibilités de recyclage interne de l'eau et d'une utilisation pouvant entraîner la détérioration de la qualité de l'eau. De plus, l'utilisation industrielle de l'eau comporte un certain nombre d'éléments interdépendants dont le prélèvement, la recirculation interne, le traitement avant et après l'utilisation et l'évacuation. On peut s'attendre, en principe, à ce que chacune de ces activités dépende de l'environnement économique et réglementaire avec lequel doit composer l'entreprise. Cette communication se penche sur les caractéristiques économiques de l'utilisation industrielle de l'eau au Canada et prend en considération les expériences des autres compétences territoriales en ce qui concerne le recours à des instruments économiques pour promouvoir la conservation de l'eau en milieu industriel. La communication évalue ensuite l'efficacité éventuelle des instruments économiques comme outils de promotion d'une gestion intégrée des ressources hydriques dans le secteur industriel au Canada. En guise de conclusion, la communication cerne les occasions et les obstacles qu'impliquerait un recours accru aux instruments économiques.

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Introduction

This paper considers how the application of economic instruments (EI's) to industrial water use can contribute towards improved water conservation and enhanced water resources management in Canada. Interestingly, an examination of the economic characteristics of industrial water use and the history of environmental regulation in Canada leads to two opposing observations. On the one hand, there is evidence that industrial water use is sensitive to economic forces and that economic instruments have been successfully employed in other jurisdictions. On the other hand, the most common approaches to regulating water allocation and protecting water quality in Canada have eschewed reliance on economic instruments. Thus, there is the possibility that EI's can be effective and efficient policy measures but there are significant informational and institutional challenges to be addressed before they are introduced.

There are a variety of economic instruments that may be employed to promote integrated water resources management amongst industrial water users. In general, the government can choose one of two approaches: it may establish or alter prices through taxes, fees and royalties or it may limit quantities through tradeable permit schemes (Grafton *et al.,* 2004). For example, all Canadian provincial governments have the authority to establish fees for the right to abstract water. Dupont and Renzetti (1999) indicate that these fees may take a variety of forms including two-part prices and volumetric charges based on consumption (the difference between intake and discharge) as well as intake. These permit fees can be designed to recover government's program costs, to act as resource royalties that capture a share of water rents from self-supplied users or to reflect the opportunity cost of water use. If the government seeks to promote efficient water use by levying fees that reflect the opportunity cost of water use, an important design issue is whether the fees will vary by location, time and source of water (surface versus groundwater). Fees can also be assigned to wastewater flows. Such 'effluent taxes' may be made functions of the volume and timing of flows as well as the chemical characteristics of the effluent flow.

Alternatively, a market for water withdrawals or water pollution emissions may be created. When the aggregate demand for water in a river-basin approaches the sustainable river flow (net of instream demands), then a market for water use allows users with relatively high-valued water uses to purchase or lease water from users with relatively low-valued water uses. In addition, recent innovations in the design of water markets include leasing arrangements for temporary reallocations, the use of a 'waterbank' to allow intertemporal trading and increased concern over protecting in-stream environmental water demands (Loomis, 1992; Weber, 2001). Markets may also be established for the trading in pollution credits. Just as water markets operate by providing a legal mechanism for water use to 'flow' from low-valued uses to high-valued uses, a pollution credit market reduces the overall cost of meeting pollution targets by transferring pollution reduction responsibilities to the agents with the lowest costs of pollution reduction.

The motivation for considering economic instruments as a way of complementing or possibly replacing established means of regulating water resources stems largely from the growing body of research and real world experience that demonstrates their ability to promote efficient water use. In a recent study of twelve environmental problems where conventional 'command and control' resource policies and/or economic instruments were employed, Harrington and Morgenstern (2004) conclude that economic instruments are generally more efficient and promote more innovation than do established regulatory approaches.

