Simulating alternate permit allocation schemes with MARKAL

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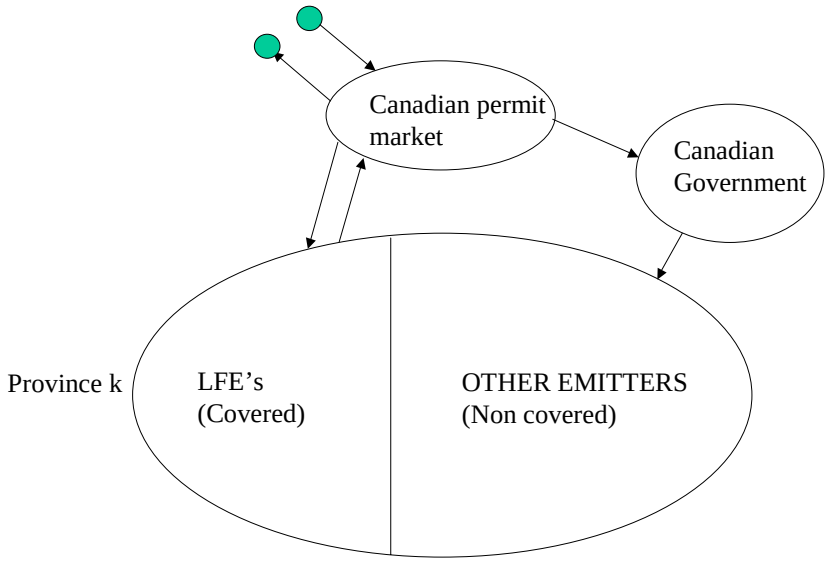
Kyoto scenarios for Canada

- Kyoto target in 2010: 1990 - 6% = 571 Mt
- BAU emissions in 2010: 1990 + 33% = 810 Mt
- Kyoto Gap: 239 Mt

- Scenario and Instruments:
  - US emits as in BAU, other Annex I countries implement Kyoto
  - International GHG permits are accessible at int'l price (2 alternative prices: $6 or $30/t CO2e).
  - Some sectors are covered by a cap-and-trade system, with gratis allocation of domestic permits. They have also access to international permits (buy or sell)
  - Other sectors (not under the cap-and-trade system), receive targeted measures. In addition, the government may buy permits on their behalf (but not sell)

I. Schematics of permit trading



MARKAL implementation of permit trading

- There are about 20 subsectors (covered and uncovered)
- For each subsector j, create one ENVGHj table (so as to obtain emissions by sector)
- Each ENV table also includes import and export variables for permit trading with the permit market
- The permit market also has two ENV tables, one for covered sectors' permits, the other for uncovered sectors' permits. The import and export variables may be bounded (e.g. for scenario with supplementarity constraint)

II. Two types of gratis allocation

- Lumped allocation: *xx* Mt allocated to each industry. The industry may buy additional permits from Int'l market, or sell some surplus permits

$$\mathbf{Alloc_k = Em_{k,\,1990} - 6\%}$$

- Output-based allocation: *yy* Mt/unit output of each industry, where *yy* is itself proportional to the historical GHG intensity of the industry

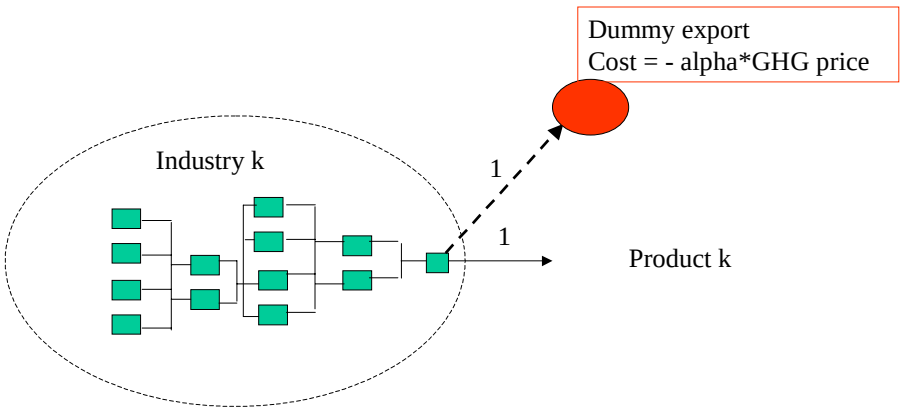
$$\mathbf{Alloc_k = GHG\_INT_{k,1990} * OUTPUT_{k,2010} * alpha}$$

