Coase, Hotelling and Pigou : The Incidence of a Carbon Tax and CO_2 Emissions

Thomas Bourany
THE UNIVERSITY OF CHICAGO

Energy and Environmental Econ 1

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Introduction – Motivation

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- Does Hotelling's (dynamic) framework provide policy implications contrasting the standard (static) Pigouvian logic ?
- By how much oil extraction and cumulative emissions are reduced with a carbon tax ?
  - Logic : Impact of a tax causes an intertemporal redistribution, but only mild reduction of total oil production
- Approach :
  - Theoretical approach : simple framework with additional ingredients
  - Exploration of policies outcome : carbon tax and cap and trade
  - Quantitative analysis on the oil market

Approach and preview of the results

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    - Cap and trade : makes the resource constraint tighter, but permits include the same scarcity rent.
  - Quantitative analysis on the oil market
    - Dynamic price increase : $200/ ton carbon tax increases today's price from $60 to $110, but don't change the price in one century ($250)
    - Only price out 4% of producers, because of very steep supply curve.

Basic model

- Given a finite stock of fossil fuel S_0, its price is decomposed as

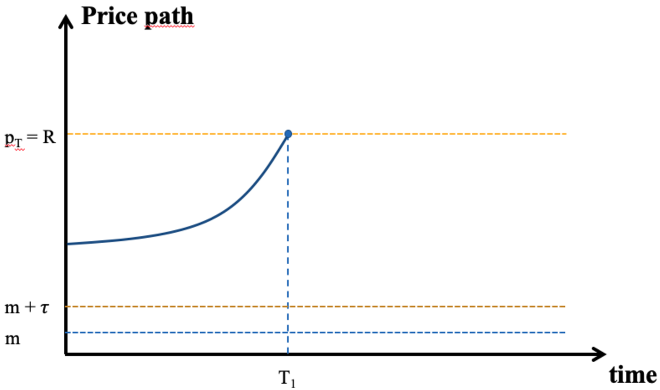
$$p_t = \underbrace{h_0 e^{rt}}_{\text{scarcity rent}} + \overbrace{m}^{\text{extraction cost}} + \underbrace{\tau}_{\text{carbon tax}}$$

- Alternative resources (say renewable) at price R so $p_t \leq R$
- Finding the time where fossil fuel is exhausted T and consume all resources before that :

$$\int_0^T D\left(p_t\right) dt = \int_0^T D\left(h_0 e^{rt} + m + \tau\right) dt = S_0$$

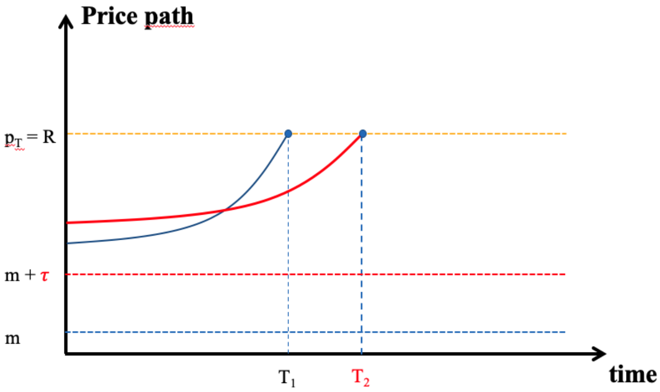
$$p_T = h_0 e^{rT} + m + \tau = R$$

Hotelling logic with low tax



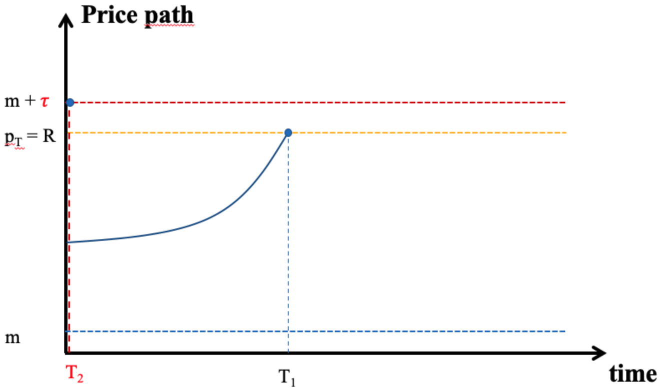
- Scarcity rent raises at rate r and extraction stops at time T when $\int_0^T D(p_t)dt = S_0$. Entire consumption reallocated to renewable production.