The paper is organized in the following fashion. The next section discusses the features of industrial water use in Canada. Of particular interest are the economic characteristics of this sector's water use. This section draws on Dupont and Renzetti (2001). The third section assesses past efforts to regulate water use in Canada while section four considers the experiences of other jurisdictions in the application of economic instruments as a strategy in water management. The fifth section assesses the challenges and opportunities for applying economic instruments as a means of promoting efficient industrial water use and, more generally, integrated water resources management in Canada.

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Features of Canadian Industrial Water Use

Water Use Data

Table 1 sets out the water withdrawals of Canada's major water-using sectors. Unlike many countries where agricultural water use dominates, Canada is typical of northern industrialized countries in that power production, manufacturing and municipalities are the principle water-using sectors. Water use in mining and oil and gas extraction is relatively small from a national perspective but can be important in specific watersheds and for its impacts on local water quality.

Table 1. Canadian Water Withdrawals, 1996.

Sector	Withdrawals MCM (% of total)
Thermal Power Generation	28,750 (64.2%)
Manufacturing	6,040 (13.5%)
Urban	4,334 (9.7%)
Agriculture	4,098 (9.2%)
Rural	979 (2.1%)
Mining[1]	519 (1.3%)
Total	**44,720**

Note:
1. Mining includes oil and gas extraction

Source: Environment Canada Freshwater website www.ec.gc.ca/water/e_main.html

Industrial water users employ water for a variety of purposes. Thermal power generating stations use massive quantities of water to produce steam which drives turbines. Extractive industries use water to facilitate mineral and fossil fuel extraction, maintain pore pressures and for on-site ore processing. Manufacturing firms typically employ water for three main reasons. First, water may be applied in a production process. This includes cleaning and moving intermediate inputs as well as inclusion in final output, such as the production of beer. Second, water can be used to cool intermediate inputs (e.g., the production of petroleum-based fuels) or to produce steam. Third, water is used for a variety of miscellaneous purposes such as plant cleaning, landscape watering and personal sanitation.

There are a number of characteristics that distinguish the manufacturing sector's water use. First, manufacturing water use, like agricultural water use, is mostly self-supplied. In 1996, the most recent year in which the Industrial Water Use Survey (IWUS) was conducted, approximately 90% of manufacturing intake was self-supplied (Scharf *et al.*, 2002). Second, most of the water (approximately 85%) used by manufacturing plants was discharged directly into a receiving water body. Furthermore, many of these discharges are known to lead to the degradation of water quality. Indeed, Scharf *et al.* estimate that approximately 40% of water discharged from manufacturing establishments was given no discharge treatment of any kind. Third, internal water recirculation is important to many manufacturing plants. Recirculation is usually undertaken to reduce energy costs, recapture valuable raw materials and to reduce effluent streams. Table 2 demonstrates that, for the entire manufacturing sector, the ratio of water recirculated to intake water was 1.15 in 1996. This average masks significant variation amongst manufacturing subsectors. Table 3 shows that the ratio of water recirculation to water intake ranges from a low of 0.22 in the Wood products sector to a high of 1.46 in the Petroleum sector. Furthermore, industrial water use is characterized by a greater heterogeneity in end-uses than any other sector (Vickers, 2001). Fourth, Table 3 also demonstrates that water intake is uneven across manufacturing subsectors. Four sectors (Paper, Primary Metals, Petroleum and Chemicals) account for 5336 MCM or 88% of the manufacturing total.

Table 2. Trends in Aggregate Water Use in Canadian Manufacturing, 1981-1996.

	1981	1986	1991	1996
Intake	9,936	7,984	7,282	6,038
Recirculation	10,746	7,813	6,806	6,958
Value of Shipments	$303,889	$313,093	$278,421	$363,016
Recirculation/Intake	1.08	0.98	0.93	1.15
Value/Intake	$31.25	$40.00	$38.46	$56.50

Notes:
1. Intake and Recirculation are measured in millions of cubic metres per year.
2. Value of shipments is measured in millions of 1991$/year.

Sources: Intake and Recirculation from Industrial Water Use Survey (Scharf *et al.,* 2002) and Value of Shipments is from Statistics Canada (Dupont and Renzetti, 2001).

