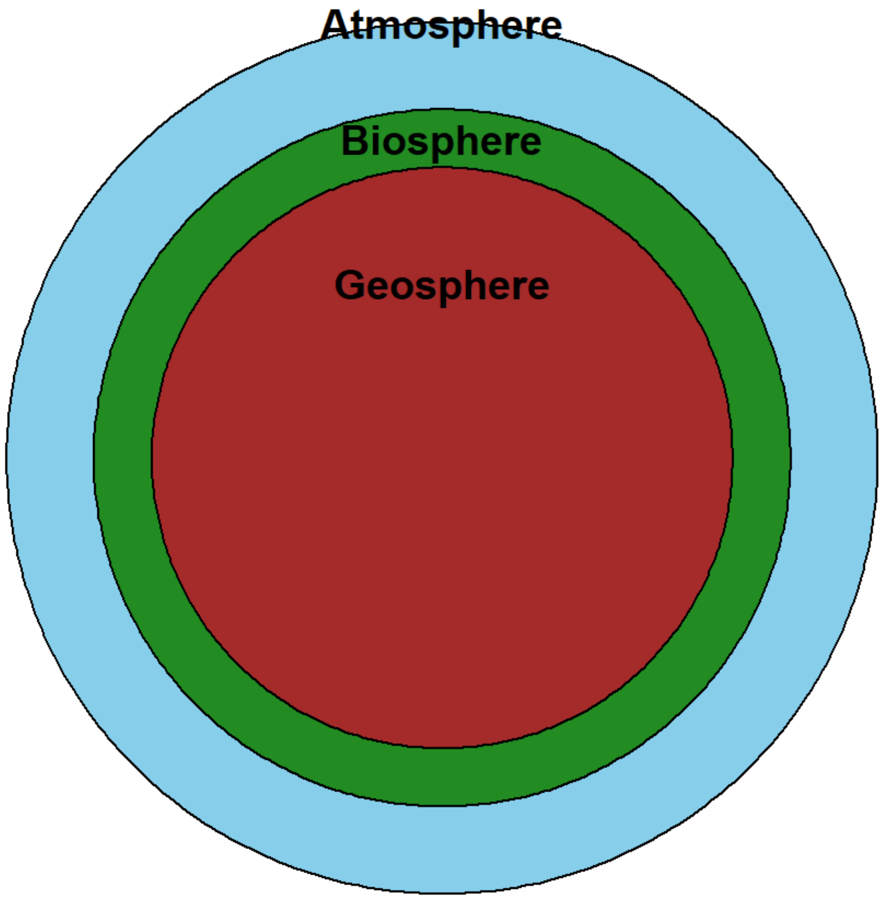
Introduction to Resource Economics

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”