Impact of gratis allocations in MARKAL

Rule: MARKAL prices are affected by GHG actions which affect marginal production costs

- A lumped gratis allocation of permits has no effect on prices (and thus no effect on equilibrium)
- An output based allocation **should** have an impact on prices, since the allocation is proportional to output, and thus enters the formation of marginal cost of production
  - MARKAL Modification: introduce a dummy export by each covered industry, with a negative cost representing the unit value of the gratis allocation

Modeling of Output based permit allocation



Four Cases for gratis permit allocations

- Case 2a: Domestic permits are allocated gratis in a lumped, grand-fathered, manner to each covered industry k

$$\mathbf{Alloc_k = Em_{k,\,1990} - 6\%}$$

- Case 2: Domestic permits are allocated gratis, proportionally to output, to each covered industry k

$$\mathbf{Alloc_k = GHG\_INT_{k,1990} * OUTPUT_{k,2010} * alpha}$$

  - Electricity and the rest of LFE's each has a total target absolute allocation, which must be reached
  - Therefore, there is need for iterating MARKAL runs so as to reach targets in each year, via above formula.

Four Cases for gratis permit allocations

- Case 2s: same as Case 2, plus supplementarity condition: permit purchases < 50% of Kyoto Gap
- Case 3: Domestic permits are allocated gratis, proportionally to output, to each covered industry **k**, each province **n**, according to a Triptych formula that selectively favors certain sectors and provinces

$$\mathbf{Alloc}_{k,n} = \mathbf{OUTPUT}_{k,n,2010} * \mathbf{alpha}_{n}$$

Case 2: allocation targets

- Electricity sector target = 89 Mt (2010, 2015, 2020)
- Other LFE's target = 164 Mt (2010, 2015, 2020)

Case 2: alpha's

	LFE-Industry			LFE-Electricity		
	2010	2015	2020	2010	2015	2020
Canada	50%	50%	50%	38%	38%	38%

5 iterations were needed to reach the 6 targets

Case 3 (triptych): allocation targets by province

	Alb	BC	Man	NB	NFL	NS	NWT	Nuna	Ont	PEI	Que	Sask	Yukon	Total
LFE electricity	28.5	7.9	3.5	3.4	4.2	5.9	0.3	0.7	20.7	0.1	13.5	5.4	0.3	**94.4**
LFE Industries	53.6	13.7	5.4	5.9	2.3	5.7	0.3	0.1	56.7	0.1	29.2	2.0	0.3	**175.3**
Non LFE	74.5	31.2	13.6	4.1	11.7	6.0	0.9	0.2	81.5	-0.4	47.9	27.8	0.5	**299.4**
TOTAL	**156.6**	**53.1**	**22.5**	**13.5**	**18.2**	**17.6**	**1.6**	**0.7**	**158.9**	**-0.2**	**90.6**	**35.1**	**1.0**	**571.7**

Case 3: alpha's by province

	LFE-Industry			LFE-Electricity		
	2010	2015	2020	2010	2015	2020
AL	42%	39%	39%	45%	43%	41%
BC	78%	74%	69%	31%	31%	29%
MB	97%	94%	92%	142%	126%	110%
NB	128%	119%	108%	41%	50%	43%
NF	119%	95%	80%	148%	36%	27%
NS	168%	162%	157%	65%	63%	71%
NUN	37%	34%	31%	110%	94%	82%
NWT	37%	14%	9%	62%	61%	55%
ON	81%	75%	70%	39%	33%	32%
PEI	136%	129%	123%	83%	83%	83%
QC	73%	69%	67%	49%	49%	49%
SAS	31%	31%	31%	40%	42%	38%
YU	33%	20%	15%	107%	104%	96%