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Table 3. Trends in Water Intake and Recycling in Canadian Manufacturing Sectors, 1981-1996

Industry	Intake 1981	Recirculation 1981	Intake 1996	Recirculation 1996	% change R/I, 1981-96
Food and Beverage	430	117	343	163	77.8
Rubber and Plastic	54	NA	25	51	NA
Textile	124	51	102	77	82.9
Wood	73	57	45	10	-254.5
Paper	2,899	4,611	2,421	3,105	-19.5
Primary Metals	2,718	1,692	1,423	1,447	64.5
Metal Fabricate	30	130	19	8	-90.3
Transportation	109	72	65	107	150.0
Minerals	83	530	102	92	-85.9
Petroleum	563	1,456	371	541	-43.6
Chemicals	2,853	1,283	1,121	1,354	148.8
Total	**9,936**	**10,746**	**6,038**	**6,957**	**6.5**

Notes:
1. Source: Environment Canada, Industrial Water Use Survey, various years.
2. Water Intake and Recirculation are measured in millions of cubic metres per year.
3. R/I is the ratio of the quantity of water recirculation to the quantity of water intake.

Finally, some of the features of manufacturing water use have changed over the period during which Environment Canada has been collecting industrial water use data. Just as the manufacturing sector has declined in its relative importance to the Canadian economy, so has aggregate manufacturing water intake. Table 2 shows that the manufacturing sector's withdrawals have fallen by 40% from 1981 to 1996. It is likely that there are a number of reasons for this decline. Potential factors include changes in the composition of the manufacturing sector (particularly decreases in the relative importance of heavy water-using industries) and more stringent water quality regulations. It is unlikely, however, that the observed decrease in water intake is directly the result of increased intake costs since provincial fees for direct water abstractions and energy costs have changed little, in real terms, over the period.

Economic Characteristics

Despite the importance and features of industrial water use, its role in industrial applications remains an understudied area. Very little econometric work has been conducted regarding water use in thermal power production and extractive industries and a small number of studies have examined manufacturing water use (Renzetti, 2002). The lack of information on the role of water in thermal power production and the analysis of conservation possibilities is particularly important given the scale of water use by this sector. Nonetheless, the available research (most recently, Reynaud, 2003; Dupont and Renzetti, 2001) does provide a number of observations regarding the economic characteristics of manufacturing water use that are relevant to the application of economic instruments and the promotion of integrated water resources management.

The first observation is that, at least in terms of cost shares, water is a relatively unimportant input for most Canadian manufacturing firms. Expenditures for water intake, treatment and discharge rarely exceed 1% of total costs. Of course, a large part of this is explained by the free or near-free access granted to industrial water users by provincial governments for self-supplied water intake as well as for sites for effluent disposal. As a result, the attention paid by firms to water has often been motivated by concerns other than water conservation or cost-saving. These other concerns have included compliance with environmental regulations, conservation of energy and intermediate materials and, in some cases, concerns with the quality of intake water.

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The limited number of econometric studies of manufacturing water demands demonstrates that water intake demand is sensitive to its own price (or marginal cost in the case of self-supplied firms). Indeed, the available evidence suggests that industrial firms' water demands may be relatively more price sensitive than agricultural or residential water demands. For example, Dupont and Renzetti (2001) estimate that the Canadian manufacturing sector's average price elasticity of intake water demand is -0.80.

There is less evidence regarding the relationship between water intake and other inputs. In both the Babin *et al.* (1982) and Grebenstein and Field (1979) studies of water use in U.S. manufacturing, water intake is found to be a substitute for labour and a complement to capital. In contrast, in Dupont and Renzetti's (2001) study of water use in Canadian manufacturing, water intake is found to be a substitute for capital, labour and energy. These estimated relationships between water and non-water inputs are potentially important because they show that policies aimed at altering non-water input prices may have significant impacts on industrial water demands. Such policies could include tax provisions that alter the price of capital, regional development subsidies that lower the price of labour and environmental policies that raise the price of energy. For example, the elasticities reported in Dupont and Renzetti (2001) indicate that a policy aimed at discouraging energy use by the manufacturing sector (for example, a carbon tax) could have mixed effects on water use. Higher energy prices may lead to greater water intake due to the substitution effect but would depress water intake to the extent that they lead to decreases in manufacturing output.

