Economic Analysis of the 2022 Federal Clean Fuels Standard

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Executive Summary

The 2022 Clean Fuels Standard (CFS) imposes a requirement to reduce the carbon intensity of liquid fuels used for transportation in Canada by about 15 percent by 2030. The plan allows for limited trading of compliance credits where credit generation can be done through a variety of closely-regulated mechanisms including provision of Electric Vehicle charging services. The backstop credit price is $300 per tonne of CO2-equivalent which is well above the federal carbon charge.

Two analyses are presented herein. In the first it is assumed that compliance will be achieved entirely through blending of ethanol into liquid fuels or through credit creation at an equivalent or higher marginal cost. The analysis assumes most of the incremental ethanol will be imported from the United States. Since US-based ethanol has been shown to have a higher lifetime carbon intensity than gasoline, the end result will be no global greenhouse gas (GHG) emission reductions, but we focus herein only on the domestic GHG emissions which can be expected to decline due to reduced carbon intensity at the consumer use stage. Since ethanol has a lower energy content and a steeper cost curve (meaning the production cost rises faster than that of gasoline as demand increases) the requirement to lower the carbon intensity of Canadian gasoline by 15 percent, if achieved through ethanol blending, will add about 50 percent to the cost of motor fuels on an energy-adjusted basis.

This scenario is shown to impose large economic costs by 2030. While GDP continues to grow it does so at a slower rate, opening up a 2.8 percent loss in potential national GDP as of 2030, a 2.6 percent gap in real income per worker, a comparative loss of 72,000 jobs nationally and a large loss of capital investment. The marginal costs to regulated entities under this scenario exceed $290 per tonne of emission reductions. The cost of fuels to households rises by between six and 16 percent by 2030, depending on the province.

The federal Regulatory Impact Assessment indicates that the government intends the cost impacts to be much lower, based on the results of its internal macroeconomic modeling. The analysis herein was therefore re-run assuming that credit creation will be facilitated so as to cover half of the compliance gap, limiting the required carbon intensity reduction to 7.5 percent by 2030, with the remaining compliance burden met by creation of credits with a maximum cost of $275 per tonne.

Even in this scenario, contrary to the government's claim that there will be virtually no effect on GDP, as of 2030 Canadian GDP will be about 1.3 percent lower than under the base case (without the CFS) and real GDP per worker will be lower by 1.2 percent. Employment will fall by 93,000 person-years over the course of the 2020s and in 2030 total employment will be about 25,000 below the base case.

This version of the policy will cause household energy costs to rise by between 2.2 and 6.5 percent depending on the province by 2030. Direct compliance costs will be $9.2 billion in 2030, only some of which will be directed to the biofuels sector as additional demand. The direct and indirect economic costs to households add up to $1,277 annually per employed person. This takes into account increased energy costs, lower wages, lower capital earnings and increased indirect costs throughout the rest of the economy.

GHG emissions in 2030 are projected to be 34 MtCO2e below the baseline, which is a much larger reduction than the federal RIA estimate of 18 MtCO2e (p. 23). About one-third of the reduction in this analysis is due to the economic contraction which is assumed not to happen in the federal analysis. The federal analysis also incorporates a much smaller change in the price of fuels, which may arise from not accounting for the loss of energy per litre, which also dampens its estimated emission reduction effect.

The CFS policy will put downward pressure on government revenues leading to an increase in the consolidated government deficit in every year of the policy's implementation, reaching $5 billion nationally in 2030 and $10 billion in 2040. The extra government debt accumulated by 2040 as a result of the policy will be $95.2 billion

Not every province will be impacted the same. The hardest hit on a proportional basis will be Newfoundland and New Brunswick, owing to the relative size of the refining industries in those provinces.

1. Introduction

This note presents an economic assessment of the likely economic consequences of the Clean Fuels Standard (CFS) as announced in the Canada Gazette Volume 156 Number 14, Wednesday July 6, 2022.[1] The core of the regulation is a requirement to reduce the carbon intensity of liquid fuels used in transportation according to the following schedule:

Year	Gasoline	Diesel	Fuel Avg.	Average Ratio
2022	95.0	93.0	94.0	1.0000
2023	91.5	89.5	90.5	0.9628
2024	90.0	88.0	89.0	0.9468
2025	88.5	86.5	87.5	0.9309
2026	87.0	85.0	86.0	0.9149
2027	85.5	83.5	84.5	0.8989
2028	84.0	82.0	83.0	0.8830
2029	82.5	80.5	81.5	0.8670
2030	81.0	79.0	80.0	0.8511

The columns labeled Gasoline and Diesel show the maximum allowed carbon intensity measured as grams of carbon dioxide equivalent (herein "CO2e") per megajoule of energy, herein denoted gCO2e / MJ. According to the regulation Section 5(5) the assumed baseline amounts are 95.0 and 93.0 gCO2e/MJ as shown in the entry for the year 2022. The prescribed caps begin in 2023 and decline through to 2030. The unweighted average of gasoline and diesel is shown in the "Fuel Avg" column. The final column, denoted "Average Ratio", shows the Fuel Average as a fraction of the baseline 2022 amount. As shown, the regulation requires carbon intensity in 2030 to be just over 85 percent of the level in 2022, thus yielding approximately a 15 percent reduction. According to the Government's Regulatory Impact Assessment (RIA), the regulation is expected to result in an overall greenhouse gas (GHG) emission reduction over the decade of between 151 and 267 megatonnes of CO2e with a central estimate of 205 Mt CO2e.

This is a different target than the 2016 Canada-Wide Clean Fuels Standard which was assessed by LFX Associates in 2020 (Lee and McKitrick 2020). Many of the criticisms in that report apply equally to the new CFS, including the following.

[1]Available at https://www.canadagazette.gc.ca/rp-pr/p2/2022/2022-07-06/pdf/g2-15614.pdf.

- Adding a regulatory measure such as a CFS on top of a carbon pricing scheme destroys the economic efficiency of carbon pricing and raises the cost of achieving the overall policy goal.
- Canada has already achieved clean fuels usage in motor vehicles through improved vehicle technology including catalytic converters and better engines. Specifically:
  - While the Canadian vehicle fleet tripled in size between 1975 and 2015, vehicle-related local air pollution infractions (carbon monoxide and nitrous oxides) fell to zero across Canada.
  - From 2000 to 2017, while total vehicle-km traveled on Canadian roads increased more than 20 percent, total vehicle emissions of carbon monoxide and carbon particulates both fell by over half.

