ECN 275/375 Environmental and natural resource economics
Exercise set 13 – Eirik's suggested answers

Exercise 13.1 – Hotelling's rule

(a) State Hotelling's rule (i) mathematically (explain terms) and (ii) verbally, and (iii) explain its implications.

Answer: (i) $P_t = P_0 e^{\delta t}$, where P_t is the resource net price at time t, P_0 is the initial net resource price (at time 0), and δ is the interest (discount) rate.

(ii) Hotelling's rule states that to be indifferent between extracting a resource at time *t* compared to today ($t = 0$), the price must grow at the same rate as the interest rate, δ.

(iii) It is a rule of no arbitrage left. Hence, it is also a prescription for how much of the resource that should be extracted over time (resource extraction profile) to maximize resource rents.

(b) When one looks at prices for major resources like oil, they frequently deviate a lot from the "Hotelling price path". What are possible reasons for this? For each item you list, provide a short justification.

Answer: On the supply side: (i) New discoveries (see Fig. 15.8), which with the increased stock yields a new and lower starting price P_0 for a new Hotelling price path that lasts until the next discovery. (ii) Revised estimates of the size of reserves. Same impacts as (i). (iii) Technological innovations that lower extraction costs. Yields a similar price pattern as (i) after the innovation is known. Recall that the Hotelling price path is based on net prices (rents). (iv) Supply side shocks, which would affect short term market equilibria $\{P_t, R_t\}$,

On the demand side: (i) New backstop technologies, which lowers the choke price (K_T in Fig. 15.3). This changes the rents associated with a Hotelling price path and may make it profitable to adjust the starting price P_0 for a new Hotelling price path. May yield a similar price pattern as supply (i). (ii) Perceived lasting changes in demand, which could yield similar changes as (i) above. (iii) Demand side shocks, which would affect short term market equilibria $\{P_t, R_t\}$. Similar effects as supply (iv).

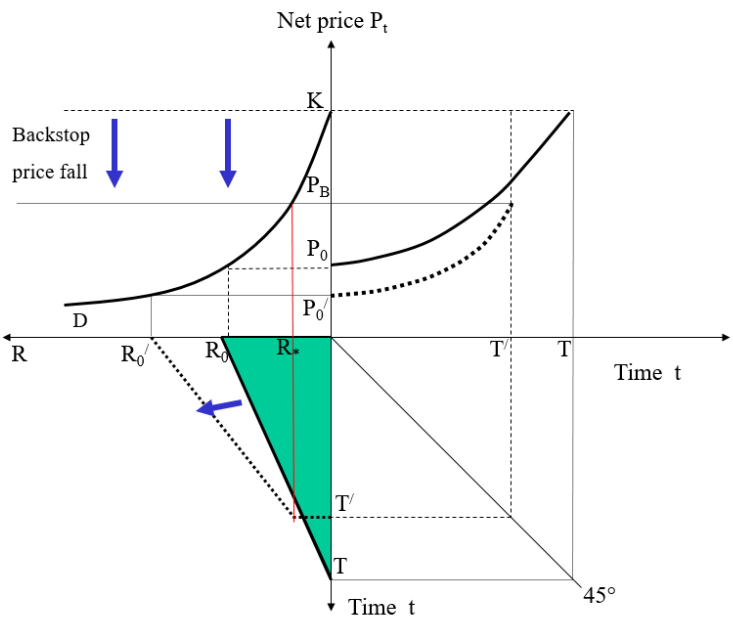
Exercise 13.2 – Analysis of resource extraction

Use Fig. 5.3 (the graph with four paneled graphs) as a starting point for the analysis.

(a) Test yourself on 1-2 of the scenarios presented in the chapter – do you get similar results as in the book.

(b) Consider a situation where the choke price (K) drops as in the figure to the right to a P_B (fig. 15.10 – left panel). Explain the changes that take in the figure.

Answer: A drop in the chokce price to P_B → the expected lifetime of the resource declines as illustrated from T to T'. Note that P_B is not a choke price as demand at P_B is not zero. This also implies that when the revised Hotelling price path

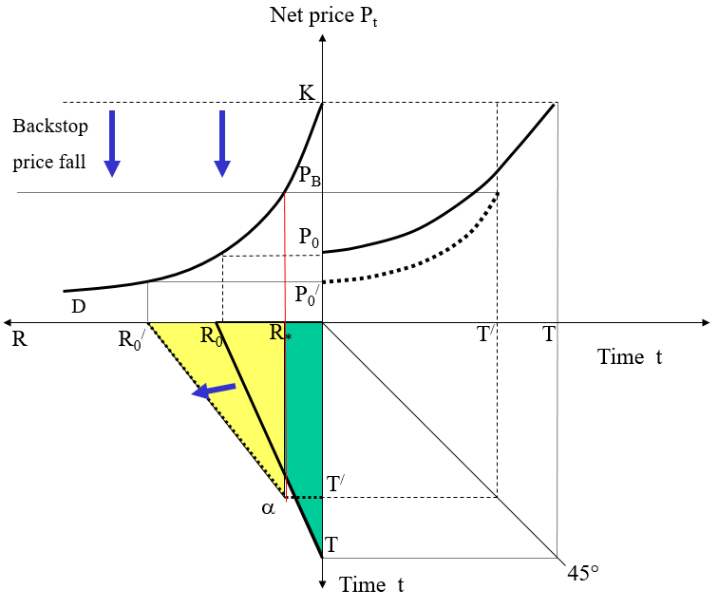


starting at a lower initial price, $P_0' < P_0$, meets the P_B line, demand is not zero.

Remark 1: If I have interpreted the panel to the right (fig.15.10.b) correctly, the yellow area equals the green area (fig. 15.10.a) on the previous page. That is, all of the resource is extracted.

The above reasoning hinges on the following – it is usually optimal to extract all of the resource.

Remark 2: Extraction of the entire resource is necessarilty not always the case (see the monopoly/cartel case fig. 15.4).



(c) Suppose extraction costs decrease over time, i.e., $\dot{c}<0$, for example due to technological progress ExpIain why decreasing extraction costs over time causes the new Hotelling price path to differ from the initial price path. Draw the new Hotelling price line.

Hint: Change notation, and give another symbol for the Hotelling price than P_t, for example θ_t.

Answer: Recall that the Hotelling price path describes rents (= market price less per unit extraction costs: $\theta_t = P_t - c_t$) over time). As $\dot{c}<0$, there is a wedge forming over time which makes the Hotelling price path deviate from the standard case with constant unit extraction costs.

Remark: The opposite case with increasing extraction costs over time ($\dot{c}>0$) is disussed in Perman *et al.* (sec 15.6.5, p. 526). I find the story behind increased extraction costs over time unconvincing with one exception: as resource stocks are depleted, extraction costs increase. BUT in that case, the narrative in the book is inconsistent with lower initial extraction, $R_t^{new} < T_t$ Hence, the reason for $\dot{c}>0$ cannot be this explanation.