Hotelling logic with higher tax



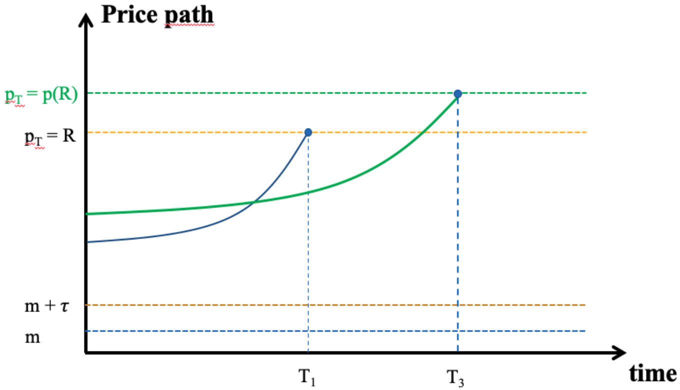
- Tax increase $\tau \uparrow$, scarcity rent drops $h_0 \downarrow$, so production lasts longer $T \uparrow$. However, cumulated extraction stay the same $\int_0^T D(p_t)dt = S_0$

Hotelling logic with too high tax



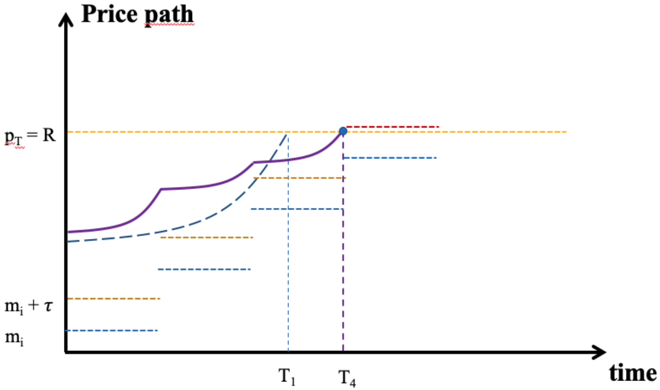
- If initial cost production of fossil fuels is too high $m + \tau > R$, we have $T = 0$ and $\int D(p) = 0$ and consumption substitute toward renewables.

Imperfect substitutability



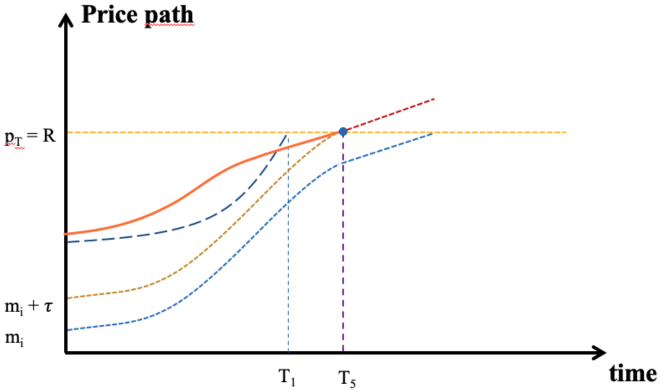
- Smooth transition, with $D(p, R) < D(p)$ and if $\widetilde{p} > R$, $D(\widetilde{p}, R) > D(p) = 0$.
  Existence of a choke price $\bar{p}(R)$ where $D(\bar{p}(R), R) = 0$.
  Production of fossil fuel until price rises at $p_T = \bar{p}(R)$

Multiple Grades of fossil fuel



- Different grades with rising $m_i < m_{i+1} < \cdots < m_I$: extraction of each of them between dates $T_i < T_{i+1}$. Price becomes : $p_{i,t} = m_i + \tau + h_{i,0}e^{rt}, T_{i-1} \leq t \leq T_i$ and total production equal each supply $\int_{T_{i-1}}^{T_i} D\left(p_{i,t}\right) dt = S_{i,0}$

Extraction dependent cost



- Stock effects : $m = c = g(z)$ with $z_t = \int_0^t E_s ds$ and price rise with the ODE $\frac{\dot{p}}{p} = r\left(\frac{p-c}{p}\right) + \frac{\dot{p_O}}{p_O}\frac{c}{p}$. There exists a thresholds $z^\star$, s.t. $g(z^\star) = R$ determining the time of reallocation toward renewable.

