The effect of CO_2 pricing on conventional and non-conventional oil supply and demand

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Outline

Introduction

Green paradox

A carbon tax rising at the rate of interest would depress the pre-tax price of fuel by the amount of the tax (Sinn, 2008).

→ the post-tax price is unchanged

→ countries outside of an international agreement benefit from cheaper oil and increase consumption and emissions, climate change accelerates.

This depends on the carbon intensity of the backstop (Newbery, 2011), (van der Ploeg and Withagen, 2010).

Question

What is the effect of a CO_2 tax on fuel use on oil supply and demand?

Does a CO_2 tax depress the pre-tax price of oil? By how much?

This paper quantifies the potential consequences of a CO2 tax in the case of a CO2-intensive backstop (synthetic crude oil).

Methodology

Interaction between conventional oil and CO_2 intensive backstop (synthetic crude oil) under CO_2 pricing

Cost: The model takes into account: depletion, experience, social cost of CO_2.

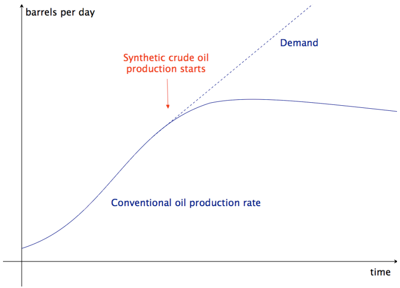
Price: Price net of extraction costs rises at the rate of interest (Hotelling, 1931):

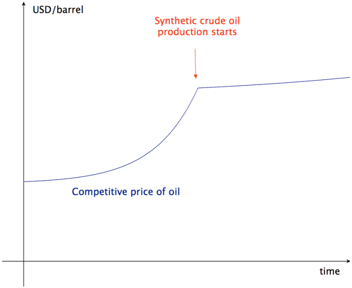
$$\lambda_t = \lambda_{t_0} \cdot e^{r \cdot (t - t_0)}$$

This rule is modified with stock effects (Heal, 1976), (Levhari & Liviatan, 1977). (The orders of magnitude are such that this does not change the results)

Subjective probability: a probability value or distribution determined by an individual's best estimate based on personal knowledge, expertise, and experience.

Model: Interaction between conventional and non-conventional oil





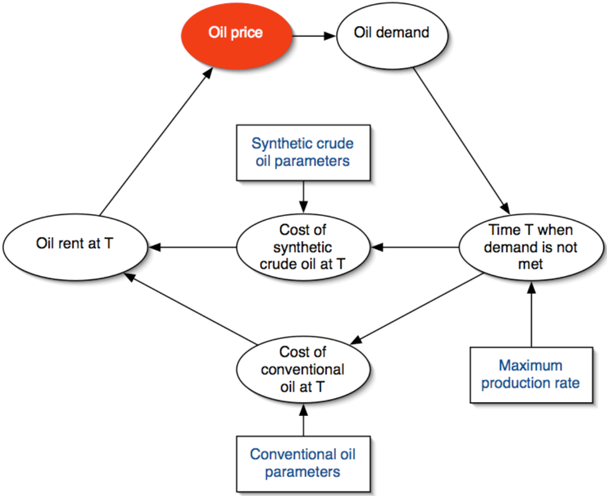
T = time when conventional oil production is unable to meet demand

Price of oil at T = initial cost of producing synthetic crude oil

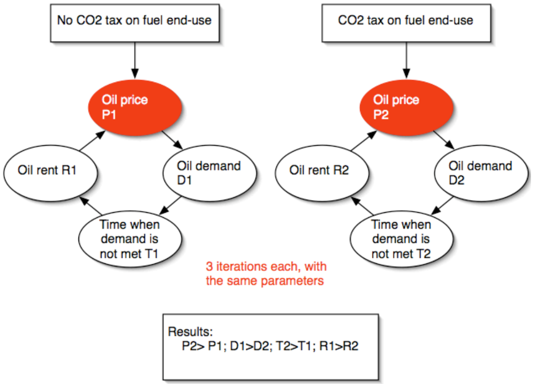
Model assumptions

- Synthetic crude oil is a substitute of conventional oil. It is treated as a backstop.
- At the beginning of the period, only conventional oil supplies the market. The price is determined by the Hotelling rule.
- Synthetic crude oil production starts when conventional oil production is unable to meet demand
- At that time T, the price of oil is set at the initial cost of producing synthetic crude oil
- The social cost of CO_2 is included in the calculations

Model structure



Model structure



CO_2 tax → higher price → lower demand → later T → lower rent → lower price → higher demand, etc.

