

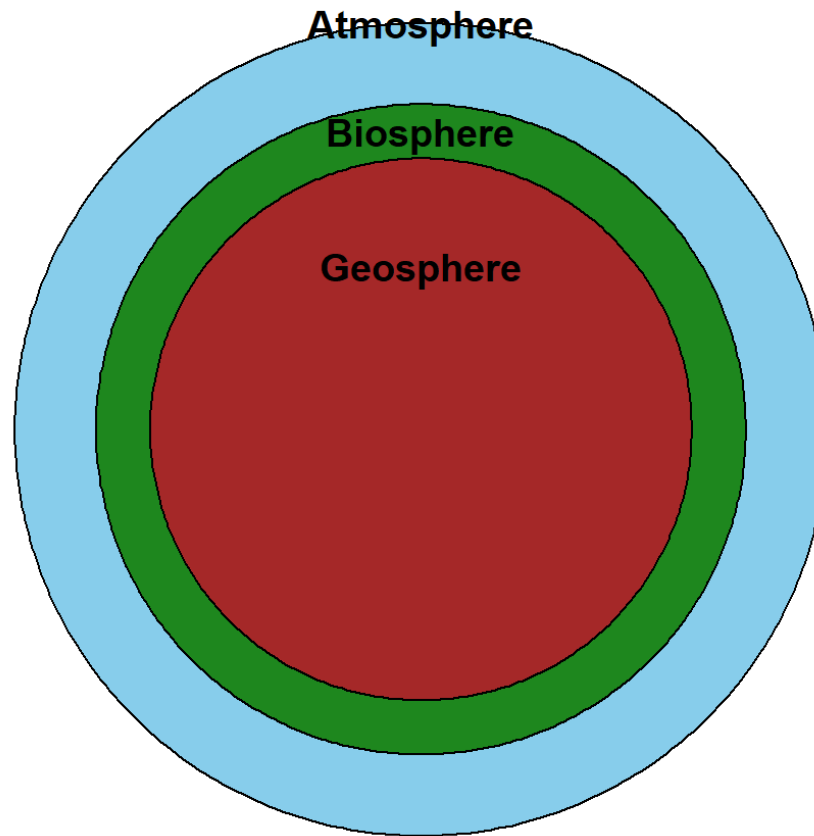
Introduction to Resource Economics



Justification for studying REE.

- Economics is about allocating resources efficiently.
- To our understanding “environment” is also a scarce resource.

What do we mean by “environment”

