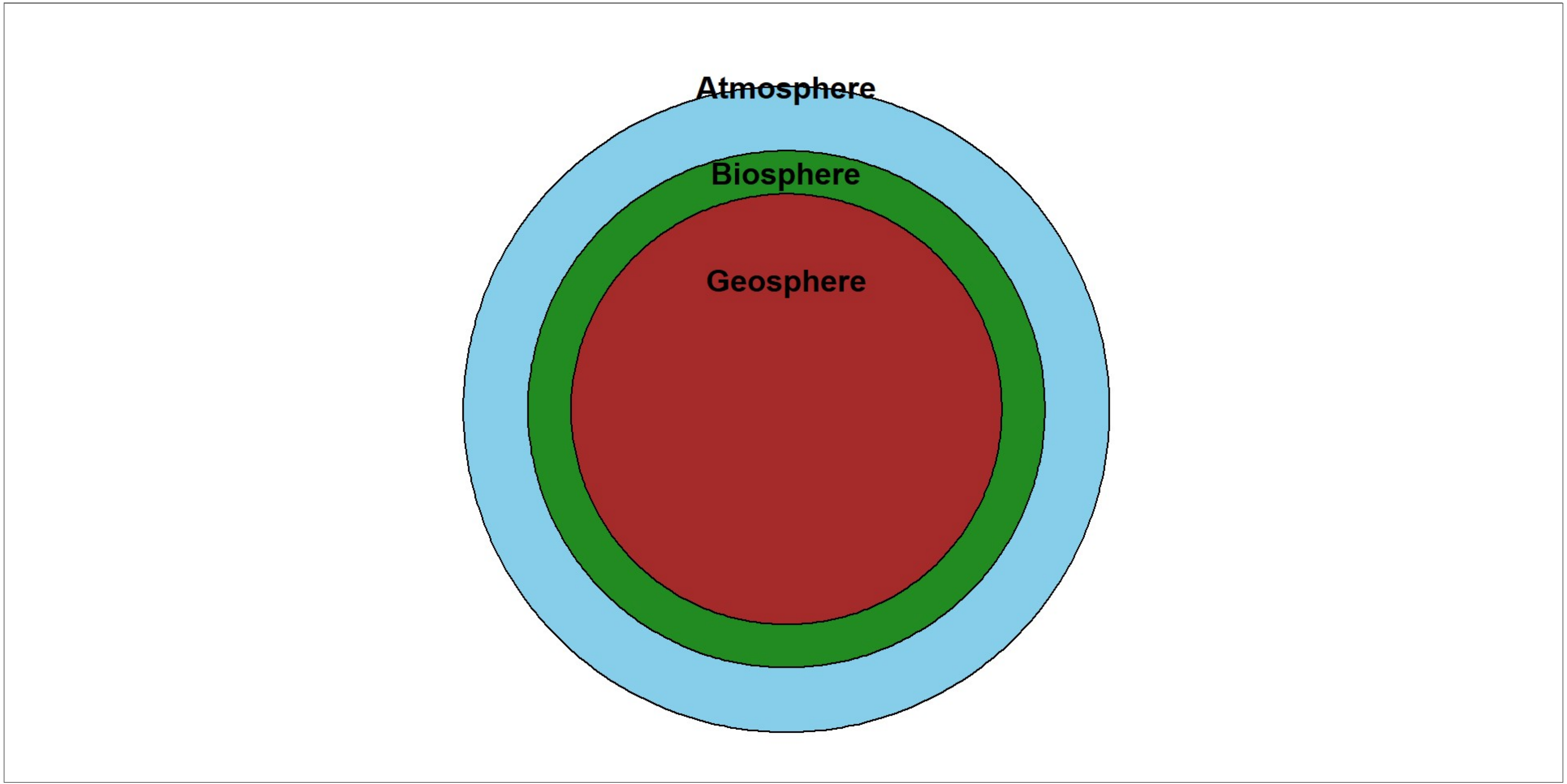
Resource and Environmental Economics

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”