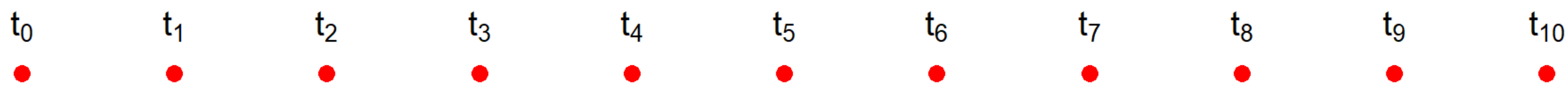


Definition of natural resource

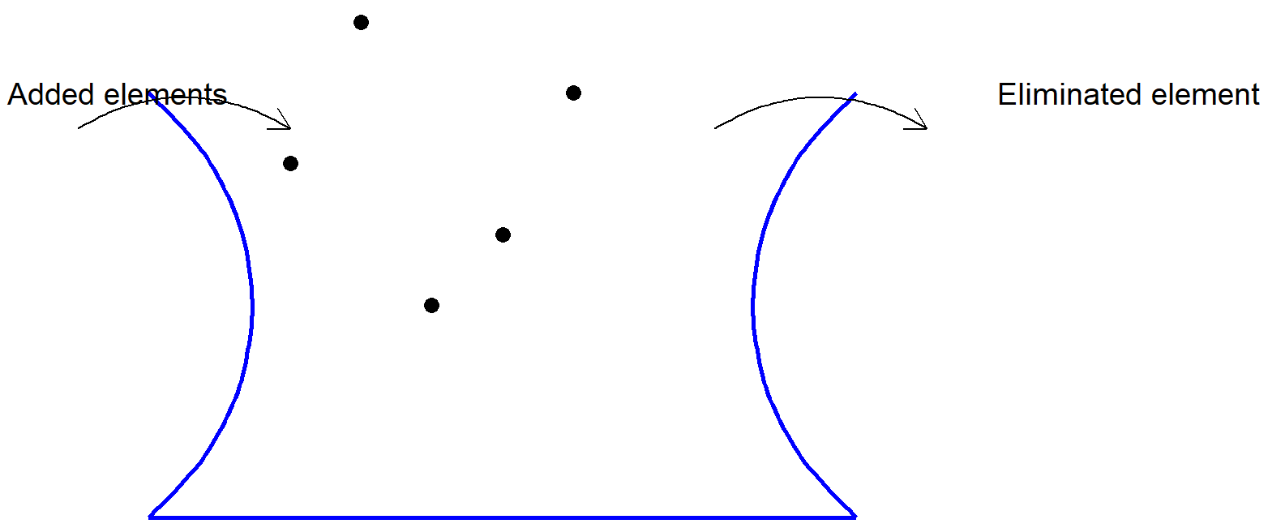
- Naturally occurring resources which can be made available for mankind under feasible **social**, **economic**, and **technological** framework.- Can we classify sea water as a natural resource?
- Two types:
  - Renewable Resources: Generating capacity - forests, fishery, solar energy, etc.
  - Non-renewable 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.



