Technical Annex to the Economic Note
"The Carbon Market: Chasing Away Jobs and Capital without Reducing GHGs"

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1. Cap-and-Trade and Carbon Taxes

There are two ways to limit the emission of pollution using the price mechanism: a carbon tax or a carbon market.

With a carbon tax, the government sets a price for carbon. This increases the prices of goods and services whose production emits GHGs, which in turn leads to behavioural changes: An attempt is made to limit emissions in order to limit the amount paid in taxes.

A carbon market works in a similar manner: The authorities set a maximum level of emissions, and emitters have to purchase emission credits in order to produce goods and services while polluting. Here again, credits increase the prices of goods and services, which encourages people to reduce pollution to avoid having to pay for these credits.

The carbon tax and the carbon market are therefore equivalent in terms of effect. The difference between the two is that in the first case, the government sets the price and the market determines the quantity of emissions, whereas in the second, the government sets the quantity of emissions and the market determines the price.[1] For this reason, the studies cited, which refer to carbon taxes or to emission credits, are considered to apply to both mechanisms.

In 2007, a group of five Western American states, including California, founded the Western Climate Initiative (WCI), which aimed to develop programs to reduce greenhouse gas (GHG) emissions.[2] In 2008, two other states and four Canadian provinces, including Quebec and Ontario, joined the agreement.[3] Four years later, in 2011, all of the American states except California left the WCI.

The most ambitious program born of this initiative, and the favoured tool for reducing GHGs, is without a doubt the greenhouse gas cap-and-trade system. Also known as a carbon market, the cap-and-trade system is a tool that uses market mechanisms to, at least in theory, reduce GHG emissions more efficiently and at lower cost for society than a series of regulatory measures forcing all emitters to reduce their pollution equally, regardless of the cost.

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[1] Youri Chassin and Guillaume Tremblay, *Practical Guide to the Economics of Climate Change: The Paris Conference and Its Aftermath*, Research Paper, MEI, November 2015, pp. 29-37.

[2] California, Arizona, New Mexico, Oregon, and Washington.

[3] Utah, Montana, British Columbia, Manitoba, Ontario, and Quebec. Western Climate Initiative, *Design Recommendations for the WCI Regional Cap-and-Trade Program*, September 23, 2008, p. 3.

Among the five remaining WCI participants, only California and Quebec went ahead with the implementation of cap-and-trade in 2013, creating a common market for trading emission credits in 2014. Ontario joined this carbon market in 2018.[4]

Companies emitting 25,000 tonnes of CO_2 equivalent (tCO_2e) or more of GHGs are subject to the regulation. In 2013-2014, only the industrial and the electricity production sectors (including imported consumption) are subject. Starting January 1st, 2015, fuel distributors are as well.[5] The agricultural and waste sectors, which represent around 16% of emissions of tCO_2e in Quebec in 2015,[6] are not subject to carbon regulation.

Emission credits, each good for one tCO_2e, are issued by the governments of the three participating jurisdictions. Companies facing foreign competition receive most of the emission credits they need free of charge. These free credits are in principle to be reduced by around 1% per year until 2023.[7] Other companies must purchase these same credits in an auction that is normally held four times a year.[8]

A price floor and a price ceiling are set for emission credits. The price floor was set at $10.75 in 2013[9] and increases by around 6% per year in nominal terms. In 2018, it is $14.35 in Quebec and $14.68 in Ontario. The average price, according to the last joint auction, was $20.07.[10]

2. Greenhouse Gas Emissions, 1990-2015 and Projections

Figure 1 of the Economic Note measures the evolution of total tCO_2e emissions in Quebec and in Ontario from 1990 to 2016, and from 1990 to 2015 for California (the most recent available

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[4] Quebec Department of Sustainable Development, Environment, and the Fight against Climate Change, “Le système québécois de plafonnement et d’échange de droits d’émission—En bref,” 2014; Government of Ontario, Cap and Trade, April 5, 2018.

[5] Quebec Department of Sustainable development, Environment, and the Fight against Climate Change, “Le système de plafonnement et d’échange de droits d’émission de gaz à effet de serre du Québec—Description technique,” 2014, p. 7.

[6] Environment and Climate Change Canada, C-Tables-IPCC-Sector-Provinces-Territories, March 26, 2018.

[7] Quebec Finance Department, *Impacts économiques du système de plafonnement et d’échange de droits d’émission de gaz à effet de serre du Québec*, August 2017, p. 15.

[8] Quebec Department of Sustainable development, Environment, and the Fight against Climate Change, *op. cit*., footnote 5.