Research has also demonstrated that water intake demands are strongly influenced by industrial output levels with higher levels of production typically requiring greater levels of water intake. This relationship suggests another avenue through which economic instruments may influence industrial water demands. For example, energy conservation policies have the potential to have substantial impacts on industrial water use because of the massive quantities of water used by thermal generating stations. Indeed, if a national energy conservation program were able to reduce energy demands by an amount that lowered the thermal energy sector's intake water demands by only one or two percent this would have approximately the same impact on national water withdrawals as a program that retrofitted every toilet in Canada.

The economic characteristics of internal water recirculation and water discharge are also important for understanding the potential for employing economic instruments to encourage water conservation. Dupont and Renzetti (2001), for example, find that water intake and internal water recirculation are substitutes but that this relationship is stronger when water is used in process applications. This would suggest that increasing water intake costs will encourage greater internal water recirculation. While there is anecdotal evidence that a range of industrial facilities have adopted water recycling as a means of conservation (Vickers, 2001), the relative importance of regulatory changes, water prices and other input prices to these efforts has not been studied (Marsalek *et al.,* 2002). Similarly, there is some evidence that manufacturing firms in the United States and Canada have decreased water intake in response to tightened regulations on water discharges (Solley *et al.,* 1999; Scharf *et al.,* 2002).

Policy Background

Federal areas of jurisdiction over water management are largely limited to interprovincial and international waters, commercial navigation, fisheries, waters on Native Canadian reserves and establishing drinking water quality guidelines. Provinces govern the allocation of water through a permit system whereby withdrawals and most in-stream uses are allowed only after the issuance of a government permit. Water quality is protected by provincial guidelines and regulations that set out maximum quantities (or in some cases concentrations) of substances that may be deposited into water bodies. Water quality is also protected indirectly through legislation regarding agricultural waste management practices, commercial forestry practices, land-use and shoreline development.

An important feature of almost all provincial laws and regulations governing both the allocation of water and the protection of water quality is the lack of reliance on economic analysis and economic instruments to effect government objectives (Virani and Graham, 1998; Olewiler and Field, 2002). For example, provincial governments issue water withdrawal permits on a 'first-come, first-served' basis at little or no charge to applicants and with no assessment

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of the value of water in the proposed application. Furthermore, permits may not be transferred once issued. Another important feature of provincial water regulation is its fragmented nature. Despite the fact that the allocation of water and the protection of water quality are both primarily provincial responsibilities, their regulation is typically conducted separately by different ministries. The allocation of water resources is usually the responsibility of a Ministry of Natural Resources, whose primary focus is on promoting the exploitation of natural resources, while the protection of water quality is usually the responsibility of the provincial Ministry of Environment. Furthermore, other facets of provincial water management such as the regulation of municipal water utilities and the regulation of hydroelectric power generating facilities, farms, forestry operations and shoreline land use are allocated to different ministries. These features of provincial water management and regulation indicate that there are few, if any, incentives in place to promote efficient industrial water use.

In the area of water quality protection, provincial laws typically follow the 'command and control' approach where polluters' allowed emissions levels are set out in permits. Polluters face the possibility of fines if they exceed permitted levels of emissions and are prosecuted. A limited number of provinces, such as Ontario, have extended their water pollution control frameworks by introducing requirements for polluting firms to adopt BAT (Best Available Technology) or BATEA (Best Available Technology Economically Achievable) to decrease emissions. Based on evidence from other OECD countries and the data available in Canada, it is very likely that this approach to water quality management has resulted in inefficient levels of expenditures being devoted to water quality protection (Harrington and Morgenstern, 2004). Examples of costly water quality programs that eschewed reliance on economic instruments include Ontario's Municipal and Industrial Strategy for Abatement (MISA) and the joint Canada-Ontario Remedial Action Program (RAP). For example, Dupont and Renzetti (2005) consider in detail the costs and benefits of the Hamilton Harbour RAP and estimate that the present value of the RAP costs are $240 million while the benefits are only $68 million.