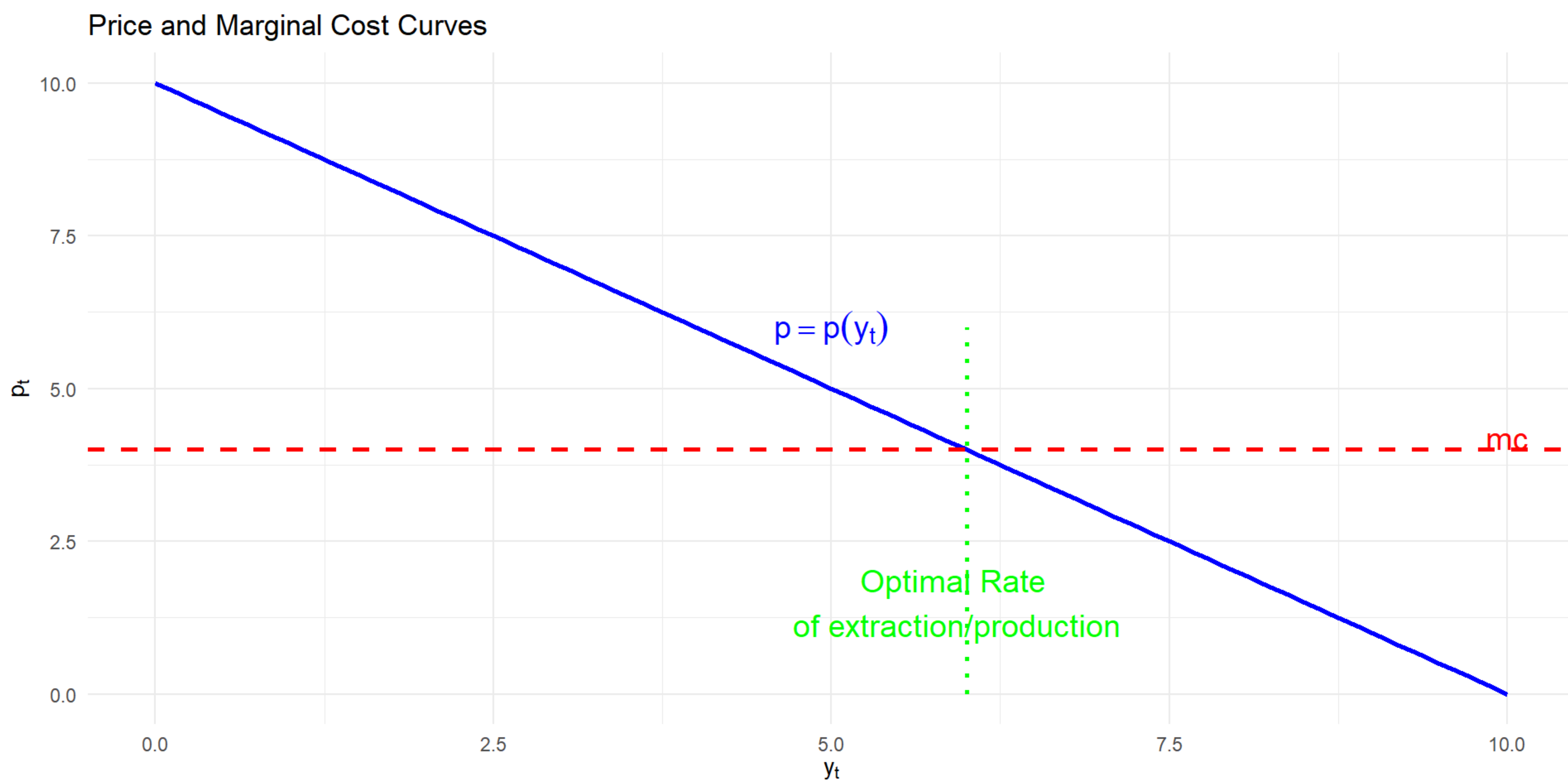
Natural resources as an open set



- Added: Uranium
- Eliminated: Extinct species of flora and fauna.