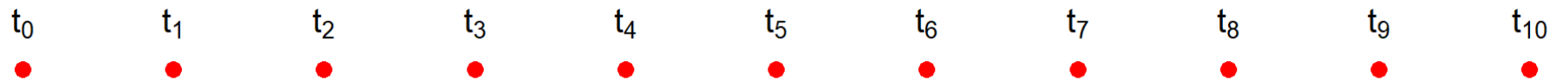


Definition of natural resource

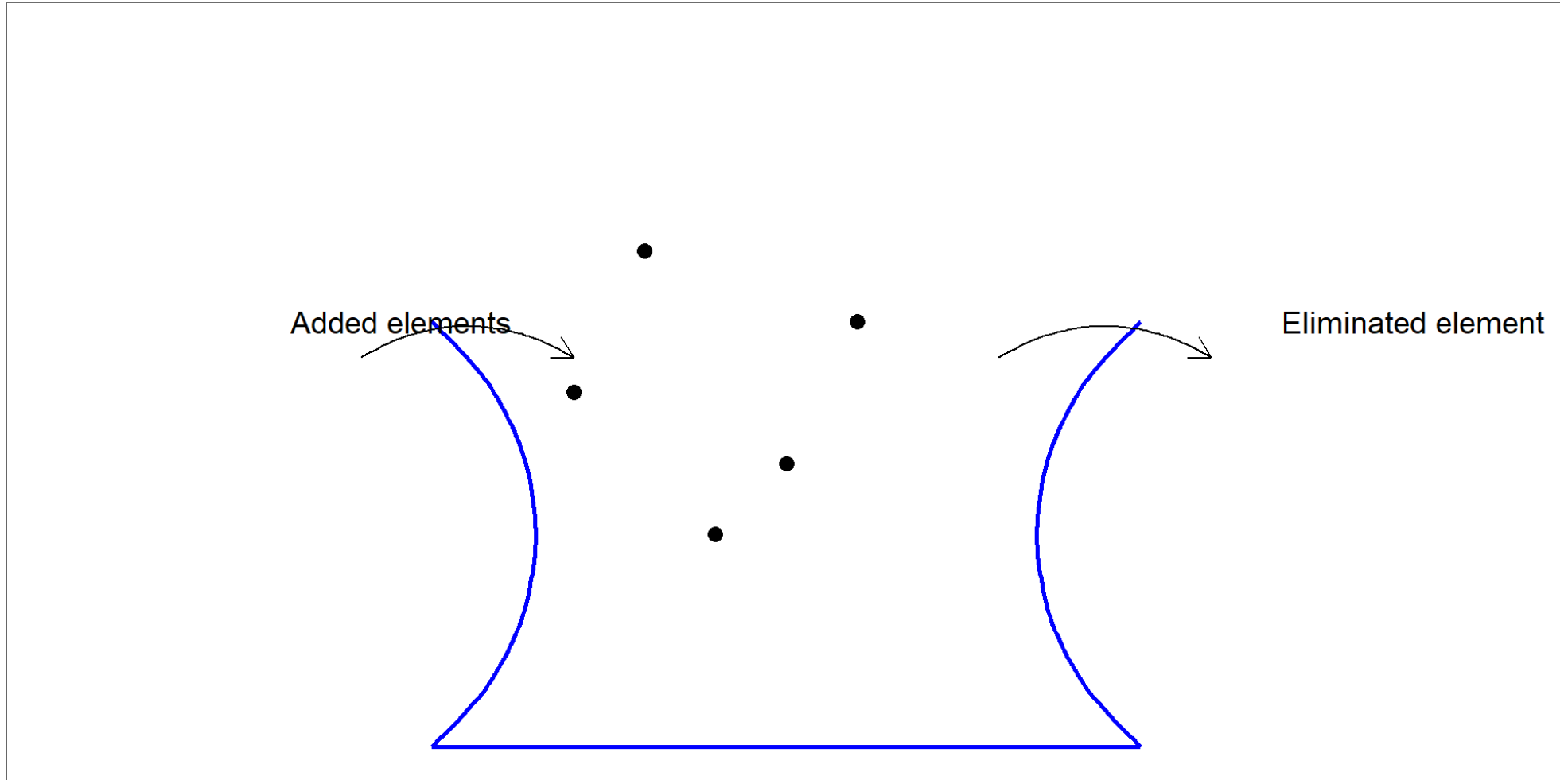
- Naturally occurring resources which can be made available for mankind under feasible **social, economic, and technological** framework.- Can we classify sea water as a natural resource?
- Two types:
 - Renewable Resources: Generating capacity - forests, fishery, solar energy, etc.
 - Non-renewable resources: No generating capacity over an economically feasible time horizon - coal, oil, etc.

- Do renewable resources also get exhausted?
 - Yes, if the rate of extraction $>$ the rate of growth.
- Are we exhausting our nonrenewable resources too rapidly or too slowly?
 - **Optimal rate of extraction:** The rate of extraction that maximises that inter-temporal benefits derived from such non-renewable resources.

- Example: 1000 kg of coal to be used over 10 years.