Despite these observations, there have been a limited number of innovations in Canadian water management policies that exhibit a willingness to employ economic instruments. These initiatives suggest a growing awareness of water scarcity and a openness to adopting novel policy measures to address it. An early and short-lived example was the Ontario Ministry of Environment and Energy's effort to work with manufacturing firms to develop innovative resource conservation strategies (Ontario Ministry of Environment and Energy, 1996; 1997). Firms in the food processing, automotive and pulp and paper sectors were provided with technical assistance and subsidized water audits. These resulted in a variety of process changes, improved materials handling practices and increased use of in-plant recycling that led to lowered energy and water use. More recently, Alberta has moved in the direction of establishing a limited market for its water withdrawal permits (Horbulyk and Lo, 1998). As discussed below, the experience of other jurisdictions with water markets strongly suggests that these institutions can increase the flexibility and efficiency of water allocations. Other provinces are retaining their system of water abstraction permits while examining either establishing or revising the fees charged for these permits (Ontario Ministry of the Environment, 2004).

Reforms in water quality protection programs are less evident than water allocation regulations. A number of provincial governments have acted recently to confront the growing challenges to water quality posed by agricultural runoff and other forms of non-point pollution (Goss *et al.,* 2002). However, given the difficulties presented by the costs of observation and enforcement, most provincial governments continue to rely primarily upon command and control style regulations that specify appropriate technologies and production processes. An interesting exception is the tradeable emissions credit program being carried out on the South Nation River in Ontario (O'Grady and Wilson, n.d.). As a result of this river's heavy phosphorous (P) loadings, environmental regulators required new potential polluters to adopt a zero discharge approach. When this proved infeasible, new polluters were ordered to adopt a 'no net increase' approach whereby any new emissions would be offset by purchased reductions in existing sources of phosphorous (largely local farming operations). Due to the uncertainty regarding the link between changes in farming operations and river phosphorous levels, regulators required new polluters to purchase 4 kg P credits for every 1 kg P emissions planned. The average

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cost of the 4 kg reduction is approximately $1,200 which compares favourably with the current average cost of emission controls for new sources of $2,000.

Experience of Other Jurisdictions

A significant number of countries have employed economic instruments as part of their water and wastewater management policies. These instruments have included effluent fees, water prices, subsidies for the installation of water treatment equipment and both informal and formal markets of water.

A number of European countries have employed charges and fees to discourage industrial water discharges and water pricing to encourage reductions in water intake (Working Party on Economic and Environmental Policy Integration, 1997; Roth, 2001). France, Germany and the Netherlands, for example, employ effluent fees that are based on a firm's location and the nature of the effluent stream to encourage in-plant treatment of discharge flows. Most recently, the European Union has adopted the ambitious Water Framework Directive (Chave, 2002). This Directive makes compulsory the recovery of both financial and environmental costs of water services for the residential, industrial and agricultural sectors. The United States has taken a different approach from European countries as it has relied on markets in arid south and southwestern states to allocate water while relying on conventional 'command and control' regulations to allocate water in the east and to address water quality issues. The extensive analysis of these water markets has found that they have played a very positive role in increasing water use efficiency (Easter *et al.,* 1999; Howitt, 1998; Anderson and Hill, 1997).

The governments of a number of developing economies have also reformed their water policies to place greater reliance upon economic instruments. One of the best known and controversial examples is Chile where the government substantially reduced its own role in regulating water allocation and introduced a market-based system of water allocation. Bauer (1998) concludes that Chile's experience has been mixed as the market-based system generated significant increases in investment in the water sector and improved the efficiency of water allocation but also has proved to be too rigid to adapt to changing social and environmental challenges of water management.

