# Dynamic Efficiency for Stock Pollutants

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# Motivation and key results (1)

- Usual view in the sparse “text book” like literature: static efficiency through time
- Stock pollutants complicate matters

  :: what not abated today carries over to future time periods
  - … “carry overs” to our understanding of efficiency in a general context?
  - … very visible for cost effectiveness (least cost way of reducing emissions): only cost considerations – trade-offs over time (trivial)
  - … more intriguing for efficiency/optimality
  - warning :: work in progress

# … motivation and key results (2)

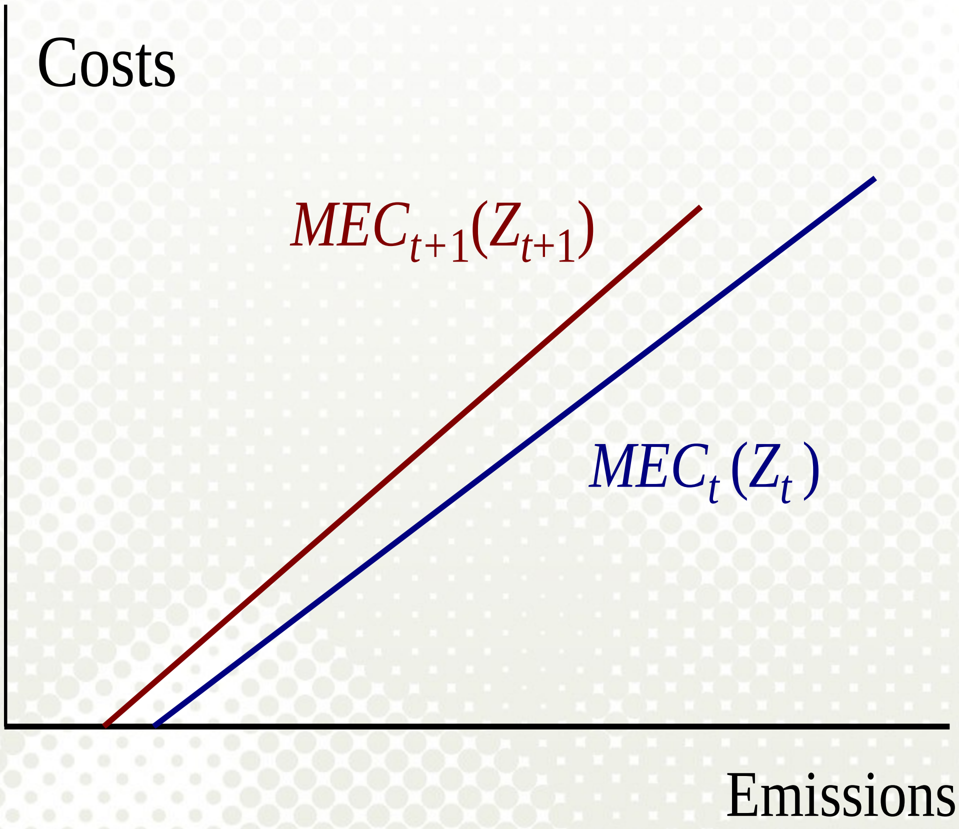
- Dynamic cost effectiveness = least cost:
  - Cost effectiveness across agents (equal MACs)
  - Time indifference: $p_t = (1+r)^t p_0$
  - Time rules … (when the static part OK)
- Dynamic efficiency/optimality
  - Coincidence if static optima were placed on the price path $p_t = (1+r)^t p_0$ through time
  - ⇒ trade-off static DW-losses vs. price path
  - … depends on relative slopes of marginal benefits and costs?

# Outline

- Stock effects
- Time indifference
- Dynamic cost effectiveness
- Dynamic optimality
- Implications

# Stock effects

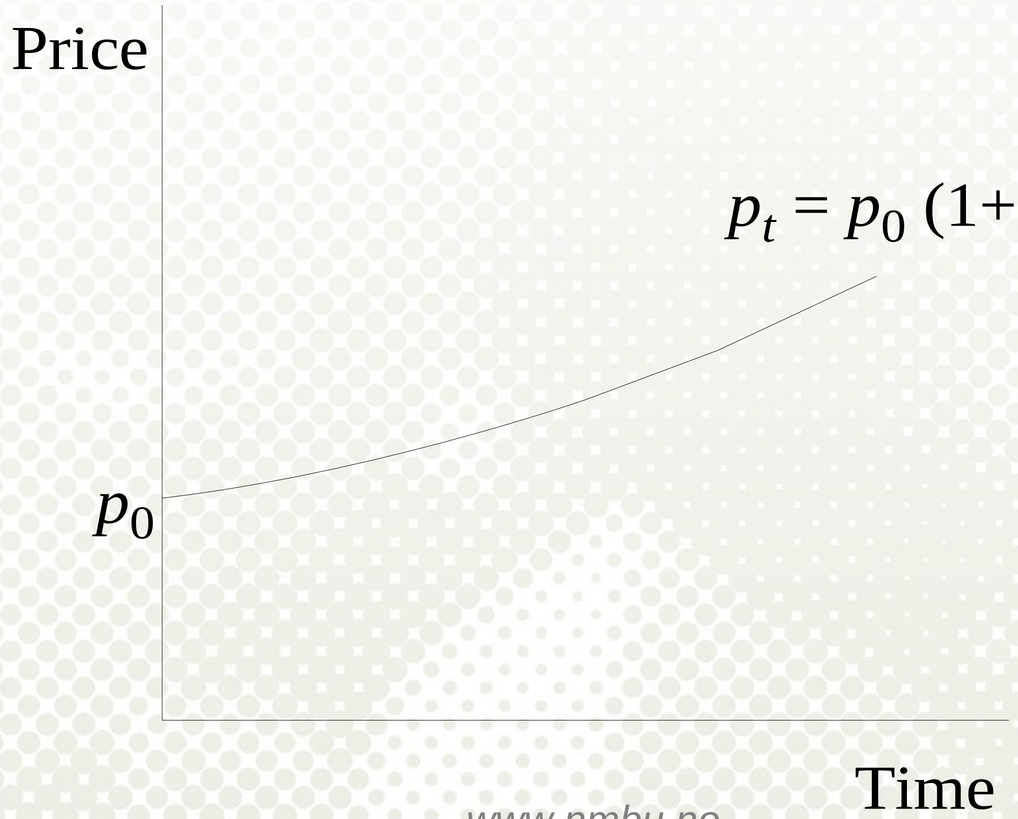
- Net emissions carry over to future periods :: $MEC_{t+1}$(accumulated past net emissions)
  - shifts back and rotates the MEC
  - dynamic analysis