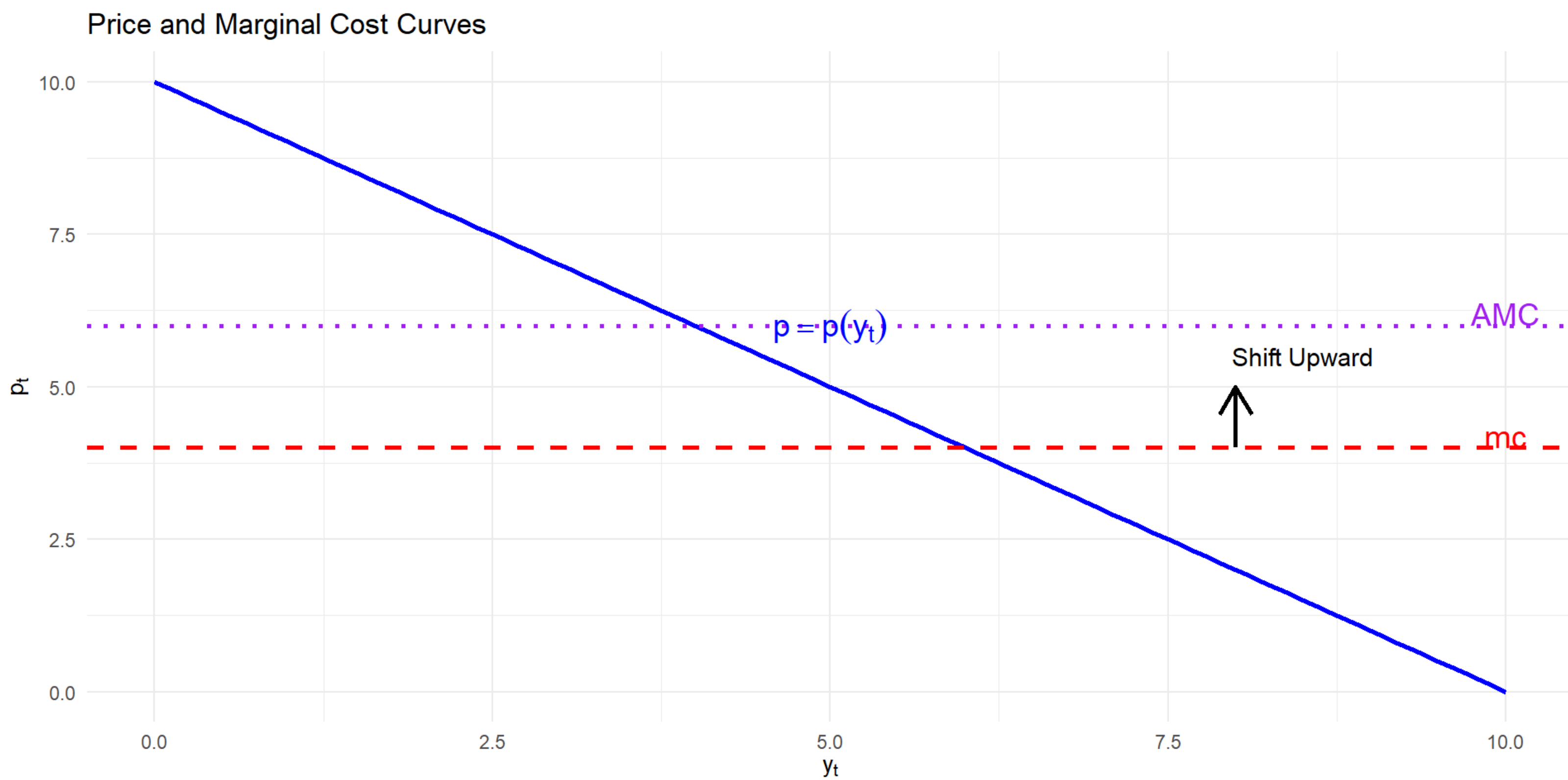
The optimal path

- 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


Price and Marginal Cost Curves
10.0
7.5
5.0
2.5
0.0
p_t
0.0
2.5
5.0
7.5
10.0
y_t
$p = p(y_t)$
mc
Optimal Rate
of extraction/production

- Can we apply `p = mc` for a NRR?
  - No, NRR are not easily replicable $\rightarrow$ 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.



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

- Let us assume we have some amount of NRR which we are going to use in 2 periods; $0 : 1^{st}\text{period}$

  $1 : \text{last period}$

  $p_0 \; : \text{price at } t_0$

  $p_1 \; : \text{price at } t_1$

- 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.

Why Do We Discount?

- Imagine you are given a choice:
  - Receive ₹100 today.
  - Receive ₹100 one year from now.
- Most people would prefer ₹100 today. Why? Because money today is worth more than the same amount in the future. This is due to:
  - Opportunity cost: You could invest the money today and earn interest
  - Inflation: The value of money tends to decrease over time.
  - Uncertainty: The future is uncertain; you may not receive the promised amount.
- To account for this, we use discounting, which adjusts future values to their present worth.

One-Period Discounting

In one-period discounting, we find the **present value (PV)** of a future amount by dividing by $(1+r)$.

$$PV = \frac{V_1}{(1+r)}$$

where:

- V_1 = future value received in one period,
- r = discount rate.

Example: Timber Harvesting

Suppose a forest owner expects **₹ 1000 next year**, and the discount rate is **5%**.

The present value today is:

$$PV = \frac{1000}{(1.05)} = 952.38$$

So, **₹ 1000 next year** is worth **₹ 952.38 today**.

Interpretation in Resource Economics

- If $PV >$ current timber price → **Wait to harvest next year**.
- If $PV <$ current timber price → **Harvest now**.

Higher discount rates **decrease** the present value of future benefits, **incentivizing earlier resource extraction**.

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

$$
\begin{aligned}
\because p_0 &= mc_e + \frac{(p_1 - mc_e)}{1+r} \\
p_1 &= mc_e + (p_0 - mc_e)(1+r) \\
p_2 &= mc_e + (p_0 - mc_e)(1+r)^2 \\
\text{In general we can write;} \\
p_t &= mc_e + (p_0 - mc_e)(1+r)^t
\end{aligned}
$$

- 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 $t \to \infty, p_t \to \infty$
- Is there any such possibility? For instance, say after 200 years or more the price of petrol becomes infinite.

- The answer is **No**.