Other developing economies have relied more on reforming industrial water prices and introducing fees for industrial wastewaters. Since the early 1980s, for example, China has pursued an aggressive policy of using effluent charges and water pricing to encourage industrial water conservation (Ping, 1998; O'Connor, 1996). More recently, India trebled prices charged to self-supplied industrial water users in an effort to encourage conservation (Centre for Science and the Environment, 2004).

A number of observations can be made regarding other jurisdictions' experience with employing economic instruments to regulate industrial water use. The first observation concerns the introduction of water prices to curb intake and the introduction of fees or charges to reduce wastewater flows. On the one hand, in a number of cases these fees have first been introduced as penalties for non-compliance with existing water quality regulations. Grafting charges onto existing regulatory schemes appears to be one way of reducing water users' opposition to charges. Furthermore, directing any revenues from charges towards subsidizing industry purchases of water treatment equipment has also muted opposition. On the other hand, the efficacy of these charges in promoting improved water quality has been harmed by the failure to raise fees to keep up with inflation or when initial levels were found to have been set too low to have the desired behavioural response. The second observation concerns the introduction of water markets. It appears that an important precondition for the successful operation of these markets is the existence of a well-functioning system of civil laws into which new water laws may be introduced (Easter *et al.,* 1999).

Prospects for the Application of EI's in Canada

In considering the prospects for the introduction and potential efficacy in Canada of economic instruments, there are two sets of opposing forces at work. On the one hand are the results of empirical research and the experiences of other jurisdictions. The former indicates that firms' decision-making regarding water intake and wastewater flows are responsive to economic conditions. Thus, to the extent that government can alter the relative costs of water and non-water inputs, it has the potential ability to influence water use and

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water discharge decisions. The latter demonstrates that a number of jurisdictions — some with significantly less well developed regulatory frameworks than Canada — have successfully grafted economic instruments onto their water management strategies.

Thus, the available evidence provides a necessary but not a sufficient basis for moving forward. This is because the available evidence indicates that most facets of industrial water use are sensitive to varying degrees to economic conditions but that information is not yet specific enough to predict on a disaggregated basis the impacts on firms or how they will react to EI's. This lack of information would perhaps suggest a case-study approach where governments could examine the efficacy of alternative EI's in particularly water-short areas such as southern Alberta and southwestern Ontario.

With respect to water allocation policies, one particularly important issue surrounds the choice between introducing (or reforming) fees for nontradable water withdrawal permits versus introducing a market for these permits and allowing them to be traded (or, more simply, allowing permit holders to retain their permits while still trading in water). While a number of provinces, such as Ontario and BC, appear to be moving in the direction of reforming permit fees while not allowing permits to be traded, it is unlikely that the Ministries of Environment in these provinces will have the institutional capacity to monitor water use and water values closely enough to ensure that the fees approximate the opportunity costs of water use. On the other hand, water markets allow voluntary trades to determine appropriate prices for water use and these prices automatically create an opportunity cost for all water permit holders. Furthermore, Ministries of the Environment already have significant experience in dealing with protecting in-stream water needs and adjudicating appeals made by parties who object to water allocation decisions — the two most common problems arising with water markets. These considerations would suggest that, while introducing or raising permit fees may seem administratively more tractable in the short-run, concentrating on efforts to introduce water use and water-discharge markets will prove more effective in achieving efficient water use in the long-run.

In addition to the sources of uncertainty already listed, there are other reasons for a cautious approach to the introduction of EI's to promote IWRM. Despite water's relatively small share in total costs, the impact of the introduction of an EI-based program on Canadian firms' international competitiveness is a potential concern. Dupont and Renzetti (1999) indicate that the introduction of a fee for direct water abstraction in Ontario would raise manufacturing costs on average by only 0.01% to 0.2%. However, there may be water-intensive sub-sectors that would experience larger cost increases. Another source of concern relates to the government's institutional capacity to design, implement and enforce EI-based programs that contribute to IWRM in a coordinated fashion. Until very recently, federal and provincial environmental regulators have demonstrated a long-standing reluctance to make use of economic analysis (such as cost-benefit or cost-effectiveness analysis) as well as adopt EI's. The informational requirements of these programs also should not be under-estimated. For example, one of the largest challenges facing the U.S. EPA in maintaining its successful SO_2 trading program has been data collection and information management (Henriquez, 2004).