15 iterations were needed to reach the 78 targets

Case 2 versus Case 3 allocations to covered sectors

CASE 2	LFE-Industry			LFE-Electricity		
HIC	2010	2015	2020	2010	2015	2020
AL	75.6	75.3	73.7	27.3	24.4	25.2
BC	9.9	10.3	10.2	11.1	9.6	9.8
MB	3.2	3.1	2.9	2.5	2.4	2.4
NB	2.2	2.1	2.1	1.9	1.5	1.7
NF	1.1	1.2	1.3	1.2	4.0	5.0
NS	1.8	1.7	1.7	3.9	2.7	3.1
NU	0.1	0.1	0.1	0.3	0.3	0.3
NWT	0.8	1.4	2.2	0.3	0.3	0.4
ON	40.5	40.3	40.5	20.1	20.5	19.1
PI	0.04	0.04	0.03	0.06	0.04	0.04
QC	22.8	23.2	23.1	17.0	20.3	21.0
SA	4.5	4.1	3.9	3.6	3.0	3.7
YU	0.6	0.9	1.1	0.2	0.2	0.2
TOTAL	**163.2**	**163.6**	**162.9**	**89.3**	**89.2**	**92.1**

CASE 3	LFE-Industry			LFE-Electricity		
	2010	2015	2020	2010	2015	2020
AL	56.4	56.5	56.4	29.8	29.9	29.8
BC	14.3	14.4	14.3	7.9	8.0	7.9
MB	5.6	5.6	5.6	3.7	3.3	3.2
NB	6.1	6.1	6.1	3.6	3.5	3.6
NF	2.4	2.4	2.4	4.2	4.2	4.2
NS	5.8	5.8	5.8	6.2	6.2	6.2
NU	0.1	0.1	0.1	0.7	0.6	0.6
NWT	0.4	0.4	0.4	0.4	0.4	0.3
ON	59.1	59.2	59.2	21.0	21.3	21.2
PI	0.11	0.11	0.10	0.10	0.01	0.02
QC	30.3	30.3	30.3	13.5	13.5	13.5
SA	2.4	2.4	2.4	5.7	5.6	5.6
YU	0.3	0.3	0.3	0.3	0.3	0.3
TOTAL	**183.2**	**183.4**	**183.3**	**97.1**	**96.8**	**96.6**

For Case 2, these are RESULTS **For Case 3, these are INPUTS**

Comments: - Industry as a whole is given more permits in Case 3 than in Case 2
- Some provinces/sectors are clearly targeted in Case 3
- Triptych is not definitive, will be fine tuned

Seven relevant combinations

	Case 2a	Case 2	Case 3	Case 2S
High CO2 Price				
Low CO2 Price				

Note: Supplementarity Condition is pertinent only for Low CO2 price

SOME ILLUSTRATIVE RESULTS

- Warning: these results are presented for illustrative purposes only. They do not reflect the views or policies of the Canadian Climate Change Implementation Process

Results: industrial outputs (% change wrt to BASE)

	High Carbon Price			Low carbon Price			
Industry	C2AHIC	C2-HIC	C3_HIC	C2-LOC	C2ALOC	C3_LOC	C2-SLOC
Electricity	-16%	1%	3%	0%	-4%	0%	13%
Chemicals	-35%	-1%	-7%	3%	-18%	4%	2%
Gas	0%	0%	0%	0%	0%	0%	0%
Iron & Steel	-18%	-4%	3%	1%	-6%	1%	1%
Mining	-20%	8%	7%	8%	-5%	8%	8%
Minerals	-31%	-31%	-25%	-28%	-31%	-13%	-27%
Conv Oil	-1%	-1%	-1%	0%	0%	0%	-1%
Oil Sands	-33%	0%	0%	0%	0%	0%	-16%
Other indus.	-10%	-6%	0%	0%	-4%	0%	-3%
P&P	-21%	4%	15%	6%	-7%	7%	-8%
Oil refining	-14%	-13%	-12%	-4%	-5%	-4%	-14%
Road transp	0%	0%	0%	0%	0%	0%	-1%
Smelting	-30%	-20%	-17%	0%	-6%	0%	-15%

Comment: Cases 2 and 3 largely succeed in avoiding output loss shown in Case 2a

Results: Costs (NPV, M CAD in 2000)

	C2AHIC	C2-HIC	C3_HIC	C2ALOC	C2-LOC	C3_LOC	C2-SLOC
INV+	-68,259	-4,255	-1,961	-10,760	3,358	5,261	-8,901
Net Fuel cost	23,637	-7,911	-3,307	-11,978	-10,459	-10,469	-6,295
Permit cost	-4,416	9,650	10,654	6,086	7,071	7,140	5,835
Output loss	60,158	19,570	12,506	15,581	-2,225	-3,842	14,786
Total = loss of surplus	**11,120**	**17,054**	**17,892**	**-1,071**	**-2,255**	**-1,910**	**5,425**