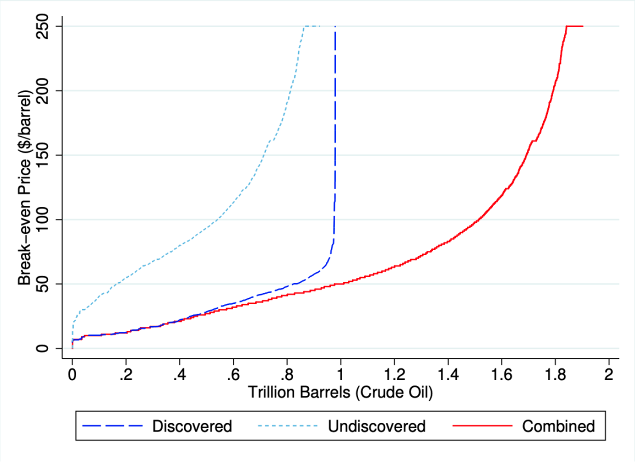
Policy : Cap and Trade

- Tighten the supply constraint $K_0 < S_0$.
- Emission permit replace oil price and the scarcity rent h_t is passed on these.
- Also equivalent effect by definition

Quantitative analysis : a Carbon tax for the Oil market

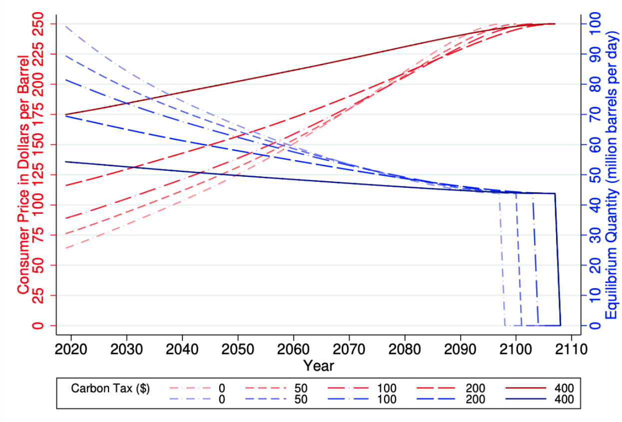
- Oil market with data
  - Inputs : marginal extraction cost for m
  - Price of the backstop technology for $R = 250$
  - Isoelastic Demand function $D(p) = \alpha p_t^\eta$
  - Discount rate $r = 0.03$
- Micro data at the oil field level from Rystad Energy
  - 15k and 27k undiscovered oil "assets"
  - 1 trillion barrels exploited (will last 30-ish years)
- Demand elasticity from Hamilton (2009)
  - Baseline $\eta = -0.6$ and range from -0.21 and -0.86
- Different scenarios from Carbon tax $\tau = 0, 50, 100, 200, 400$
  - A carbon tax of $\$1$ per CO_2 : surcharge of 0.84 cents/gallon and 0.35 cents/barrel of oil.

Oil market : steep supply curve



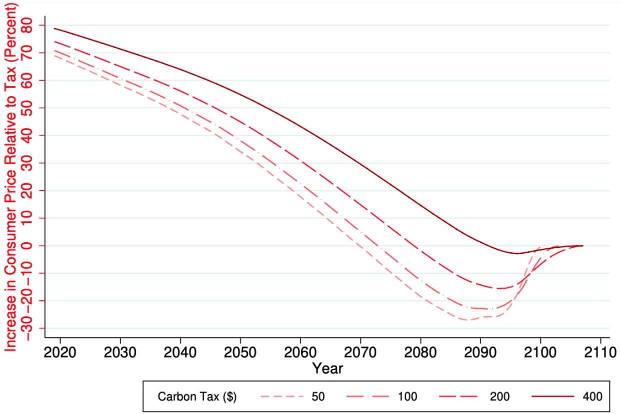
- Distribution of marginal costs *m* of Rystad oil fields