As the model converges one effect takes over, leading to either higher or lower demand and extraction.

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Main model parameters

Cost of oil: function of cumulative production (experience, depletion)

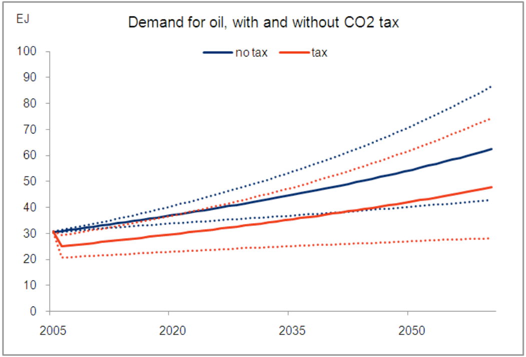
- *The social cost of CO_2*
  Initial cost of CO_2 (26, 100, 322) USD/tCO_2
  Social cost of CO_2 growth rate (2.0, 2.5, 3.0) % per year

- *Production and demand (conventional oil)*
  Maximum production rate (90, 101, 121) million barrels per day
  Price elasticity of demand (-0.6, -0.3, 0.0) no unit
  Income elasticity of demand (0.4, 0.9, 1.4) no unit

- *Cost of synthetic crude oil from Canadian in-situ bitumen*
  Initial cost of SCO (without CO_2) (41, 47, 52) USD/barrel
  Initial emissions (0.09, 0.16, 0.23) tCO_2/barrel SCO
  Cost of synthetic crude oil at T: (45, 100, 156) USD/barrel

- *Discounting*
  Consumption discount rate (0.9, 2.6, 4.2) % per year

Results: Oil demand



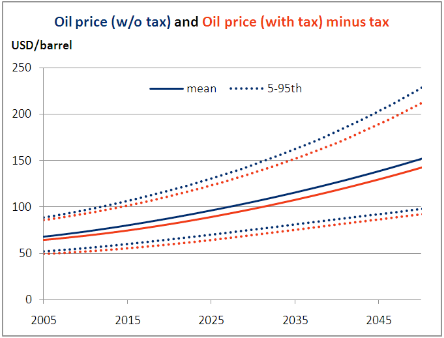
Full line: mean - Dotted lines: 5^{th} and 95^{th} percentiles

A tax on CO_2 from fuel use would reduce demand and extraction, despite the effect of the reduced oil rent.

Results: is there a Green paradox?

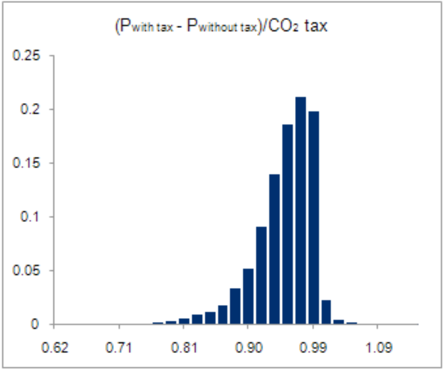
W/o an int'l agreement on CO_2: all countries see $P_{w/o\ tax}$

With an int'l agreement on CO_2: inside countries see $P_{post\ tax}$
outside countries see $P_{pre\ tax}$
$P_{pre\ tax} = P_{post\ tax}$ - CO_2 tax



$P_{pre\ tax}$ is not far below $P_{w/o\ tax}$: the effect seems rather limited

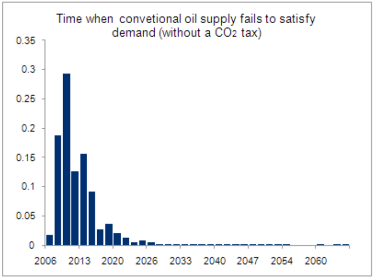
Results: CO_2 tax carried into the final oil price