- The regulation will require heavy reliance on increased ethanol production, much of it imported from the US, which has negative environmental consequences of its own and which may be even worse than those associated with gasoline.

On the latter point, new research published in the Proceedings of the US National Academy of Sciences (Lark et al. 2022) evaluated the environmental and social impacts of renewable fuel mandates in the US and concluded the following.

- Mandates to use ethanol in motor fuels raised the price of corn by 30% and the prices of other food crops by 20%.
- The policies also led to an increase in fertilizer use of between 3 and 8%, with an attendant reduction in water quality of between 3 and 5%.
- Corn ethanol produced under the Renewable Fuel Standard has a life-cycle carbon intensity of about 115.7 gCO2e/MJ, which is 24 percent higher than that of gasoline.

Consequently, while the analysis herein will assume that the carbon intensity of motor fuels in Canada declines as prescribed in the legislation when computing domestic GHG emissions, the reader should bear in mind that on a life-cycle basis, for Canada and the US together, the federal Clean Fuels Standard will likely result in a fuel supply with higher overall carbon emissions intensity.

2. The Modeling Framework

The analysis uses the LFX Canadian Model version 5.0, which is substantially revised and improved compared to the version used for Lee and McKitrick (2020). A detailed description of the model is available in McKitrick (2022). Here we provide a brief summary.

The core of the model is an array of provincial input-output tables that resolve intermediate and final demand across 26 economic sectors, with special focus on energy sector detail that allows tracking of CO2 and methane emission sources. Input-output coefficients are determined each period based on current prices. Within each sector the model tracks tax and subsidy payments, labour and capital demands, returns to investors and final output. The model employs recursive dynamics in which investment (fixed capital formation) responds to the market returns to existing capital. Households earn income from supplying labour and capital and provide net savings to fund capital investment and government borrowing. Markets for all intermediate and final goods clear using the Leontief equation (a standard national accounting identity) while markets for labour and capital clear using a price search algorithm. A search algorithm also selects an interest rate to clear the market for savings and borrowing, and an exchange rate to balance the current and capital accounts.

Regulatory policies are represented in the model using efficiency loss parameters that measure the increase in marginal operating costs associated with regulations, that do not accrue elsewhere as additional revenue. These are called regulatory rents. Where the regulation yields an improvement in, for example, GHG emission intensity, this is reflected in the GHG accounts. The CFS standard increases the marginal cost of producing fuels in Canada, and reduces the GHG emissions per unit of fuel consumption. The projected change in the cost of fuel production is explained in Section 9 of McKitrick (2022). The CFS also causes the refinery sector to demand more non-petroleum inputs than otherwise, much of which is assumed to be imported due to capacity constraints on the Canadian ethanol sector (Pratt 2019).

3. International Crude Sources

The life-cycle carbon intensity of crude oil differs considerably by source, even within countries. The volume-weighted average carbon intensity of Canada's Suncor Synthetic H crude is 58.8 gCO2e/MJ compared to 51.9 (Cold Lake), 44.6 gCO2e/MJ (Milk River), 36.3 gCO2e/MJ (Western Canada Conventional Light Sweet) and 35.4 gCO2e/MJ (Hibernia) (Jing et al. 2020, Supplementary Table 5). Internationally, crude from Iran, Saudi Arabia and many other Middle Eastern states tends to have a carbon intensity in the 30s (although Basrah blends from Iraq tend to be in the 40s) as does Texas, Russian oil varies from the low 30s to the 50s, Alaskan North Slope crude is 47.7 gCO2e/MJ, Chinese and Venezuelan crude tends to be in the 50s, etc. (Jing et al. 2020).

For this reason, while one of the compliance options for domestic fuel producers is to source out international crude with a lower life-cycle carbon intensity, practical constraints mean this will not likely help with compliance. First, we assume that no additional Russian crude will be used. Second, Venezuelan crude has, on average, a higher carbon intensity than Canadian crude (although, as with Canada, carbon intensities differ widely among fields within Venezuela). Third, light crudes from the Middle East are already used in Eastern Canadian refineries, but they have a similar carbon intensity to Hibernia, so substitution will not likely affect the overall average. Finally, while it is conceivable that Canada might seek to import more West Texas Intermediate crude even while we export most of our domestic crude to the US, pipeline constraints across the Canada-US border make this effectively impossible.

Therefore the analysis herein assumes that compliance with the CFS cannot be achieved simply by changing international crude oil sources.

4. Costs of Full Compliance Through Fuel Blending

All simulations herein assume in the base case that the carbon price follows the government's prescribed nominal schedule, reaching $170 per tonne by 2030, although this is adjusted for inflation so its real value in 2018 dollars is only $125 in 2030 and declines thereafter. The Output-Based Pricing System (OBPS) is implemented in the LFX model as described in Section 8 of McKitrick (2022), namely as an output price subsidy for each sector based on average exceedances of an emissions intensity target. This policy system is assumed in place in both the base case (without CFS) and policy experiment (with CFS) case. The OBPS pricing threshold is held at 90 percent of the mean emissions intensity (rather than declining as prescribed in the recent Emission Reduction Plan) in both the base case and policy experiment case.

The CFS allows for a trading system to ease compliance. The process of creating credits is somewhat onerous and the trading process requires applications to the Minister for approval. Credits have a backstop price of $300 per tonne (Sct. 112(3)) and the optional compliance fund which costs $350 per tonne, both of which are much higher than the per-tonne carbon tax price. Credits are only available for activities that are additional to those already undertaken. Since the federal carbon charge already creates an incentive for emission reduction activity the only activities undertaken for the purpose of credit creation would have to occur at a higher marginal cost than the carbon charge itself.

The CFS also allows for credit creation through the operation of subsidized electric vehicle charging stations. The LFX model includes a vehicle stock-flow model with growing adoption of electric vehicles depending in part on the price of fuel versus the cost of electricity; however outside of large urban areas their market penetration is not projected to be substantial. This is in part because it remains the case that, even with large subsidies and price incentives, EVs are very costly to purchase compared to traditional cars and vehicle makers incur large losses on each unit (CVMA 2016). The RIA (p. 38) assumes that 50 percent of cars sold in 2030 will be EVs, and 100 percent in 2035 will be EVs, but does not take into account the costs to the economy of imposing such a requirement. The RIA projects that relatively few compliance credits will be generated from EV charging prior to 2030.