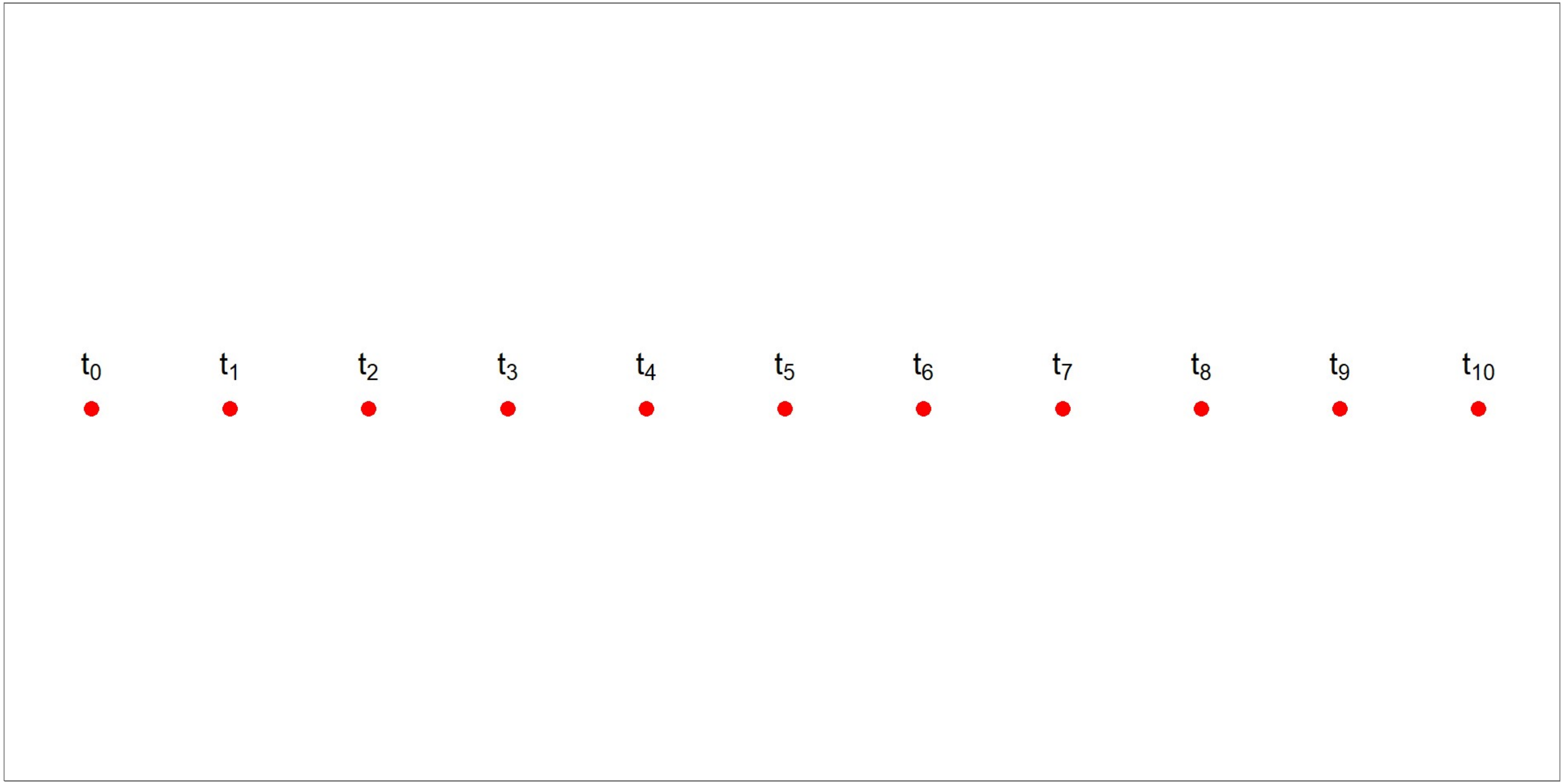


Definition of natural resource

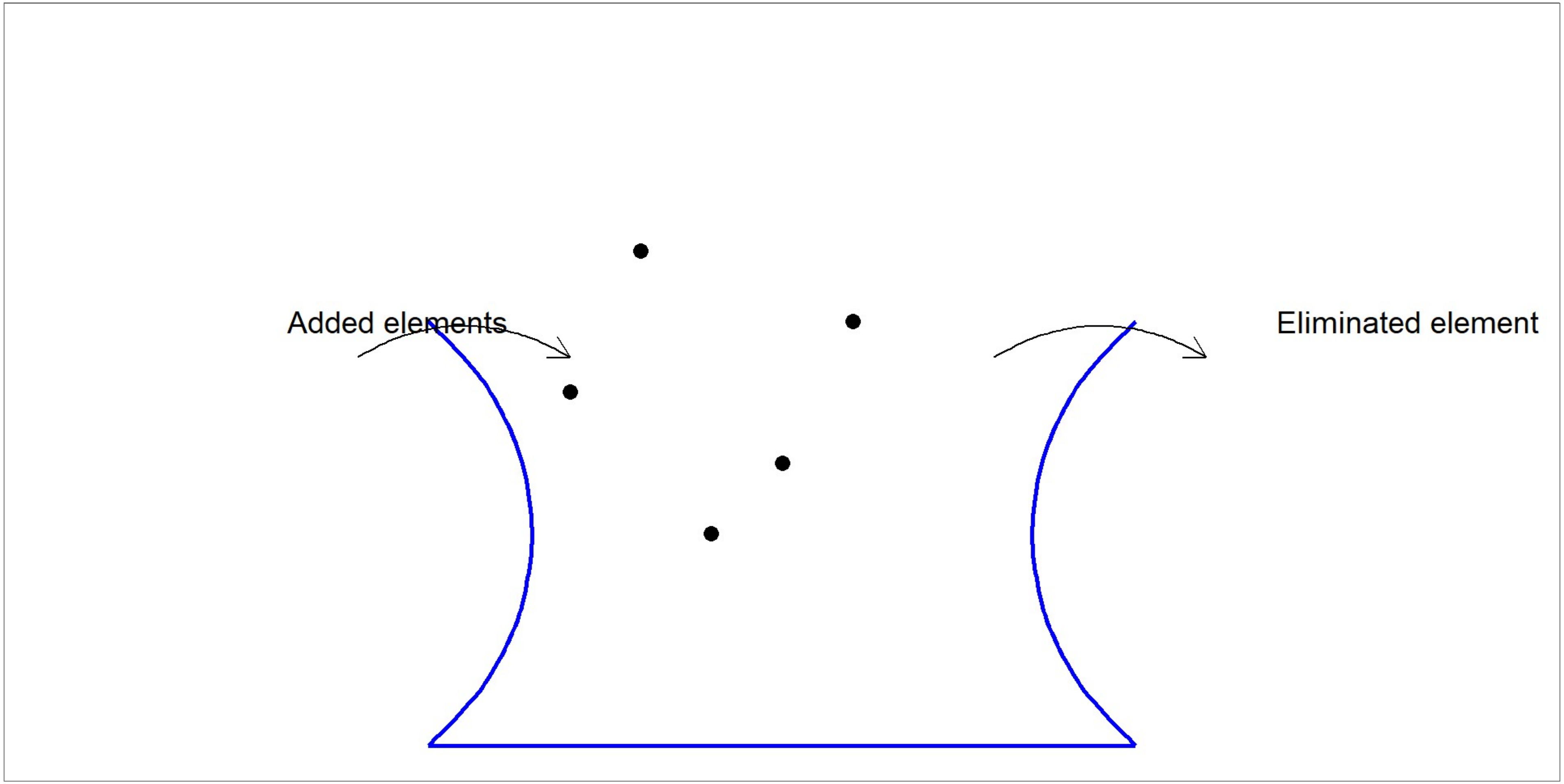
- Naturally occurring resources which can be made available for mankind under feasible **social**, **economic**, and **technological** framework.- Can we classify sea water as a natural resource?
- Two types:
  - Renewable Resources: Generating capacity - forests, fishery, solar energy, etc.
  - Non-renewable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