[9] Quebec Department of Sustainable Development, Environment, and the Fight against Climate Change, “Vente aux enchères d’unités d’émission de gaz à effet de serre du Québec du 3 décembre 2013—Rapport sommaire des résultats,” December 3, 2013, p. 3.

[10] The average price indicated is that of the February 2018 auction, whereas the price floors are for May 2018. Quebec Department of Sustainable Development, Environment, and the Fight against Climate Change, “Vente aux enchères conjointe n° 14 de février 2018—Rapport sommaire des résultats,” February 28, 2018, p. 4; Quebec Department of Sustainable Development, Environment, and the Fight against Climate Change, “Avis de vente aux enchères,” March 16, 2018, p. 5.

year), and establishes projections for the period from 2016 to 2050, based on objectives that the relevant provincial or state governments have set for themselves.[11]

The data for the Canadian provinces are drawn from the annexes of the "National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada."[12] Using emission estimates based on methods that conform to the 2006 guidelines of the Intergovernmental Panel on Climate Change (IPCC), this report is presented each year to the United Nations Framework Convention on Climate Change (UNFCCC). The estimates are for carbon dioxide (CO_2) emissions, as well as other greenhouse gases (CH_4, N_20, PFC, HFC, SF_6, NF_3) in several sectors.[13]

The data for California come from the state government's Air Resources Board (CARB). They are comparable with the Canadian data, as they use a similar methodology that also follows the IPCC's 2006 guidelines.[14]

For emission projections during the 2016-2050 period, we calculated the average annual growth rate for the 2010-2015 period for each of these jurisdictions. This methodology is also used by the Chair of Energy Sector Management at HEC Montréal.[15] We added onto the Figure the targets of each government.

Table A-1 presents the data for total emissions and for emissions in certain sectors mentioned in the Note for the 1990-2015 period.[16]

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[11] For Quebec and Ontario, we used the most recent inventory, in which the data were slightly revised downward for the entire period. The general trends were not affected by these changes, however, and we assume that the new data are comparable with the most recent inventory for California.

[12] Environment and Climate Change Canada, National and Provincial \/ Territorial Greenhouse Gas Emission Tables, April 3, 2018.

[13] For more details on the methodology used, see https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary.html

[14] California Air Resources Board, California Greenhouse Gas Emission Inventory - 2017 Edition, June 6, 2017.

[15] Johanne Whitmore and Pierre-Olivier Pineau, *État de l'énergie au Québec 2018*, Chair in Energy Sector Management, HEC Montréal, December 2017, p. 43.

[16] Rapport d'inventaire national 1990-2015. Sources et puits de gaz à effet de serre au Canada - Annexe Tableau A11-2 : Résumé des émissions de gaz à effet de serre pour le Québec et l'Ontario, 1990-2015; California Air Resources Board, California Greenhouse Gas Inventory for 2000-2015 — by Sector and Activity; California Greenhouse Gas Inventory (millions of metric tonnes of CO_2 equivalent) for 1990-2004 — By Sector and Activity (for the years 1990 to 1999).

Table A-1 – Emissions in Quebec, Ontario, and California in different sectors, millions of tCO_2e, 1990-2015

		1990	1995	2000	2005	2010	2015
Quebec	**Total**	**87**	**83**	**86**	**86**	**80**	**78**
	Transport	28	29	31	34	35	34
	Agriculture	7	7	7	8	8	8
	Waste	5	5	5	5	4	4
Ontario	**Total**	**179**	**179**	**208**	**205**	**174**	**163**
	Transport	48	52	60	64	61	61
	Agriculture	10	11	10	10	10	10
	Waste	5	6	6	7	6	6
California	**Total**	**437**	**422**	**467**	**482**	**446**	**440**
	Transport	150	154	175	183	162	164
	Agriculture	21	22	29	31	33	32
	Waste	11	11	9	10	10	11

Sources: Environment and Climate Change Canada, C-Tables-IPCC-Sector-Provinces-Territories, March 26, 2018; California Air Resources Board, California Greenhouse Gas Inventory for 2000-2015 — by Sector and Activity, June 6, 2017; California Air Resources Board, California Greenhouse Gas Inventory for 1990-2004 — By Sector and Activity, November 19, 2007

3. Price Projections for the Carbon Market

To establish estimates of future prices for GHG emissions, two sources were used. The first is ICF Consulting, a firm that produced estimates at the request of the Ontario government. These estimates established the price of emissions on the carbon market in constant 2017 Canadian dollars according to three scenarios.[17] The hypotheses upon which the different scenarios are based are detailed in Table A-2.[18]

[17] ICF Consulting Canada, *Long-Term Carbon Price Forecast and Marginal Abatement Cost Curve for Assessment of Natural Gas Utilities' Cap and Trade Activities*, July 19, 2017
[18] *Ibid*. p. 3.