The regulation also allows for credit creation through carbon capture projects. The LFX model includes a carbon capture component whereby CCUS projects with marginal costs below the carbon charge are assumed to be adopted and implemented, with the adoption schedule set using a function derived from data compiled by the US National Academy of Sciences and Engineering. These are assumed not to qualify under the additionality requirements of the CFS regulation. For the current simulation it was assumed that no additional CCUS projects are introduced for the purpose of credit creation, however this assumption is relaxed in the next simulation.

As noted above the CFS prescribes an approximately 15 percent reduction in the allowable carbon content of liquid fuels between 2023 and 2030. The model was run with and without the policy sequence in place and the effects on GHG emissions and the economy were obtained. The policy was represented by pairing the prescribed CI reduction each year with the fuel cost adjustment as computed using the method shown in Section 9 of McKitrick (2022).

The representation in the LFXCM5 of consumer costs from ethanol mandates is discussed in detail in McKitrick (2022). Ethanol may cost more per litre to produce than gasoline depending on the world price of oil. The marginal cost of ethanol production rises more quickly in response to demand increases compared to gasoline due to its greater scarcity. Ethanol also contains less energy per volume than gasoline. The cost curve derived in McKitrick (2022) takes account of the energy content difference and indicates that a required 15 percent reduction in the carbon intensity of Canadian gasoline, to be achieved through ethanol blending, would raise the cost to consumers of motor fuels on an energy-adjusted basis by about 50 percent.

The results of the simulations under the assumption that compliance will be achieved only through biofuels blending will not be presented in detail because the costs to the economy are so large in comparison to the federal RIA expectations that we can assume the Government would not proceed with implementation once the costs become apparent. The main macroeconomic findings are summarized in Figure 1 and Table 1.

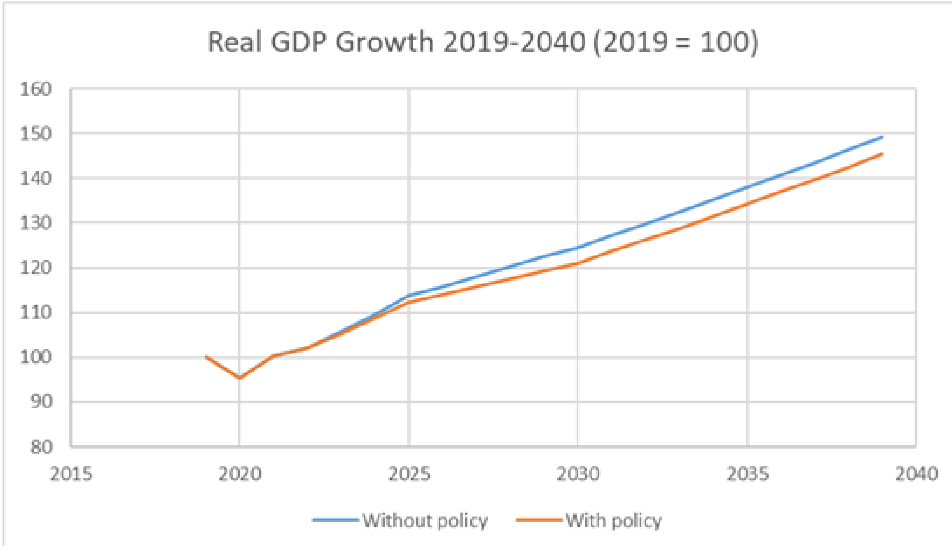

Figure 1. GDP growth 2019 to 2040 under the CFS, blending-only option.

Region	Change in: GDP (%)	Employment (%)	GDP/worker (%)	GHG Emissions (%)	Compliance Costs ($b)
Canada	-2.8	-0.2	-2.6	-11.9	$20.2
British Columbia	-1.9	0.0	-1.9	-10.6	$0.5
Alberta	-3.3	-0.7	-2.7	-8.7	$5.6
Saskatchewan	-3.3	-0.8	-2.5	-9.7	$1.6
Manitoba	-1.6	-0.1	-1.5	-12.2	$0.0
Ontario	-2.5	-0.0	-2.5	-12.6	$4.6
Quebec	-2.7	-0.2	-2.4	-11.6	$4.2
New Brunswick	-4.6	-1.4	-3.2	-23.9	$2.5
Nova Scotia	-2.3	-0.2	-2.0	-15.4	$0.0
PEI	-2.9	1.8	-4.6	-20.0	$0.0
Newfoundland	-5.7	-1.3	-4.5	-13.0	$1.4

Table 1: Macroeconomic consequences as of 2030 (comparison to base case) of reaching the CFS target only through biofuel blending.

GDP falls by 2.8 percent nationally, or in absolute terms, rather than rising by 24.6 percent from 2019 to 2030 it only rises by 21.1 percent. Employment doesn't fall much compared to the base case, instead income per worker absorbs the losses. GHG emissions fall by 11.9 percent which, in combination with the carbon tax almost gets Canada to the Paris target although emissions begin growing again in the 2030s and diverge from the Net Zero policy trajectory. Finally, direct compliance costs in the form of economy-wide regulatory rents are $20.2 billion, with the largest costs incurred by Alberta ($5.6b), followed by Ontario and Quebec.

5. Cost of Compliance with Credit Prices Capped at $275 per tonne

On the assumption that the government does not intend to impose such large costs on the economy the analysis was re-run under the same assumptions as before, but with the policy path changed so that a third of the compliance path is covered by credits that cost the same as or less than the marginal regulatory rents associated with an ethanol blending requirement. These credits are assumed to be associated with actions that do not directly reduce GHG emissions but nevertheless confer an exemption from compliance through fuel blending. An example in this case would be the use of CCUS project-related emission cuts which would have been implemented in response to the carbon tax anyway, but which are credited under the CFS. The result is that, in this simulation, by 2030 the carbon intensity of transportation-related fuel combustion in Canada is lower by 7.5 percent rather than 15 percent.

The modeling work undertaken by the federal government using the federal Environment Department's EC-Pro model, under their assumptions about credit availability, projects only very small impacts on GDP (a reduction of 0.3 percent), with some variation across provinces. The RIA assumes that the regulations will increase production costs for fuel producers, but also assumes (p. 59) that the policy will make low-carbon fuels and other substitutes for petroleum fuels less expensive. This assumption is at odds with the evidence that policies like the US Renewable Fuel Standards increased the price of ethanol inputs (Lark et al. 2022) and from standard findings that the supply elasticity of ethanol is positive, meaning that the marginal cost rises as production increases (Luchansky and Monks 2009). Consequently the federal RIA is not a reliable guide to the likely costs of complying with the CFS standard.