Ultimately, forces beyond the concern for more efficient and effective environmental policies may push Canadian regulators in the direction of greater reliance on EI's. There is a clear trend worldwide of governments adopting EI's to pursue water allocation and water quality policies. In addition, recent downloading of regulatory responsibilities to local and regional governments as well as cuts to the budgets of federal and provincial environmental regulators may combine to promote innovation and creativity in Canada's water policies.

Conclusions

This paper has examined the economic characteristics of Canadian manufacturing water demands and considered their implications for the implementation of economic instruments to promote enhanced water resources management in Canada. Econometric studies and experience from other jurisdictions demonstrate that manufacturing water intake and discharges are responsive to EI's.

The most significant barrier to implementation arises from the fact that the historical approach of Canadian government agencies responsible for the regulation of water allocation and protection of water

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quality has been to eschew EI's. This feature, combined with the impacts of cuts to the budgets of environmental ministries, suggests that the institutional capacity for introduction of EI's for integrated water resources management may be lacking at this time. This situation calls for innovation: case studies, partnerships and learning from other jurisdictions should provide Canada's environmental ministries with the knowledge base to move forward in the adoption of economic instruments to promote efficient industrial water use.

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References

Anderson, T. and P. Hill. 1997. (Eds.), *Water Marketing — The Next Generation*. Political Economy Forum Series. Rowman and Littlefield, Lanham, MD and London.

Babin F., C. Willis and P. Allen. 1982. "Estimation of Substitution Possibilities between Water and Other Production Inputs." *American Journal of Agricultural Economics,* 64(1): 148-151.

Bauer, C.J. 1998. *Against the Current: Privatization, Water Markets, and the State in Chile.* Kluwer Academic Publishers, Boston, MA.

Centre for Science and the Environment. 2004. "Cheapest Pickings." *Down to Earth,* Supplement on Water Use in Industry, February 24, 2004, Centre for Science and the Environment, New Delhi, India. Available at www.cseindia.org (Accessed July 2004).

Chave, P. 2002. *The EU Water Framework Directive: An Introduction.* IWA Publishing, Colchester, UK.

Dupont, D. and S. Renzetti. 1999. "An Assessment of the Impact of a Provincial Water Charge." *Canadian Public Policy*, 25(3): 361-378.

Dupont, D. and S. Renzetti. 2001. "Water's Role in Manufacturing." *Environmental and Resource Economics,* 18(4): 411-432.

Dupont, D. and S. Renzetti. 2005. "Cost-Benefit Analysis of Water Quality Improvements in Hamilton Harbour, Canada." In Brouwer, R. and D. Pearce (Eds.), *Cost-Benefit Analysis and Water Resources*, Edward Elgar Publishing, forthcoming.

Easter, K.W., M. Rosegrant and A. Dinar. 1999. "Formal and Informal Markets for Water: Institutions, Performance and Constraints." *The World Bank Research Observer,* 14(1): 99-116.

Goss, M., K. Rollins, K. McEwan, J. Shaw and H. Lammers-Helpo. 2002. "The Management of Manure in Ontario With Respect to Water Quality." Commissioned Isssue Paper #6, The Walkerton Inquiry, Toronto: The Queen's Printer of Ontario. Available at www.attorneygeneral.jus.gov.on.ca/english/about/pubs/walkerton/ (Accessed May 2003).

Grafton, R.Q., W. Adamowicz, D. Dupont, H. Nelson, R. Hill and S. Renzetti. 2004. *Economics of the Environment and Natural Resources*. Blackwell Publishers, Malden, MA.

Grebenstein, C. and B. Field. 1979. "Substituting for Water Inputs in U.S. Manufacturing." *Water Resources Research,* 15(2): 228-232.

Harrington, W. and R. Morgenstern. 2004. "Economic Incentives versus Command and Control: What's the Best Approach for Solving Environmental Problems?" *Resources,* Issue 152, Resources for the Future.