Comments: - Overall, Case 2a is the most efficient for North America, but not always for Canada (see C2_LOC, vs. C2A_LOC)
- However, Case 2 remarkably reduces industrial output losses
- Case 3 is quite close to Case 2, hence Triptych succeeds in re-suffling provincial burdens w/o disturbing overall Canadian costs.
- Supplementarity constraint (C2S_LOC) fairly expensive for Canada

Results: Int'l permits purchased (Mt in 2010)

	C2AHIC	C2-HIC	C3HIC	C2ALOC	C2-LOC	C3 LOC	C2SLOC
Gas Pipelines	0.3	2.0	1.6	0.8	3.5	2.7	2.6
Gas extraction excep	8.0	8.6	10.2	8.1	9.2	10.4	8.1
Oil Sands	16.5	5.5	15.3	37.1	12.0	21.8	9.7
Oil Refining	1.1	7.6	4.3	4.4	10.5	6.5	9.1
Chemicals	-10.0	-2.5	-6.7	-6.4	-1.7	-5.5	-2.6
Iron and Steel	-0.6	4.0	-0.4	1.4	4.8	-0.2	4.0
Minerals	-2.4	2.8	1.2	-2.4	3.1	1.5	2.7
Mining	-0.5	-4.0	-3.0	0.4	-3.3	-2.4	-3.9
Other Industries	0.9	10.5	3.4	5.3	13.8	5.8	12.4
Pulp and Paper	0.9	4.5	-1.2	4.8	7.6	2.2	5.6
Smelting	1.3	5.5	3.8	5.6	8.6	6.5	7.3
Electricity	-64.2	-36.7	-42.7	17.4	26.2	20.6	55.0
CH4-Upstream - Gas	6.9	6.9	9.7	7.6	7.6	10.4	6.9
Upstream oil	-1.7	0.6	3.3	3.0	3.0	5.7	-1.7
GHG-Commercial-Mt	2.5	0.7	3.5	4.5	4.5	7.5	-6.8
GHG-Residential-Mt	-9.1	-14.0	-10.4	-4.0	-5.3	-0.5	-25.5
GHG-Transport-Mt	40.0	40.0	56.0	42.4	42.4	58.4	32.0
Landfill GHG	-2.8	-2.8	-0.4	-2.8	-2.8	-0.4	-2.8
Other Emissions	8.6	8.6	8.9	10.8	10.8	11.1	8.6
TOTAL	**-4.1**	**47.8**	**56.2**	**137.9**	**154.5**	**162.1**	**120.8**

Results: GHG intensities (% change w.r.t. to BASE)

Industry	C2AHIC	C2-HIC	C3_HIC	C2ALOC	C2-LOC	C3_LOC	C2-SLOC
Electricity	-75%	-59%	-58%	-10%	-8%	-7%	1%
Chemicals	-6%	-7%	-11%	-5%	-5%	-7%	-3%
Gas	-11%	-12%	-12%	-10%	-10%	-10%	-11%
Iron & Steel	-1%	-3%	-2%	-1%	-1%	-1%	0%
Mining	0%	-9%	-10%	1%	-6%	-6%	-7%
Minerals	-1%	-1%	-2%	-1%	-1%	-1%	-1%
Conv Oil	-30%	-23%	-23%	-16%	-16%	-16%	-30%
Oil Sands	-11%	-10%	-10%	0%	0%	0%	5%
Other indus.	-9%	-8%	-8%	-1%	-2%	-2%	-1%
P&P	-11%	-22%	-24%	1%	-6%	-6%	-9%
Oil refining	-15%	-16%	-15%	-9%	-9%	-9%	-6%
Road transp	-9%	-9%	-9%	-8%	-8%	-8%	-13%
Smelting	-13%	-12%	-12%	1%	0%	1%	4%

Concluding Comments

- Various permit allocations may be modeled with MARKAL (lumped, output-based)
- Iterative approach required for output based allocations
- Output based allocations have a profound 'mitigating' effect on industrial output losses
- However: are free trade principles respected?