Natural resources as an open set

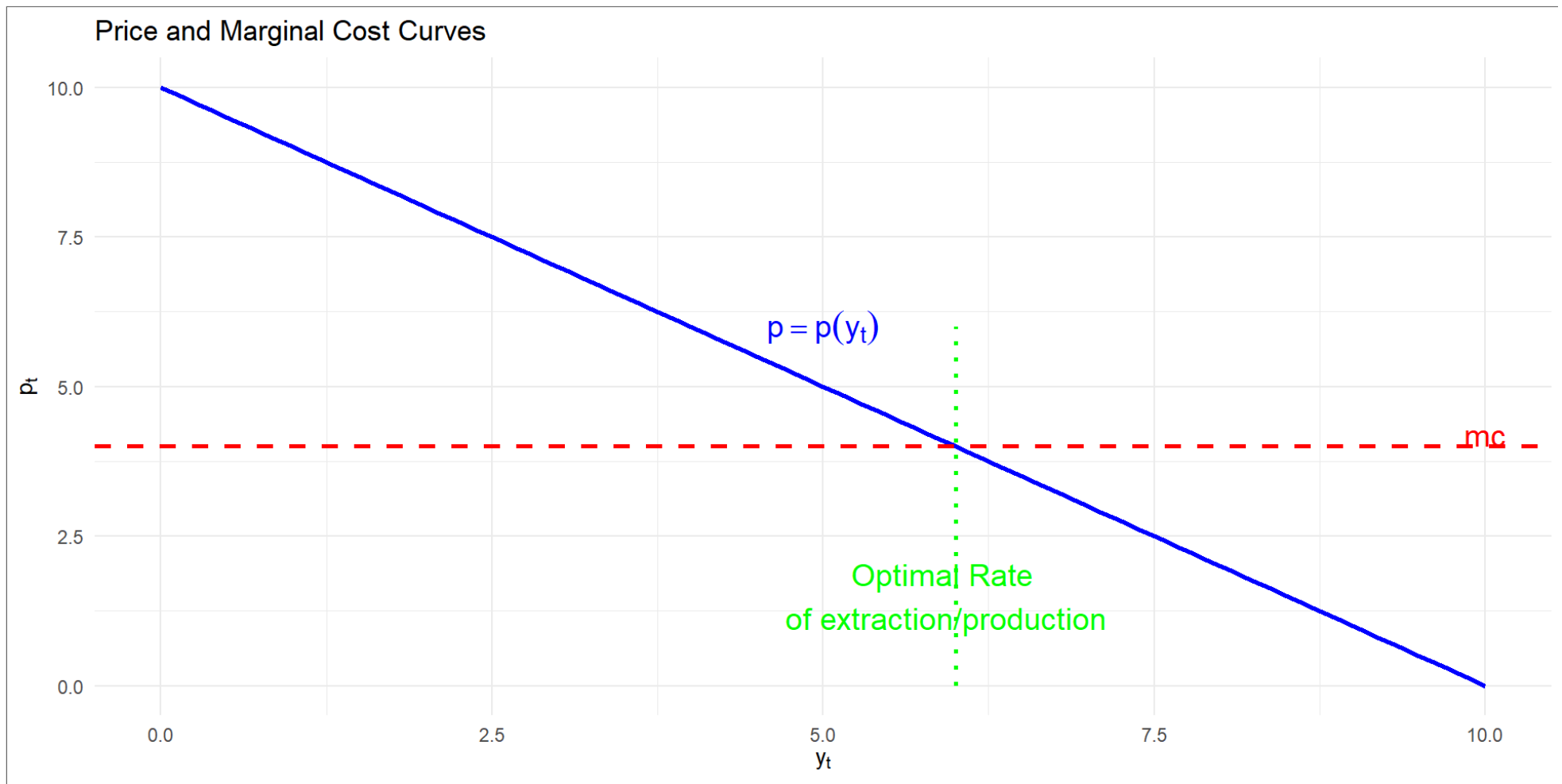


- Added: Uranium

- Eliminated: Extinct species of flora and fauna.