Path of prices with different taxes



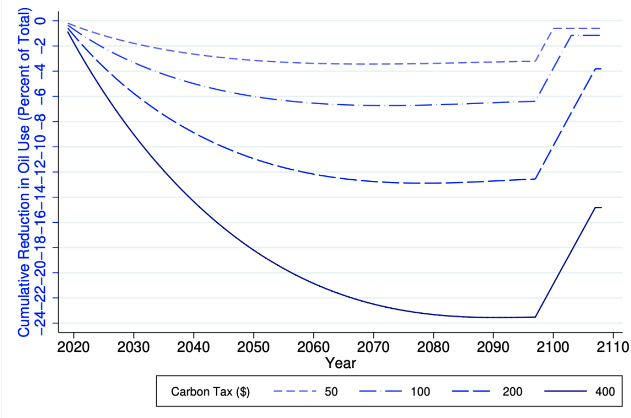
- Different paths of prices p_t and cumulative extractions $\int_0^t D(p_s)ds$:
  Carbon tax redistributes over time, and extend lifetime of oil by 10 years)

Share of taxes paid by consumers



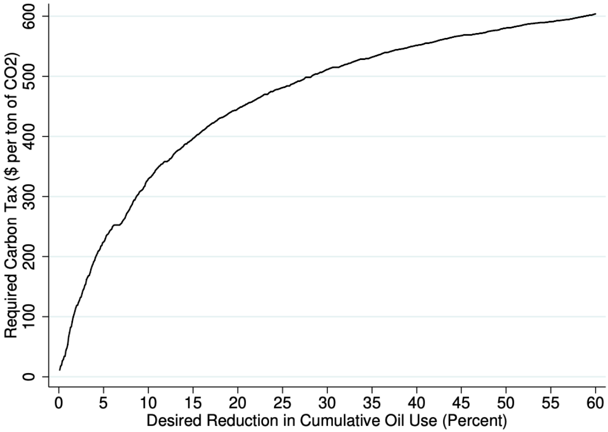
- Share of tax paid by consumers $\frac{p_t}{\tau}$ in percent.
  Become negative because oil prices fall below the level without tax.

Cumulative reduction in Oil use



- Cumulative saving fairly small but non linear effect :
  \$100 carbon tax ≈ 1.6% reduction in emissions, but from \$500 to \$600 reduce emissions by an additional 30%)

Required Carbon tax

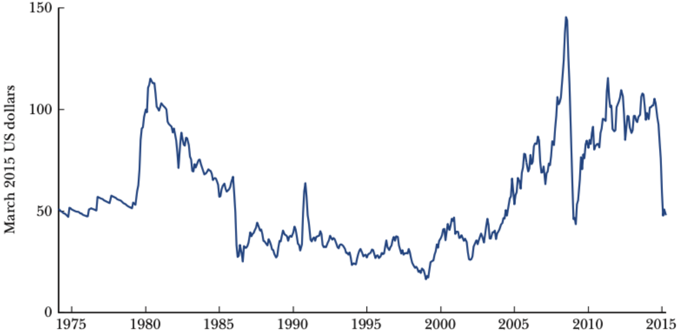


- Large non linearity due to flat portion of the supply curve for low prices and steep curve for higher prices

Discussion

- Clear model exposition and different mechanisms at play (including the very concrete quantitative exercise)
- Drawbacks :
  - Don't include imperfect substitutability and fixed cost of production in the quantitative analysis :
    - I expect the highest cost producers (shale oil ?) to be priced out earlier, especially with potential substitutability toward renewable
    - On the questions
  - Reduction in renewable energy $\Leftrightarrow$ carbon tax
    - I would have liked maybe a supply curve for the backstop technology : would adjustment costs matter for transition ? can carbon tax alleviate these costs ?
    - Similarly, would the conclusion change with a (forecastable) increase in technology of renewable energies ?
  - More on the dynamics on the policy side + welfare analysis : optimal policy ?

Price of oil



Source: US Energy Information Administration.
Note: The West Texas Intermediate (WTI) oil price series has been deflated with the seasonally adjusted US consumer price index for all urban consumers.

- Is Hotelling framework the most suited for this market ?
- Should one focus also on the coal market ?