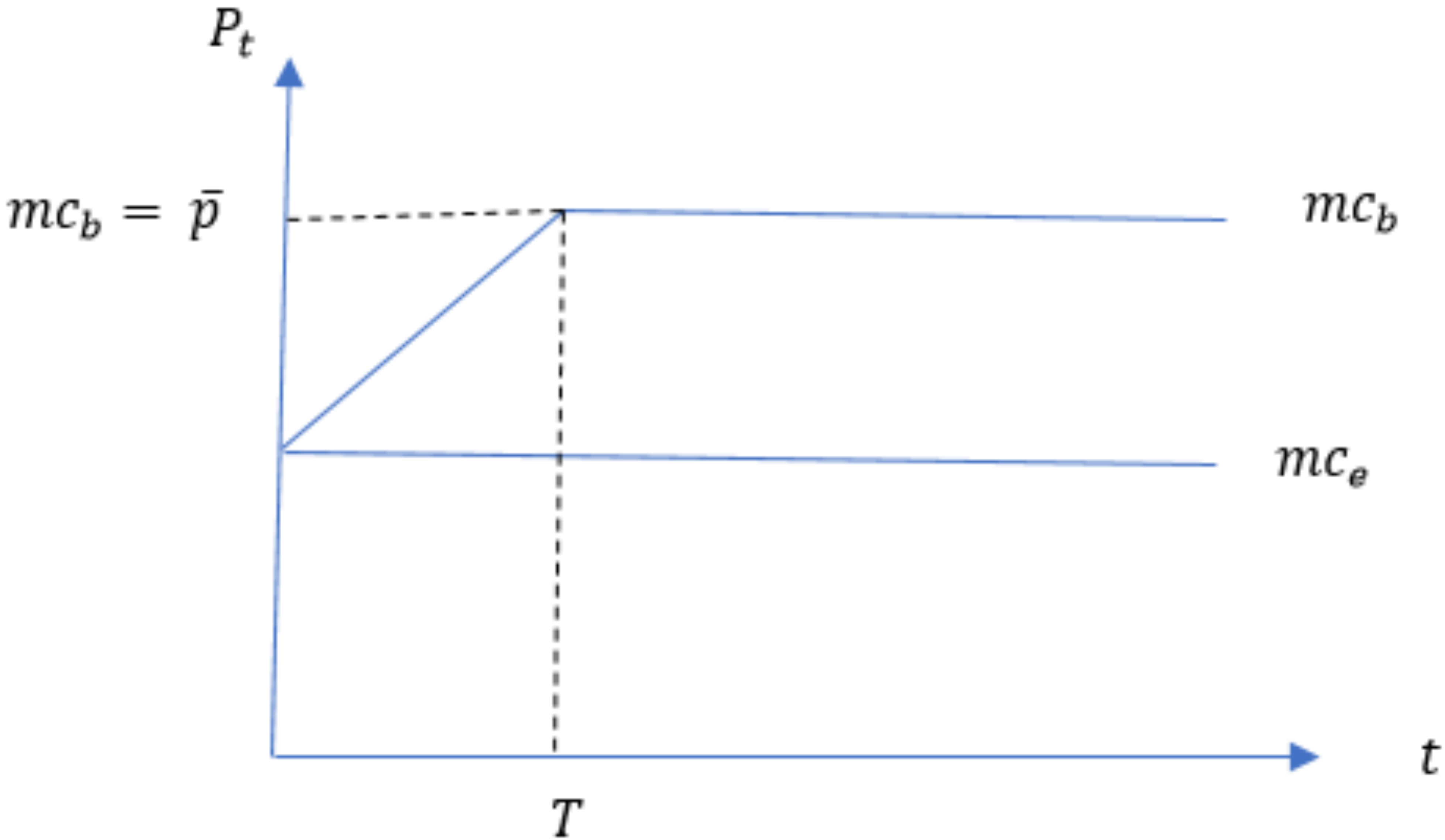
1. After 200 years or more we might find a substitute or an alternative resource or technology for petrol.

- **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.


P_t
$mc_b = \bar{p}$
mc_b
mc_e
t
T

- **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

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

- Since there is no user cost for backstop,

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

where,

p_T: price of the backstop

From (1) and (2), we get

$$\implies mc_b = mc_e + (p_0 - mc_e)(1+r)^T$$
$$\implies p_0 - mc_e = \frac{mc_b - mc_e}{(1+r)^T}$$
$$\implies p_0 = mc_e + \frac{mc_b - mc_e}{(1+r)^{T-0}}$$

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

p_t is the price of the existing resource at time t in the presence of a backstop.

Insights

1. Marginal cost of extraction for the backstop mc_b determines the price path of the existing resource at t.
2. If mc_b is high i.e. the probability of harvesting a backstop is low, then p_t will also be high and vice-versa.
3. mc_b sets an upper limit on the price of the existing resource at time t.

Sample Questions:

1. What defines a natural resource, and how do renewable and non-renewable resources differ?
2. Explain why even renewable resources can become exhausted. Provide an example.
3. What is the significance of Hotelling's Rule in resource extraction economics?
4. How does the concept of "marginal user cost" impact the pricing of non-renewable resources?
5. A resource owner has 1000 kg of coal to use over 10 years. What factors would influence their extraction strategy?

6. How does the discount rate affect a resource owner's decision to extract a resource today versus tomorrow?
7. What role does a "backstop" play in determining the optimal extraction path of a non-renewable resource?
8. Why can't the price of a non-renewable resource like petrol increase indefinitely?
9. Compare and contrast the economic considerations for extracting renewable versus non-renewable resources.
10. How might technological innovations impact resource extraction strategies?