Henriquez, B.P. 2004. "Information Technology: The Unsung Hero of Market-Based Environmental Policies." *Resources,* Issue 152, Resources for the Future.

Horbulyk, T. and L. Lo. 1998. "Welfare Gains from Potential Water Markets in Alberta, Canada." In *Markets for Water: Potential and Performance,* Easter, K., M. Rosegrant and A. Dinar (Eds.). Kluwer Academic Press, Boston, MA, p. 241–257.

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Howitt, R. 1998. "Spot Prices, Option Prices, and Water Markets: An Analysis of Emerging Markets in California." In *Markets for Water: Potential and Performance,* Easter K., M. Rosegrant and A. Dinar, (Eds.), Kluwer Academic Press, Boston, MA, p. 119-140.

Loomis, J.B. 1992. "The 1991 State of California Water Bank: Water Marketing Takes a Quantum Leap." *Rivers,* 3(2): 129-134.

Marsalek, J., K. Schaefer, K. Exall, L. Bronner and B. Aidan. 2002. *Water Reuse and Recycling,* Canadian Council of Ministers of the Environment: Winnipeg, Manitoba, CCME Linking Science to Policy Workshop Series, Report 3.

O'Connor, D. 1996. "Applying Economic Instruments in Developing Countries: From Theory to Implementation." Economy and Environment Program for South-East Asia Research Report. Available at www.eepsea.org (Accessed August 2004).

O'Grady, D. and M.A. Wilson. (n.d.) "Phosphorus Trading in the South Nation River Watershed, Ontario, Canada." Available at www.envtn.org (Accessed May 2004).

Olewiler, N. and B. Field. 2002. *Environmental Economics,* Second Canadian Edition, McGraw-Hill Ryerson, Toronto, ON.

Ontario Ministry of the Environment. 2004. "White Paper on Watershed-based Source Protection Planning." Available at www.ene.gov.on.ca/envision/water/spp.htm (Accessed February 2004).

Ontario Ministry of Environment and Energy. 1996. "Guide to Resource Conservation and Cost Savings Opportunities in the Adhesives, Paints and Coatings Sector." Industry Conservation Branch, Toronto, ON.

Ontario Ministry of Environment and Energy. 1997. "Project Profiles: Green Industrial Analysis." Industry Conservation Branch, Toronto, ON.

Ping, Y. 1998. "The Pollution Charge System in China: An Economic Incentive?" Economy and Environment Program for South-East Asia Research Report 1998-09. Available at www.eepsea.org (Accessed August 2004).

Renzetti, S. (Ed.). 2002. *The Economics of Industrial Water Use,* Edward Elgar, Cheltenham, UK.

Reynaud, A. 2003. An Econometric Estimation of Industrial Water Demand in France." *Environmental and Resource Economics,* 25(2): 213-232.

Roth, E. 2001. "Water Pricing in the EU: A Review." European Environmental Bureau Report 2001/02 Available at www.eeb.org (Accessed August 2004).

Scharf, D., D. Burke, M. Villeneuve and L. Leigh. 2002. *Industrial Water Use 1996.* Environment Canada, Ottawa, ON .

Solley, W., R. Pierce and H. Perlman. 1999. *Estimated Use of Water in the United States in 1995.* United States Geological Survey Circular 1200. Available at http://water.usgs.gov/watuse/pdf1995/html/.

Vickers, A. 2001. *Handbook of Water Use and Conservation,* Waterplow Press, Amherst, MA.

Virani, S. and S. Graham. 1998. *Economic Evaluation of Environmental Policies and Legislation.* Report prepared for the European Commission Directorate General III (Industrial Affairs). Available at http://europa.eu.int/comm/environment/enveco/others/environmental_policies_and_legislation.pdf (Accessed June 2003).

Weber, M. 2001. "Markets for Water Rights under Environmental Constraints." *Journal of Environmental Economics and Management,* 42(1): 53-64.

Working Party on Economic and Environmental Policy Integration. 1997. *Industrial Water Pricing in OECD Countries,* OECD, Paris.

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