The credits trading system can be assumed to yield an equi-marginal distribution of compliance costs among fuel suppliers, and this assumption is used in the LFXCM5 model. But given the restrictions on credit trading and contributions to the compliance fund, in the absence of information regarding the likely availability of low-cost credits we maintain the assumption that the credits system will not reduce the overall marginal compliance cost below that of ethanol blending itself.

Note that we examine herein only the effects on carbon dioxide (CO_2) and methane (CH_4). Base case emissions and policy targets for each are based on isolating them out of the total GHG emissions for Canada as a whole.

The macroeconomic impacts of the CFS are summarized in the following nine charts. Each one compares the outcome under the CFS as described relative to the base case (which includes the carbon tax).

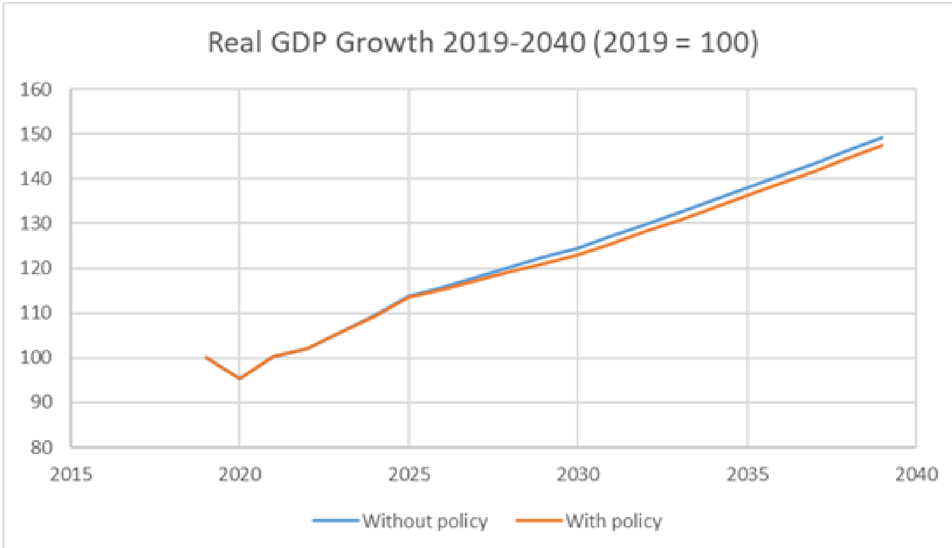

Figure 2: GDP growth 2019 to 2040 under the CFS, capped credit cost option.

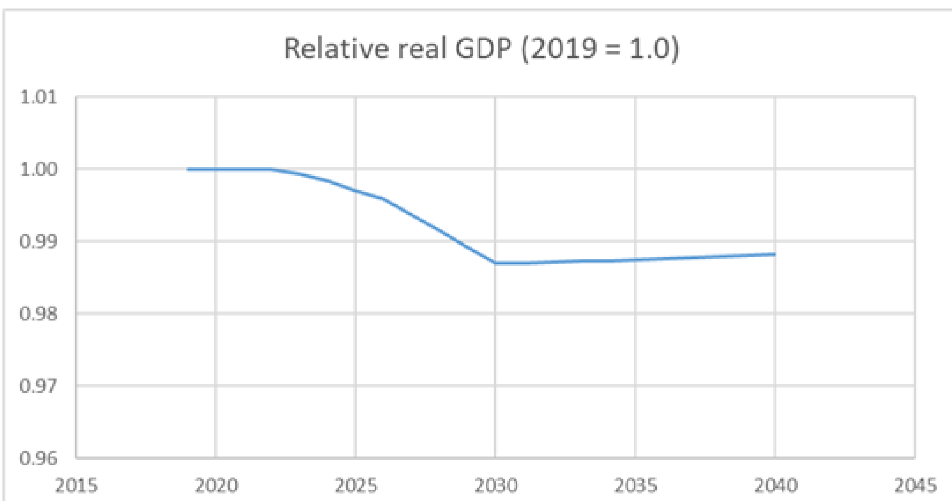

Figure 3: Real Gross Domestic Product as a fraction of the base case.

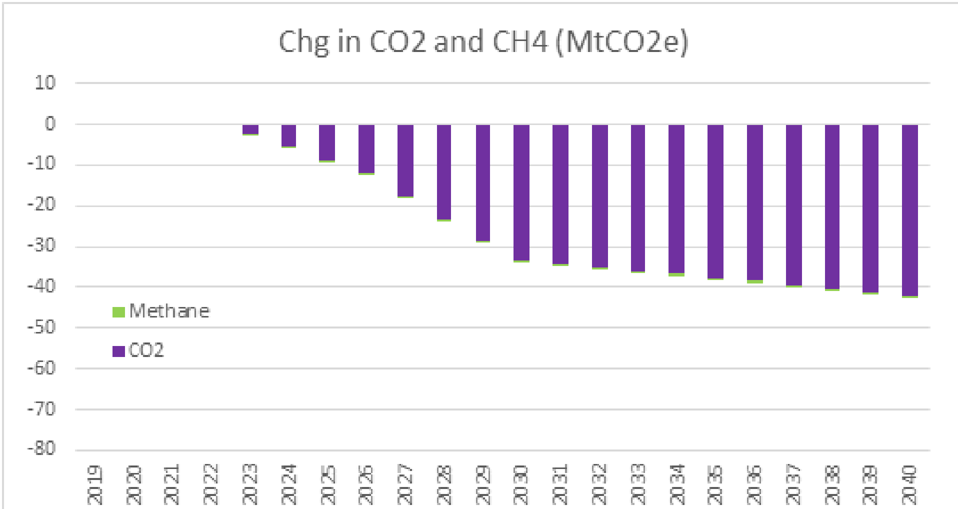

Figure 4: Change in GHG emissions compared to the base case.