Table A-2 –Scenarios used by ICF Consulting to estimate the price of emissions on the carbon market

Price level	Hypotheses
1 – Low	- Ontario sets its price according to the WCI carbon market; - There is a surplus of emission credits relative to demand through 2028; - Price follows the floor price as defined in Ontario Regulation (based on California regulation); - California inflation rate of 1.8% taken into account.
2 – Medium	- Ontario sets its price according to the WCI carbon market; - Hypothesis based on the situation of current environmental policies, economic growth, and current carbon market rules; - The California-Quebec market would experience a shortage of emission credits starting in 2020, with a cumulative shortage during the 2020s; - The arrival of Ontario will provoke the shortage sooner.
3 - Maximum	- Ontario does not set its price according to the WCI carbon market.

Source: ICF Consulting Canada, *Long-Term Carbon Price Forecast and Marginal Abatement Cost Curve for Assessment of Natural Gas Utilities' Cap and Trade Activities*, July 19, 2017, p. 23.

We did not take into account scenario 3 in order to keep only the estimates related to the carbon market situation with the three participating jurisdictions.

The second source used to establish projections is the California Air Resources Board (CARB), which has been carrying out this kind of exercise for several years based on past emissions and other variables specific to California.[19] In order to make comparison easier, we kept only scenarios 1 (low price estimate) and 3 (high price estimate) among the three cases presented in Table A-3.

Table A-3 – Scenarios used by the California Air Resources Board to estimate the price of emissions on the carbon market

Estimates	Assumptions
1- Low	- High consumption scenario, the price aligning itself with the floor price.
2- Medium	- Medium consumption scenario, price in between the two other scenarios.
3- Maximum	- Low consumption scenarios, the price aligning itself with the ceiling price.

Source: California Air Resources Board, Revised 2017 IEPR Carbon Price Projections for Use in Simulation Modeling (GHG emitting generating resources in California only), electricity rates, and natural gas rates, January 16, 2018.

[19] California Air Resources Board, Revised 2017 IEPR Carbon Price Projections for Use in Simulation Modeling (GHG emitting generating resources in California only), electricity rates, and natural gas rates, January 16, 2018.

Since the data were expresses in constant 2016 US dollars, we converted them into constant 2017 dollars by using the implicit estimate of the GDP price index used by the CARB. We then converted the result obtained into Canadian dollars using the OECD's most recent purchasing power parity index (1.260 in 2017), which approaches the average exchange rate over the long term.[20]

Table A-4 presents the evolution of the floor price and the ceiling price through to 2030 based on these two sources. The estimates of the two sources are relatively close, especially for the low price scenario.

We used the lowest (ICF, low estimate) and the highest (CARB, high estimate) data points for Figure 2 in the Economic Note, as well as the estimates of capital flight in 2030 for Ontario and Quebec.

Table 4 – Estimates of emission credit prices according to ICF and the CARB, different scenarios, in constant 2017 Canadian dollars

	2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
ICF, low estimate	$17	$18	$18	$19	$20	$21	$22	$23	$24	$25	$27	$28	$30
CARB, low estimate	$19	$20	$21	$22	$23	$25	$26	$27	$29	$30	$32	$33	$35
ICF, high estimate	$17	$18	$18	$19	$20	$21	$31	$36	$43	$50	$57	$60	$63
CARB, high estimate	$18	$21	$24	$28	$32	$37	$43	$50	$58	$67	$77	$90	$104

Note: For Ontario, ICF's estimates went until 2028. We therefore calculated projections for 2029 and 2030 based on the projected annual rate of growth for the years from 2024 to 2028.

Sources: Authors' calculations. California Air Resources Board, Revised 2017 IEPR Carbon Price Projections for Use in Simulation Modeling (GHG emitting generating resources in California only), electricity rates, and natural gas rates, January 16, 2018; ICF Consulting Canada, "Long-Term Carbon Price Forecast and Marginal Abatement Cost Curve for Assessment of Natural Gas Utilities' Cap and Trade Activities," Document prepared for the Ontario Energy Board, July 19, 2017.

[20] OECD, Data, Purchasing power parities, 2017.