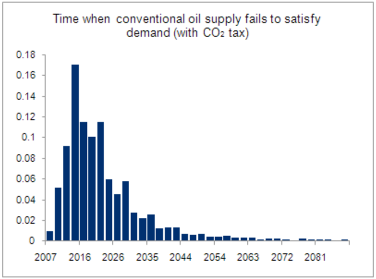


Between 87 and 99% of the CO_2 tax is carried into the oil price.

Countries that remain outside an international agreement would benefit from oil prices 1% to 13% lower than without the tax.

Results: Time T with and without a CO_2 tax





Without a CO_2 tax on fuel use
T between 2008 and 2021
(mean value: 2013)

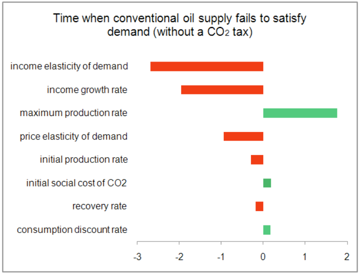
With a CO_2 tax on fuel use
T between 2011 and 2050
(mean value: 2024)

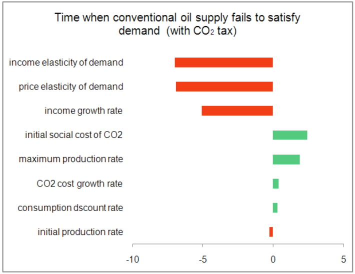
UKERC (2009): Peak oil between 2009 and 2031

Shell (2008): Easy oil and gas fails to match demand by 2015

Influences on T with and without a CO_2 tax

Influences show the change of T (years) when a parameter is increased by one standard deviation.





Large influence of the price elasticity of demand and the demand growth rate parameters, with and without a CO_2 tax on fuel use.

With a CO_2 tax:
· a reduction of 0.20 units of the income elasticity would delay T by 7 years.
· an increase of 0.12 unit of the price elasticity would delay T by 7 years.

Conclusion

- Between 87% and 99% of a CO_2 tax would be carried into the final oil price.
- Oil prices seen by countries outside of an international agreement would be 1 to 13% lower than without the tax.
- A CO_2 tax enforced worldwide would still reduce oil demand and production, hence CO_2 emissions from oil production and use.
- A CO_2 tax on fuel use would delay T by about 11 years (mean value)
- T is very sensitive to the price elasticity of demand and the demand growth rate: great potential of demand-side measures to smooth the transition to low-carbon liquid fuel alternatives.

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References

Devarajan, S., Fisher, A.C., 1981. Hotelling's "Economics of Exhaustible Resources": Fifty Years Later. *Journal of Economic Literature* 19 (1) 65-73.

Heal, G., 1976. The Relationship between Price and Extraction Cost for a Resource with a Backstop Technology. *The Bell Journal of Economics* 7 (2) 371-378.

Hotelling, H., 1931. The Economics of Exhaustible Resources. *The Journal of Political Economy* 39 (2) 137-175.

Levhari, D., Liviatan, N., 1977. Notes on Hotelling's Economics of Exhaustible Resources. *The Canadian Journal of Economics* 10 (2) 177-192.

Newbery, D., 2011. Oil shortages, climate change and collective action. *Phil. Trans. R. Soc. A* 369 1748-1761.

Shell, 2008. Shell Energy Scenarios to 2050.

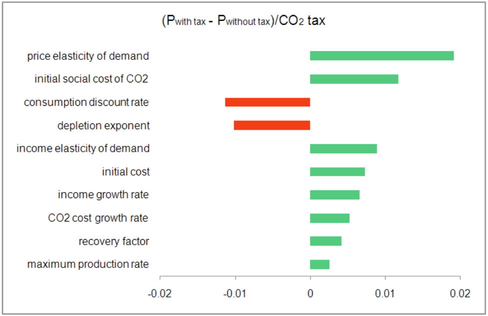
Sinn, H.W., 2008. Public policies against global warming. *International Tax and Public Finance* 15 (4) 360-394.