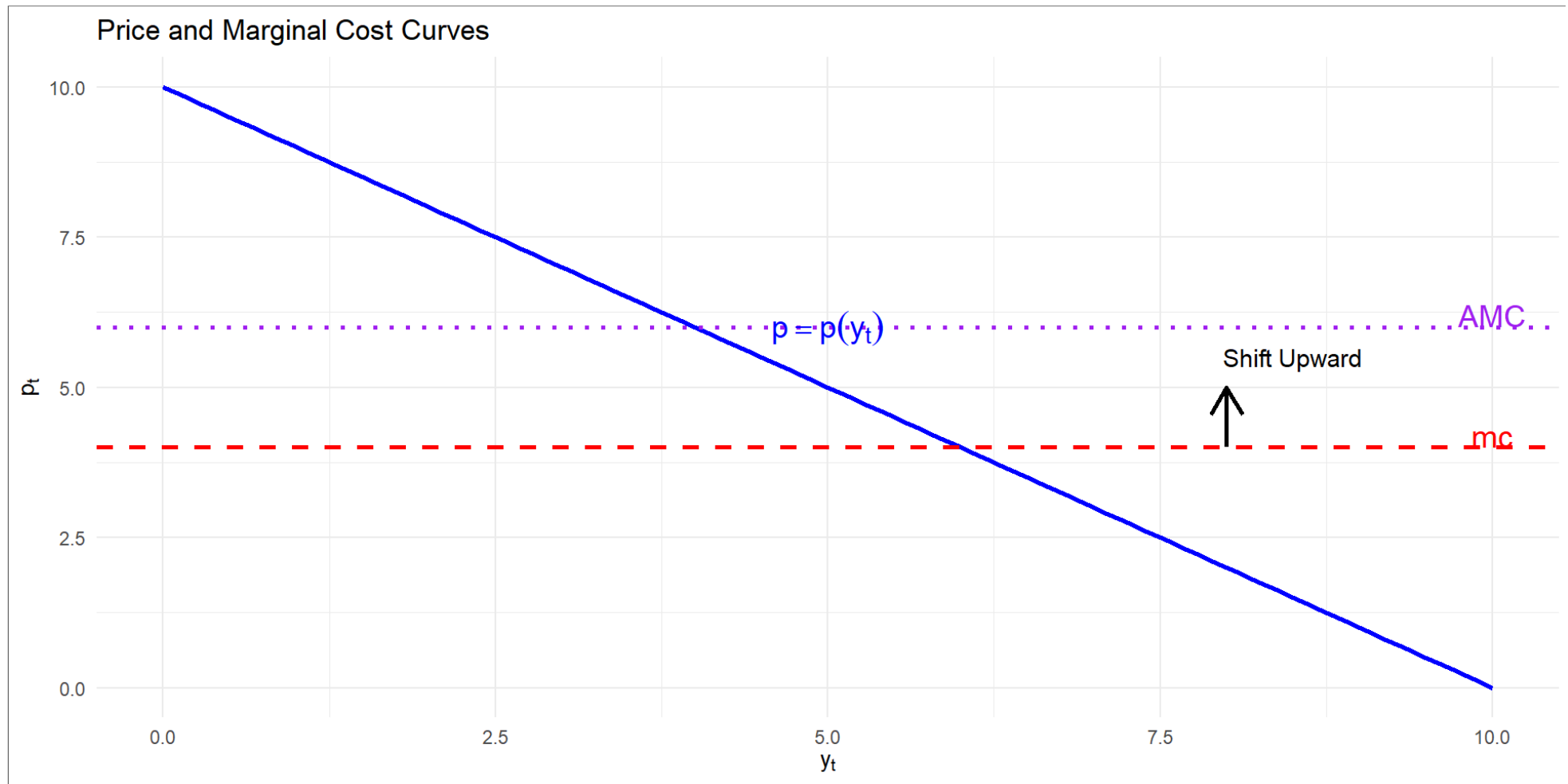
The optimal path

- What should be the optimal path (*if we join the points we get a path*) of extraction for a non-renewable resource (NRR)?
- For market goods
 - $p = mc$, p - price , mc - marginal cost



- Can we apply $p = mc$ for a NRR?
 - No, NRR are not easily replicable → today's production/extraction has some opportunity cost as the *same resource is not available for tomorrow*.

- In this situation we have an additional (opportunity) cost.



$p = mc_e + mc_u$ where; - mc_e : marginal cost of extraction - mc_u : marginal user cost

- Let us assume we have some amount of NRR which we are going to use in 2 periods;
 - $0 : 1^{st}$ period
 - $1 : \text{last period}$
 - p_0 : price at t_0
 - p_1 : price at t_1
- The resource owner has to decide **whether to use the resource today or keep it for tomorrow.**
 - $p_0 - mc_e$: Today's benefit
 - $p_1 - mc_e$: Tomorrow's benefit (if the resource is left for tomorrow)

- At t_0 , the owner has to convert tomorrow's benefit to today's benefit.
- This benefit is given by

$$\frac{p_1 - mc_e}{1 + r}$$

where r is the rate of interest or the discount rate.

- We are converting tomorrow's benefit to today's benefit by discounting *and the discount rate is r* .
- If $(p_0 - mc_e) > \frac{(p_1 - mc_e)}{1+r} \implies$ the resource owner should use it today. The RHS is also called the **discounted benefit**.
- If $(p_0 - mc_e) < \frac{(p_1 - mc_e)}{1+r} \implies$ the resource owner should use it tomorrow.
- If $(p_0 - mc_e) = \frac{(p_1 - mc_e)}{1+r} \implies$ the resource owner is indifferent between today's use and tomorrow's.