4. Estimates of the price required to meet reduction objectives

To establish the price required to hit GHG reduction targets, we based ourselves on a study from the Carbon Pricing Leadership Association. Their estimate assumes that in Canada, no other public policy than the carbon market will be put in place to reduce greenhouse gas emissions and reach the Paris climate accord objectives.[21]

Another estimate, cited in the same report, considers that the price of an emission credit should be $50 in 2020 and then increase by $10 per year in order for the GHG emission reduction objectives to be met. This latter assessment is based on a scenario integrating other public policies into the model. It presupposes among other things the setting up of performance standards as well as regulatory policies.[22]

These two scenarios are expressed in constant 2015 Canadian dollars and apply to Canada as a whole. Prices are set with a view to reducing per capita emissions below two tCO_2e by 2050, in accordance with the objective of limiting the growth of global temperature to $2^{o}C$ with a probability above 66%.[23]

5. The transfer of funds from Quebec and Ontario to California

Given the gap between the emissions target for 2030 and the level of emissions that will be achieved if trends continue, Quebec and Ontario will respectively have to purchase credits for 15.2 million and 15.8 million tCO_2e in 2030. This projection takes into account the effect of cap-and-trade as estimated by the Quebec Finance Department, which predicts that 20% of the effort to be made to achieve the objective will be made by 2030 thanks to carbon pricing, excluding the effect of other policies aiming to accelerate the decarbonization of the economy. The total amount is obtained by multiplying these quantities by the price estimated by the Ontario government and by the California Air Resources Board for 2030, namely from a minimum of $29.91 and a maximum of $103.77 per tCO_2e.[24]

6. Concrete examples of the effects on the economy of substantial changes in the price of energy

A recent Ontario policy offers a telling illustration of the carbon leakage effect. Between 2010 and 2016, the price of electricity including taxes for large users increased by 53% in Ottawa and 46% in Toronto, versus 10% in Montreal, 12% in Detroit, and 19% in Winnipeg, and a decrease of

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[21] Carbon Pricing Leadership Coalition, *Report of the High-Level Commission on Carbon Prices*, May 29, 2017, p. 31.

[22] Chris Bataille *et al*., *Pathways to Deep Decarbonization in Canada*, SDSN – IDDRI, September 2015, pp. 12-14.

[23] Carbon Pricing Leadership Coalition, *op. cit*, footnote 21; Chris Bataille *et al*., *Ibid*.

[24] Quebec Finance Department, *op. cit.*, footnote 7.

19% in Chicago. The Ontario increase was by far the largest of all Canadian provinces, and the price level in Ontario is now among the highest in North America.[25]

This price increase in Ontario was not caused by the cap-and-trade system, but is nonetheless related to policies aiming to reduce GHG emissions. A Fraser Institute study evaluated the effects on Ontario's manufacturing sector. Between 2006 and 2016, manufacturing investment fell by 26% in Ontario, whereas it increased by 11% in Quebec, by 15% in British Columbia, and by 35% in Saskatchewan.[26]

Over the same period, the share of the Canadian manufacturing sector based in Ontario went from 49% to 46%. Production for the most energy-intensive manufacturing industries fell the most. According to the Fraser Institute, the substantial increase in the price of electricity is responsible for nearly 75,000 manufacturing job losses in Ontario.[27]

The arrival of very affordable natural gas in the United States, on the heels of the introduction of hydraulic fracturing, is a negative example of carbon leakage. Regions where this low-price natural gas was available experienced a manufacturing renaissance, both in terms of production and in terms of jobs.[28]

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[25] Based on the average price per kWh including taxes in Canadian dollars, solely for total consumption of between 5,000 and 3.06 million kWh. Hydro-Québec, *Comparison of Electricity Prices in Major North American Cities*, 2010 and 2016 editions.

[26] Ross McKitrick and Elmira Aliakbari, *Rising Electricity Costs and Declining Employment in Ontario's Manufacturing Sector*, Fraser Institute, October 2017, p. 12. Other studies also confirm that environmental policies can lead to job losses. See Michael Greenstone, "The Impacts of Environmental Regulation on Industrial Activity," *Journal of Political Economy*, Vol. 110, No. 6, pp. 1175–1219; Matthew E. Kahn and Erin T. Mansur, "Do Local Energy Prices and Regulation Affect the Geographic Concentration of Employment? A Border Pairs Approach," *Journal of Public Economics*, Vol. 101, March 2013, pp. 105–114.

[27] Ross McKitrick and Elmira Aliakbari, *Ibid*., pp. 12 and 27.

[28] Jason Tolliver *et al.*, "The US Manufacturing Renaissance: Driving a Resurgence in Industrial Real Estate," 2016.