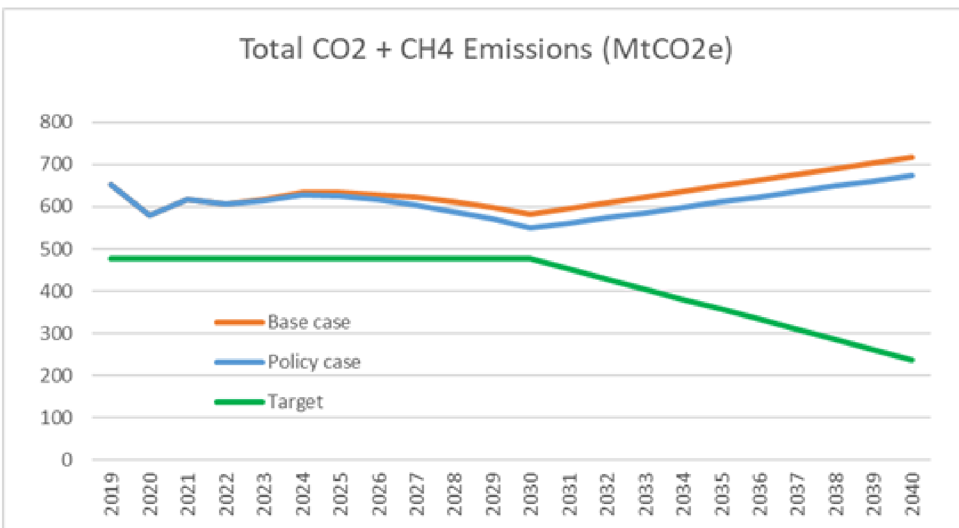

Figure 5: GHG Emissions under base case and policy case (with CFS) compared to Paris/Net Zero target.

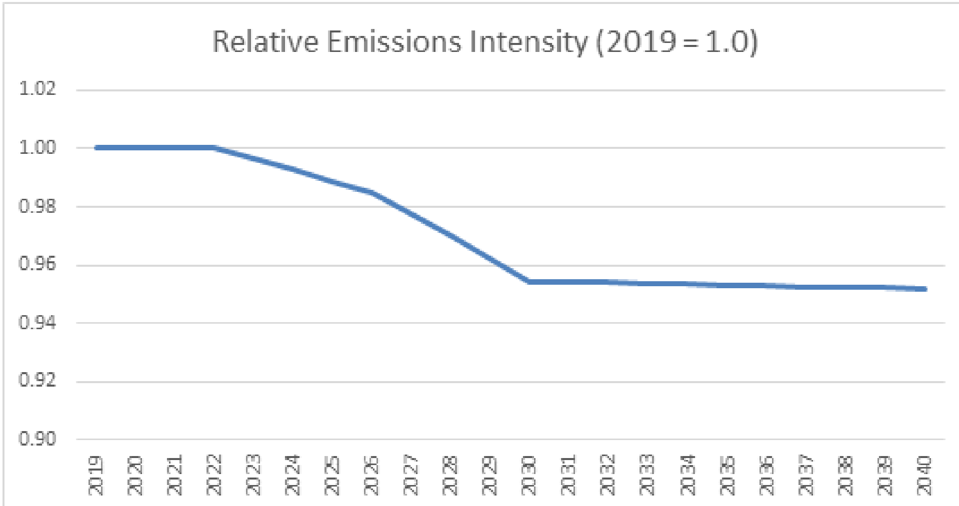

Figure 6: Emissions intensity (GHG/GDP) under the CFS as a fraction of the base case.

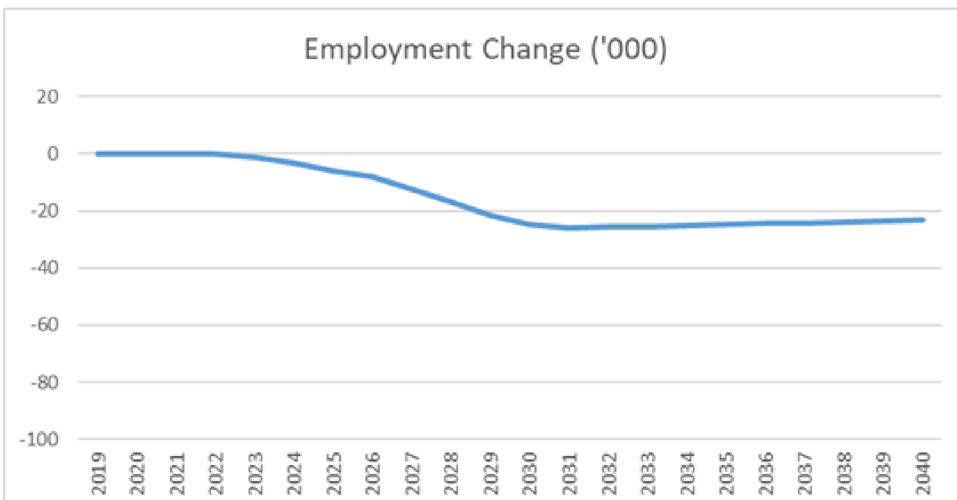

Figure 7: Change in equilibrium employment (thousand jobs) compared to base case.

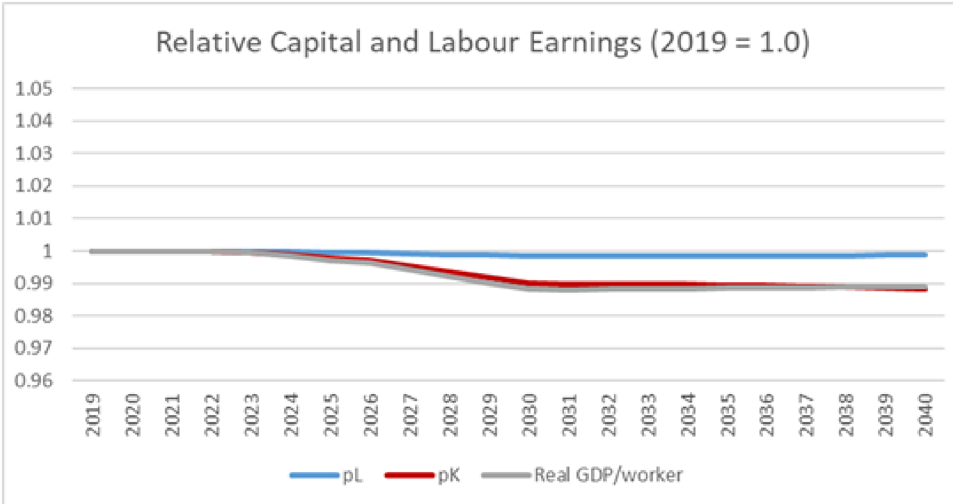

Figure 8: Prices of labour and capital (pL, pK respectively) and Real GDP/ worker as a fraction of the base case.