- $(p_0 - mc_e) = \frac{(p_1 - mc_e)}{1+r}$ is called the equilibrium condition.
- $p_0 = mc_e + \frac{(p_1 - mc_e)}{1+r}$
- Since the marginal cost pricing is not applicable for NRR, an additional opportunity cost was added to mc_e .
- This component of cost is known as the marginal user cost (muc) where

$$mu_c = \frac{(p_1 - mc_e)}{1+r}$$
- $mc_e + mu_c =$ augmented marginal cost
- If the mu_c is not added to the mc_e then the NRR may not be available for extraction tomorrow.

$$\begin{aligned}\therefore p_0 &= mc_e + \frac{(p_1 - mc_e)}{1 + r} \\ p_1 &= mc_e + (p_0 - mc_e)(1 + r) \\ p_2 &= mc_e + (p_0 - mc_e)(1 + r)^2\end{aligned}$$

In general we can write;

$$p_t = mc_e + (p_0 - mc_e)(1 + r)^t$$

- This is the **price path** or a **series of optimal prices** for optimal extraction at various points in time.
- This indicates that p_t is a **dynamic optimization** problem rather than a static optimization.

$$\begin{aligned}\because p_1 &= mc_e + (p_0 - mc_e)(1 + r) \\ (1 + r) &= \frac{(p_1 - mc_e)}{(p_0 - mc_e)} \\ r &= \frac{(p_1 - mc_e) - (p_0 - mc_e)}{(p_0 - mc_e)}\end{aligned}$$

- This $p - mc_e$ is also known as **Marginal Resource Rent**
 - where; p_1 : price of NRR
 mc_e : cost of extraction of one unit of NRR
 r : growth of marginal resource rent

- We can now say that *along the optimum path of marginal resource extraction, the marginal resource rent should grow at the rate of discount i.e. $r = \frac{(p_1 - mc_e) - (p_0 - mc_e)}{(p_0 - mc_e)}$.*
- In other words; *the most socially and economically profitable extraction path of a NRR is one along which marginal resource rent (MRR) must grow at the rate of interest or discount: **Hotelling's Rule (1931).***

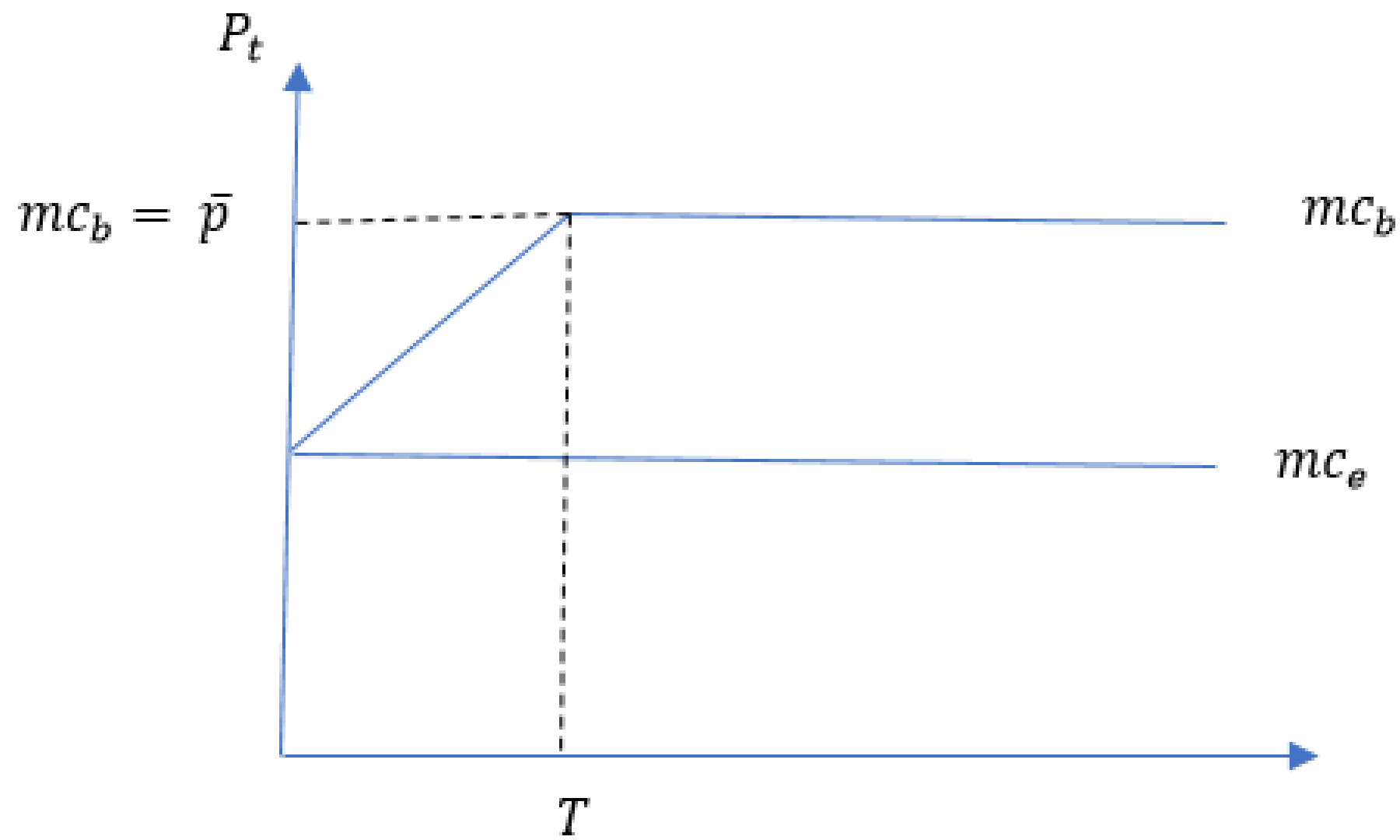
- Note that optimum extraction depends on two things p_1 : tomorrow's price and r : the discount or the interest rate
- p_1 is the expected price that the resource owner will use.
- r varies from person to person.
 - Bias for today then use heavy discount rate.