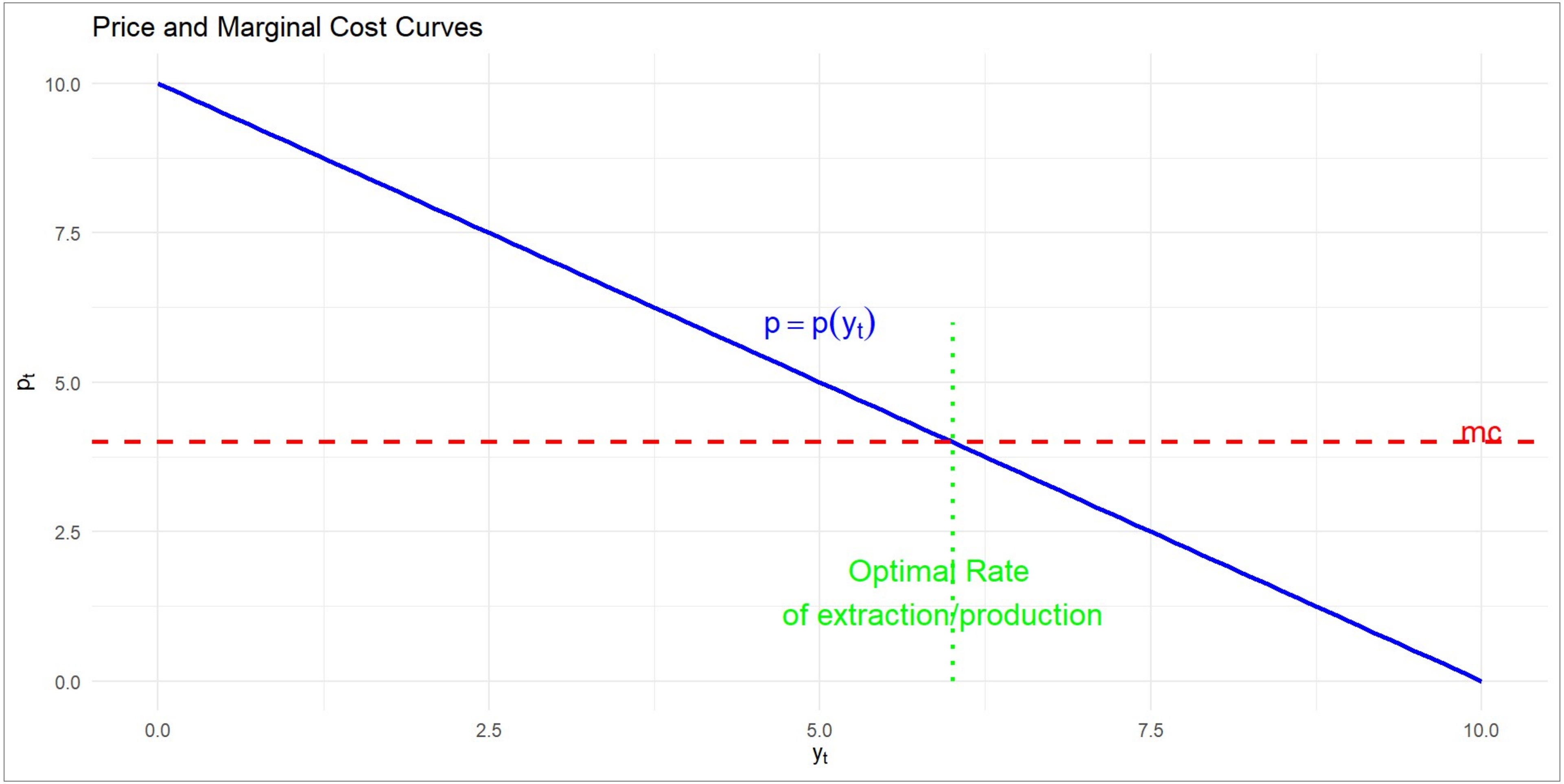
Natural resources as an open set



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

The optimal path

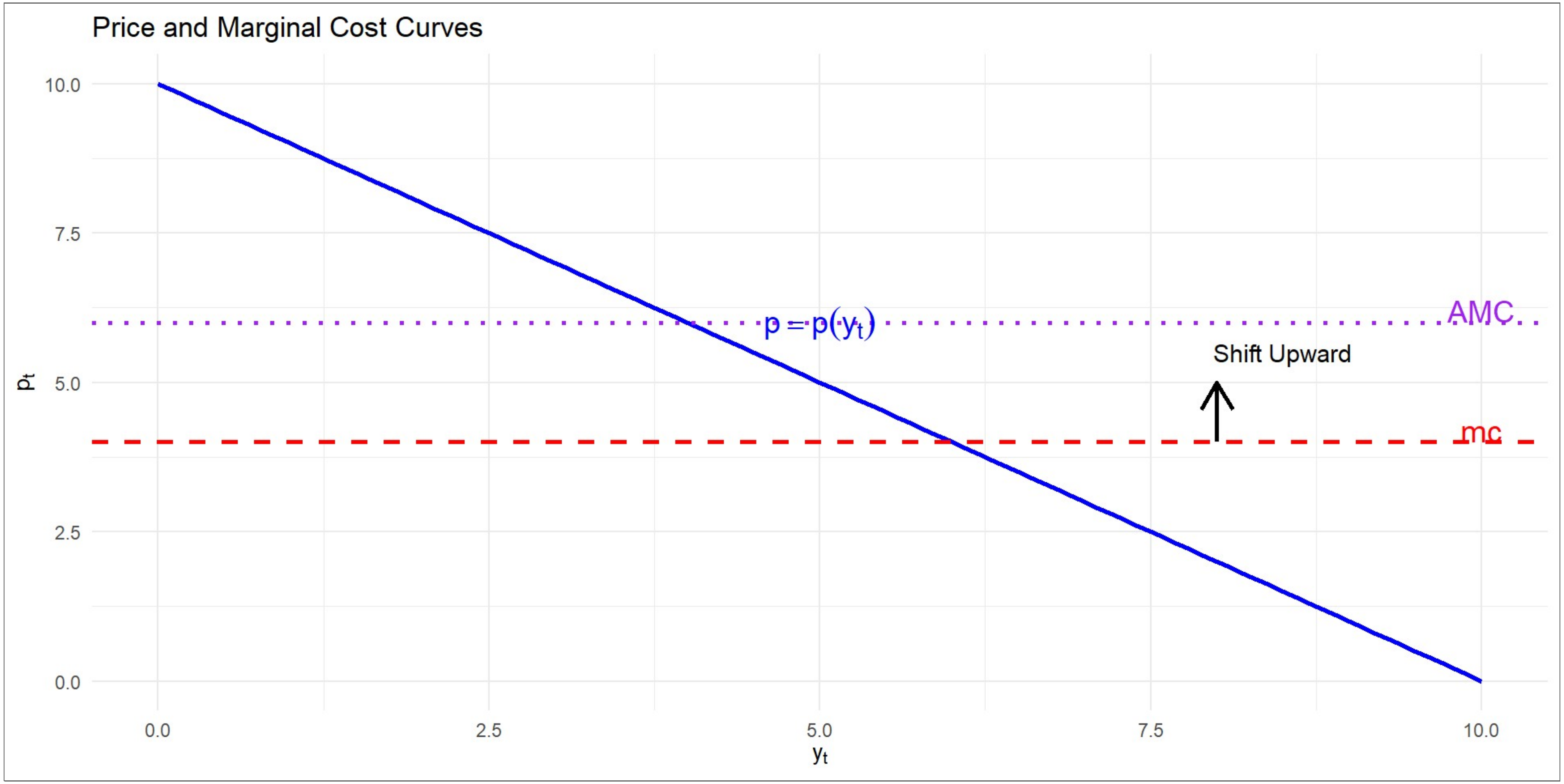
- What should be the optimal path (*if we join the points we get a path*) of extraction for a non-renewable resource (NRR)?
- For market goods
  - $p = mc, p$- price , mc- marginal cost



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.

- 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.

$$\because p_0 = mc_e + \frac{(p_1 - mc_e)}{1+r}$$
$$p_1 = mc_e + (p_0 - mc_e)(1+r)$$
$$p_2 = mc_e + (p_0 - mc_e)(1+r)^2$$

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 $t \to \infty, p_t \to \infty$
- 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.

- **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

$$\text{From (1) and (2), we get}$$
$$mc_b = mc_e + (p_0 - mc_e)(1+r)^T$$
$$p_0 - mc_e = \frac{mc_b - mc_e}{(1+r)^T}$$