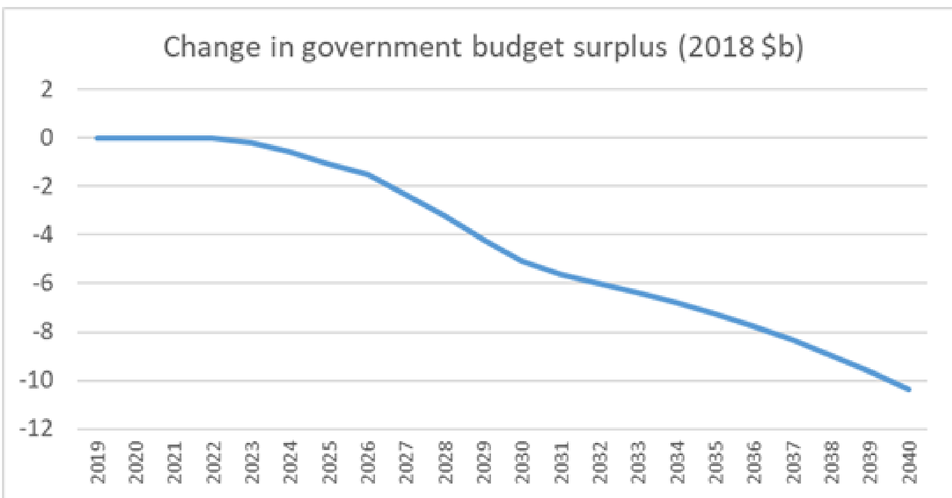

Figure 9: Effect on Consolidated Government Budget Surplus under policy case.

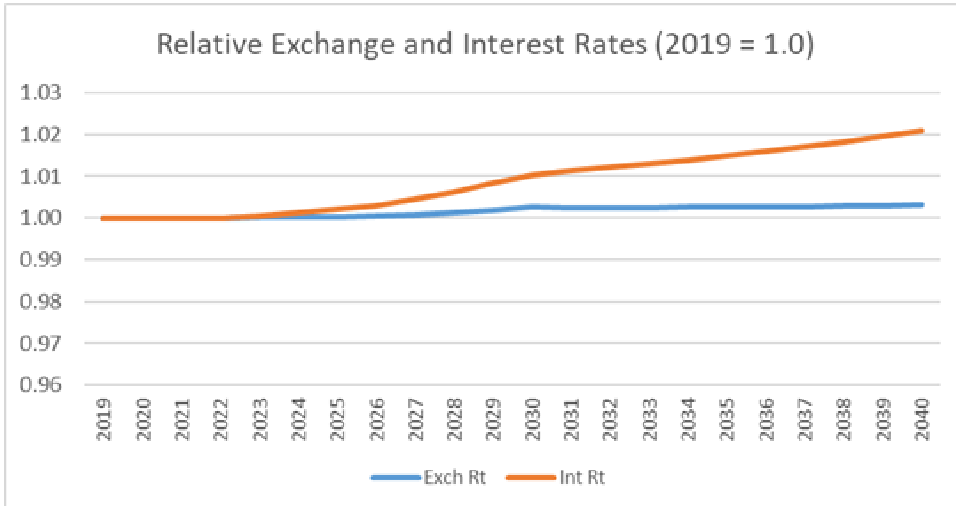

Figure 10: Exchange rate and interest rate as fractions of base case.

As shown in Figures 2 and 3, real GDP grows but more slowly than under the base case, opening up a gap of 1.3 percent as of 2030. In absolute terms, instead of the economy growing by 24.6 percent between 2019 and 2030 it only grows by 23.0 percent. GHG emissions fall by 33 Mt CO2e (Figure 4). As shown in Figure 5 this, combined with the carbon pricing system, brings the economy within about 71 Mte of the Paris target as of 2030, but with continued growth of the population and economy in the 2030s the emissions path diverges from the Net Zero target and later in the decade returns to current levels. Emissions intensity of GDP declines by 4.6 percent by 2030 and the gap stays approximately constant thereafter (Figure 6).

Figure 7 shows that total employment in the Canadian economy declines by about 25,000 jobs against the base case as of 2030, which is 0.1 percent of the projected work force. Note that this is an equilibrium estimate, meaning it represents the change after unemployment has cleared from the job market. Also note that this assumes the Government expands employment by nearly 11,000 workers as of 2030 in response to changing labour market conditions due to the policy. Over the 2020s the employment loss (even after expanding government employment) totals 93,000 person-years. Employment begins to recover very slowly in the 2030s and by 2040 is still about 23,000 below the base case. Figure 8 shows that factor markets clear primarily through a drop in the price of capital rather than labour. Coupled with this, real fixed capital investment falls by 1.0 percent, a much larger adjustment than the reduction in employment. Returns to capital also fall resulting in a drop in GDP per worker of 1.2 percent as of 2030, with no recovery thereafter.

Figure 9 shows that the policy causes the consolidated (provincial plus federal) government budget deficit to increase by about $5 billion as of 2030 and by about $10 billion as of 2040 with a total accumulated debt increment of $95.2 billion by 2040. The modeled scenario does not impose the requirement of a balanced budget or a constant surplus (or deficit). Consequently the macroeconomic effects include an expansionary fiscal position of the government sector. One consequence is that interest rates rise slightly. Figure 10 shows that the real interest rate rises by a factor of about 1.01 as of the early 2030s compared to the base case. This does not mean that rates go up by 100 basis points, instead it means that the interest rate in 2030 would be 1.01 x the rate that otherwise would have been observed. The exchange rate goes up very sightly, less than one percent. Since this is the price of purchasing foreign exchange it represents a depreciation of the currency, not an appreciation.

Tables 2 to 5 provide further detail on the economic effects. Table 2 presents percent changes in 2030 compared to the base case by province in GDP, Employment, GDP per worker and GHG Emissions, as well as compliance costs in $b nationally and by province. GDP losses vary widely by province, peaking at 2.6 percent in Newfoundland followed by 2.0 percent in New Brunswick, and 1.5 percent in Alberta and Saskatchewan. These numbers are high because the refinery sectors constitute a relatively large role in those provinces and refineries stand to face significant costs to comply with the CFS.