UKERC, 2009. Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production.

van der Ploeg, F., Withagen, C., 2010. Is there really a Green Paradox? CESIFO Working Paper 2963.

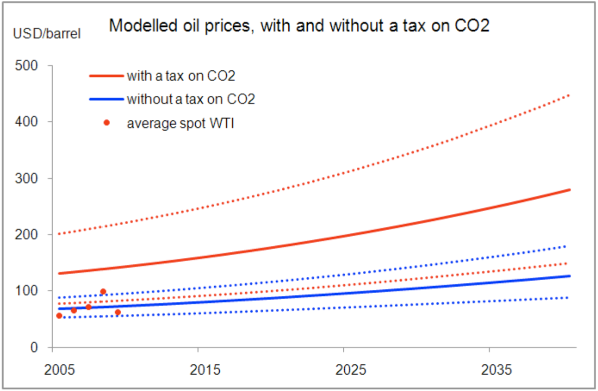
Appendix

Influences show the change of the CO_2 tax carried into the final oil price when a parameter is increased by one standard deviation.



Appendix

Oil price with ($P_{post\ tax}$) and without ($P_{w/o\ tax}$) a CO_2 tax.



Parameters' ranges (1/2)

Parameter	Minimum	Most likely	Maximum	Std dev.	Unit
CO_2 cost					
Initial CO_2 costs (C_{CO_2,t_0})	26	100	322	64	USD/tCO_2
CO_2 costs growth rate (α)	0.02	0.025	0.03	0.00	per year
Non-conventional oil initial cost					
Upgrading efficiency (Y_U)	0.78	0.82	0.86	0.02	no unit
Initial in-situ costs (C_{IS,t_0})	17.0	18.5	20.0	2.9	USD/barrel
Initial upgrading costs (C_{U,t_0})	22.0	25.0	27.0	1.0	USD/barrel
Non-conventional oil emissions					
In-situ initial emissions (e_{IS,t_0})	0.049	0.082	0.115	0.02	tCO_{2e}/barrel
Upgrading initial emissions (e_{U,t_0})	0.038	0.064	0.090	0.010	tCO_{2e}/barrel*
Conventional oil resources					
Resources in place (Q_{conv})	7.0E+12	7.5E+12	8.0E+12	2.0E+11	barrels
Recovery rate (R_{conv})	0.35	0.43	0.50	0.04	no unit
Conventional oil demand					
Income growth rate (g)	2.0	3.0	5.0	0.6	% per year
Initial demand (d_{t_0})	3.00E+10	3.05E+10	3.10E+10	2.04E+08	barrels/year
Price elasticity of demand (pe)	-0.6	-0.3	0	0.12	no unit
Income elasticity of demand (ie)	0.4	0.9	1.4	0.2	no unit
Conventional oil production					
Maximum production rate ($x_{conv,max}$)	3.32E+10	3.67E+10	4.02E+10	1.42E+09	barrels/year
Decline rate ($\alpha_{decline}$)	0.0	2.0	4.0	0.008	% per year
Initial cumulative production (X_{conv,t_0})	1.0E+12	1.0E+12	1.0E+12	0.0E+12	barrels

Parameters' ranges (2/2)

Conventional oil costs and learning					
Maximum depletion costs ($C_{max,conv}$)	86	104	121	7.14	USD/barrel
Depletion exponent (γ)	1.04	2.50	4.00	0.60	no unit
Initial costs (C_{conv,t_0})	34	39	44	2.04	USD/barrel
Learning rate (LR_{conv})	0.04	0.05	0.06	0.004	no unit
Minimum costs ($C_{conv,min}$)	10	20	30	4.1	USD/barrel
Conventional oil emissions					
Initial emissions (e_{conv,t_0})	0.022	0.026	0.029	0.0014	tCO_{2e}/barrel
Other					
Consumption discount rate (r)	0.9	2.6	4.2	0.7	%/year

* barrel SCO