- We know that at equilibrium $p_t = mc_e + (p_0 - mc_e)(1 + r)^t$.
- Now as $t \rightarrow \infty, p_t \rightarrow \infty$
- Is there any such possibility? For instance, say after 200 years or more the price of petrol becomes infinite.

- The answer is **No**.
1. After 200 years or more we might find a substitute or an alternative resource or technology for petrol.
- **Backstop:** The availability of alternative (substitute) resource (technology) which makes the utilization of existing resource more efficient. E.g. solar energy.
2. The availability of a backstop will impact (reduce) the demand for petrol and hence put a cap on the upper limit of the price.

Role of Backstop in determining the optimal price path of an existing NRR

- Let's assume mc_b is the marginal cost of extraction of the backstop, and $mc_b > mc_e$
- We also assume that there is no user cost for the backstop (unlike the NRR) because we have just discovered the backstop and have it in adequate supply.



- **Shift date:** the time at which the NRR gets exhausted.
- Let us denote this as T .
- The price path of the existing NRR at time T is

$$p_T = mc_e + (p_0 - mc_e)(1 + r)^T \dots (1)$$

- Since there is no user cost for backstop,

$$p_T = mc_b \dots (2)$$

where, p_T : price of the backstop

From (1) and (2), we get

$$\begin{aligned} mc_b &= mc_e + (p_0 - mc_e)(1 + r)^T \\ p_0 - mc_e &= \frac{mc_b - mc_e}{(1 + r)^T} \\ \implies p_0 &= mc_e + \frac{mc_b - mc_e}{(1 + r)^{T-0}} \\ \implies p_1 &= mc_e + \frac{mc_b - mc_e}{(1 + r)^{T-1}} \\ &\vdots = \vdots \vdots \\ \implies p_t &= mc_e + \frac{mc_b - mc_e}{(1 + r)^{T-t}}; \forall t < T \end{aligned}$$

$$p_t = mc_e + \frac{mc_b - mc_e}{(1 + r)^{T-t}}; \forall t < T$$

- Insights:
 - Marginal costs of extraction for the backstop (mc_b) determines the price path of the existing resource at t .
 - If mc_b is high i.e. the possibility of harvesting the backstop is low, then p_t will also be high and viceversa.
 - mc_b sets an upper limit on the price of an existing resource at time period t .