Region	GDP	Employment	GDP/worker	GHG Emissions	Direct Compliance Costs ($b)
Canada	-1.3	-0.1	-1.2	-5.8	$9.2
British Columbia	-0.9	-0.0	-0.9	-5.2	$0.2
Alberta	-1.5	-0.3	-1.2	-4.2	$2.5
Saskatchewan	-1.5	-0.4	-1.1	-4.7	$0.7
Manitoba	-0.8	-0.0	-0.7	-5.9	$0.0
Ontario	-1.2	-0.0	-1.2	-6.2	$2.1
Quebec	-1.2	-0.1	-1.1	-5.7	$1.9
New Brunswick	-2.0	-0.7	-1.4	-11.8	$1.2
Nova Scotia	-1.1	-0.1	-1.0	-7.6	$0.0
PEI	-1.3	2.3	-3.5	-9.8	$0.0
Newfoundland	-2.6	-0.6	-2.0	-6.5	$0.6

Table 2. Cols 1—4: Percentage changes by province in major macroeconomic indicators at 2030. Col 5: Direct cost of complying with regulation ($b). Total may not add due to rounding.

Employment losses also vary by province and indeed some provinces experience no net change or, in the case of PEI, a gain, due to reductions in the costs of hiring workers necessary to clear the labour market elsewhere. But the drop in real income per worker is highest in PEI at -3.5 percent. This measure takes into account losses in both labour and capital earnings. Newfoundland also experiences a large drop (2.0 percent) followed by New Brunswick (1.4 percent) and Ontario and Alberta (1.2 percent). Total compliance costs nationally (in the form of regulatory rents which do not accrue anywhere else as income) are $9.2 billion.

Region	Consumption	Imports	Exports
Canada	-0.7	0.7	0.1
British Columbia	-0.4	0.6	0.2
Alberta	-1.1	1.1	0.0
Saskatchewan	-1.2	1.4	0.0
Manitoba	-0.6	0.1	0.2
Ontario	-0.5	0.5	0.2
Quebec	-0.7	0.7	0.2
New Brunswick	-1.2	2.5	0.0
Nova Scotia	-0.8	0.2	0.1
PEI	-1.0	0.1	0.4
Newfoundland	-2.1	2.4	0.0

Table 3: Percentage changes against base case (2030) by province in real household consumption, nominal imports and nominal exports.

Table 3 provides further detail on the economic costs. Real consumption per household drops by 0.7 percent nationally with the largest drop in Newfoundland, followed by Saskatchewan, New Brunswick then Alberta and PEI. Both imports and exports rise in most provinces. Increases in imports are relatively largest in provinces that need to import substitutes for petroleum, chiefly in the form of ethanol.

Table 4 provides sectoral detail on output, labour demand and capital demand at the national level. Output in the Refined Fuels sector drops by 5.6 percent. Other sectors experiencing large output reductions are Air, Rail and Bus Transportation and Trucking, Courier and Storage, both of which are major users of transport fuels. Labour and capital demands do not merely follow output changes. Some sectors respond by making changes in employment that are relatively large compared to changes in output, such as Construction and Wholesale and Retail Sales and Entertainment. These results arise in the model based on the historic patterns of adjusting labour demand and returns to capital in response to market conditions.

Sector (Canada-wide)	Output (%)	Labour Demand ('000)	Capital Demand (%)
Agriculture, Fishing and Trapping	-0.6	0.1	0.3
Forestry and Logging	-0.5	0.7	1.6
Oil Sands	0.0	0.1	0.4
Conventional Crude Oil	-0.3	-0.3	0.1
Natural Gas	-1.3	-0.6	-0.4
Oil and Gas Support Activities	-0.8	-0.3	-0.1
Coal	-0.3	0.0	0.6
Other Mining	-0.4	0.7	0.4
Electricity	-1.1	-1.5	-0.7
Other Utilities incl. Gas Distribution	-1.4	-0.6	-0.9
Construction	-1.0	-5.3	-0.4
Food Production	-0.5	-0.9	0.0
Semi-durables	-0.4	-0.5	0.1
Refined Fuels	-5.6	-1.0	-4.8
Other Petrochemicals	-0.2	-0.5	0.2
Cement and Concrete	-0.9	-0.1	-0.2
Automotive Parts and Assembly	-0.4	-1.0	-0.1
Other Manufacturing	-0.5	-3.8	0.0
Wholesale and Retail Sales	-0.6	-7.6	-0.1
Air, Rail & Bus Transportation	-2.4	-1.8	-0.1
Gas Pipelines	-0.2	0.0	0.1
Crude Pipelines	-0.7	0.0	-0.3
Trucking, Courier and Storage	-1.8	-1.4	-0.2
Media, Banking, Finance, IT, Other Prof Svc	-0.4	-5.5	0.0
Education& Health	-0.2	1.8	0.3
Entertainment & Misc	-0.6	-6.0	-0.1
Government		10.8	

Table 4: Changes in key economic indicators by sector as of 2030. Output and Capital demand: Changes are in % terms. Labour demand: thousand workers.

Finally Table 5 presents some key national summary indicators of the consequences of the CFS policy. Direct regulatory compliance costs nationally are $9.2 billion or $414 per employed person. Total policy costs, taking into account regulatory rents and income declines, are $1,277 per employed person in 2030. Regulatory costs per tonne of emission reduction are $274, well above the federal RIA estimate of $151 per tonne (RIA p. 25). Since this is much larger than even the largest Social Cost of Carbon estimates in the mainstream literature (including the outliers relied upon by the RIA for its strained justification of the policy) the CFS fails a cost-benefit test. The final entry in Table 4 shows that, on average, by 2030, Canadian private sector firms will be earning 1.7 percent less on invested capital compared to sector-specific historical average returns. This indicates that the CFS policy will drive capital investment out of the country.

National Indicator	
Total Regulatory Compliance Costs	$9.2b
Direct regulatory costs per employed person (2018$)	$414
Total costs per employed person incl. income losses	$1,277
Regulatory Costs per tonne GHG reduced	$274
Capital returns relative to average	-1.7%

Table 5: National compliance cost indicators (2030).

6. Comparison of Costs and Benefits

The costs of compliance in this analysis are capped at $275 per tonne. To assess whether this cost is justified requires comparison against the Social Cost of Carbon or SCC. The federal RIA provides a selective and misleading summary of current research on the SCC. It cites a 2017 paper by William Nordhaus as providing a "central" 2020 SCC estimate of US$105 from his DICE model under a 3% discount rate, which came from taking an estimate provided by Nordhaus (US$87 in 2010 dollars) and converting it to 2021 Canadian dollars. However, the $87 figure is not Nordhaus' "central" overall estimate nor is it even a proper DICE model estimate.

Nordhaus (2017) reports that the central DICE model estimate for the 2020 SCC value is US$37 which would be about US$45 in 2021 dollars, not US$105. The DICE model generates an internal discount rate by solving for the equilibrium rate of return on investment using the so-called Ramsey equation. One of the drivers of the discount rate using this approach is the social aversion to intertemporal inequality. In order to impose a 3% discount rate in DICE, Nordhaus has to make several changes, including setting inequality aversion to zero, meaning we place equal weight on the interests of tomorrow's rich as we do of today's poor. While this allows Nordhaus to present SCC estimates for comparison with other models that impose a 3% discount rate, he has cautioned that obtaining this output requires special restrictions that are inconsistent with the overall structure of the DICE model and with empirical evidence. The RIA did not explain this, and by describing the US$105 figure as Nordhaus' "central" estimate created a misleading impression as to Nordhaus' actual finding, which is that the best estimate of the SCC is less than half the amount highlighted by the RIA.

The RIA also cites Bressler (2021), which augmented the Nordhaus DICE model[2] with a mortality cost

[2] Dynamic Integrated model of Climate and the Economy.

function and thereby caused the SCC estimate for 2020 to jump considerably. Bressler's 2020 mortality-augmented estimate is US$258 in 2010 dollars which is inflated to US$312 in 2021 dollars. With a SCC estimate this large the RIA is able to claim that the policy "plausibly" passes a cost-benefit test. The DICE model already contains mortality costs from warming although they are assumed to be very small since on a global basis, cold is twenty times deadlier than heat (Gasparrini et al. 2015). Bressler justified adding an augmented mortality effect by speculating that the risks will change in the distant future due to warming. However the RIA fails to mention that Bressler's mortality function uncertainty estimates are so wide that the augmented effect is statistically insignificant across all warming rates,[3] and that the only non-zero net mortality effects are associated with a rapid emissions path called RCP8.5, which has already been shown to be unrealistic and exaggerated (Hausfather and Peters 2020, Pielke Jr. and Ritchie 2020, Burgess et al. 2021). Consequently Bressler's modification of the DICE analysis cannot be used as the basis for policy conclusions.

The RIA was also selective by only referring to published studies that examined model changes that raise the SCC estimate, while ignoring studies that yielded decreases. For example they did not cite Dayaratna et al. (2020), who incorporated updated evidence on carbon dioxide fertilization effects on agriculture into the FUND model and implemented updated empirically-based estimates of the parameter governing climate sensitivity to carbon dioxide levels. These changes sharply decreased the SCC, which fell to nearly zero at least through 2050.

The central view of the SCC in the economics profession is close to Nordhaus' estimate. A recent survey of over 440 climate economists (Drupp et al. 2022) revealed the median estimate of the 2020 value of the SCC is US$40 and US$70 in 2030, far below the costs of compliance with the new CFS.

Furthermore, the proper comparison for Cost-Benefit Analysis is between the cost per tonne of compliance and the SCC normalized by the marginal cost of public funds, not the SCC on its own. This has been understood by economists for decades (e.g. Sandmo 1975). For Canada the normalized value of the SCC is much lower than the SCC on its own because the marginal cost of public funds is high, due to the size of our tax burden (Dahbly and Ferede 2018).

For these reasons it is clear that the CFS imposes higher costs than the value of the environmental benefits it generates, and the policy fails a cost-benefit test.

7. Conclusions

The CFS as announced by the federal government will have long-lasting negative economic consequences. While it will reduce GHG emissions, likely by more than the federal government estimates, even on the assumption that generous credit creation will be permitted at a capped value of $275 per tonne, the policy will impose total economic costs of $1,277 per employed person in combined direct compliance costs and indirect income losses, and by 2030 the Canadian economy will be about 1.3 percent smaller than it otherwise would have been. The Government's Regulatory Impact Analysis ignores many important categories of cost, overstates the value of emission reductions and is wrong to assert that the policy passes a cost-benefit test. In reality it will reduce incomes, drive down the rate of return to investment in Canada and further dampen growth prospects. Since most of the ethanol used for compliance will be imported from the United States where its carbon intensity exceeds that

[3] For instance, Table 1 in Bressler's paper estimates a 90 percent confidence interval on the mortality effect for the year 2100 ranging from -0.000171 to 0.000678 which means the effect is statistically indistinguishable from zero.

of gasoline, the net international effect is likely to be an increase in GHG emissions. While the ethanol sector (and alternative fuels generally) will benefit from the rule, the economy overall will experience notable losses. Provinces that depend heavily on the oil and gas refining sector, such as New Brunswick and Newfoundland, are particularly at risk.

8. About the Author

Ross McKitrick holds a Ph.D. in economics from the University of British Columbia (1996) and is Professor of Economics at the University of Guelph in Guelph, Ontario. He is the author of Economic Analysis of Environmental Policy published by the University of Toronto Press in 2010. He has been actively studying climate change, climate policy and environmental economics since the mid-1990s. He built and published one of the first national-scale Computable General Equilibrium models for analysing the effect of carbon taxes on the Canadian economy in the 1990s. His academic research publications have appeared the *Journal of Environmental Economics and Management, The Canadian Journal of Economics, Canadian Public Policy, Journal of the Royal Statistical Society, Energy Economics, Journal of Forecasting, Climatic Change, Climate Change Economics, Proceedings of the National Academy of Science, Journal of Geophysical Research, Climate Dynamics, Environmental Economics and Policy Studies*, and many other highly-ranked outlets. Professor McKitrick has served as an expert reviewer for both Working Groups I and II of the Intergovernmental Panel on Climate Change for the past three Assessment Reports. He has also written policy analyses for the Fraser Institute (where he is a Senior Fellow), the CD Howe Institute, the University of Calgary School of Public Policy and other Canadian and international think tanks. Professor McKitrick appears frequently in Canadian and international media and is a regular contributor to the Financial Post comment page. His writings and other outputs are available at rossmckitrick.com.

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