# Time indifference

- Hotelling price path $p_t = (1+r)^t p_0$

  for agents to be indifferent between selling/buying a good in time period *t* or 0.



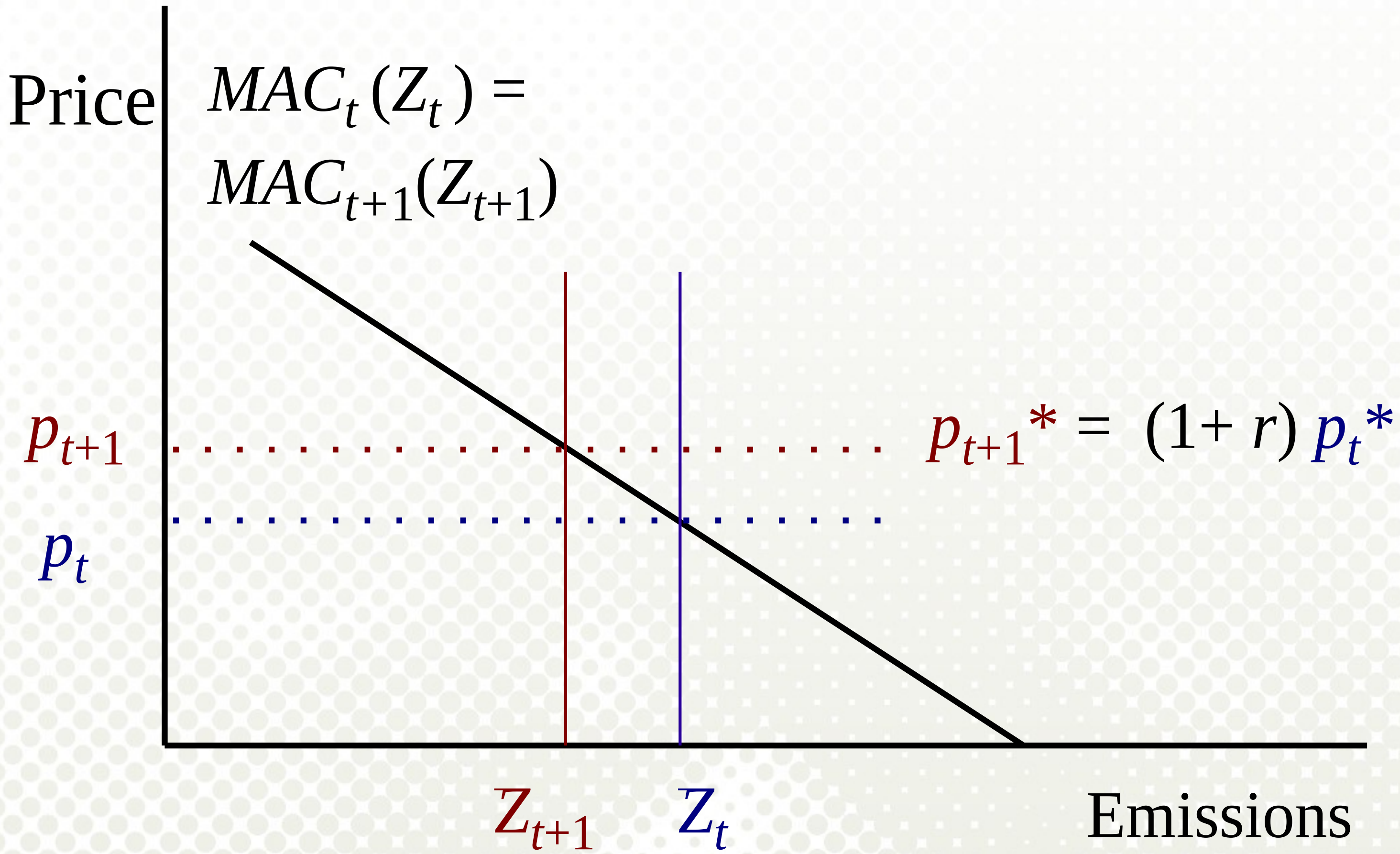
# Dynamic cost effectiveness (1)

- Statics: equal marginal abatement costs for each agent, evaluated at that agents emission level :: $MAC_i(z_i^*) = MAC_j(z_j^*)$
  - absence of arbitrage between agents

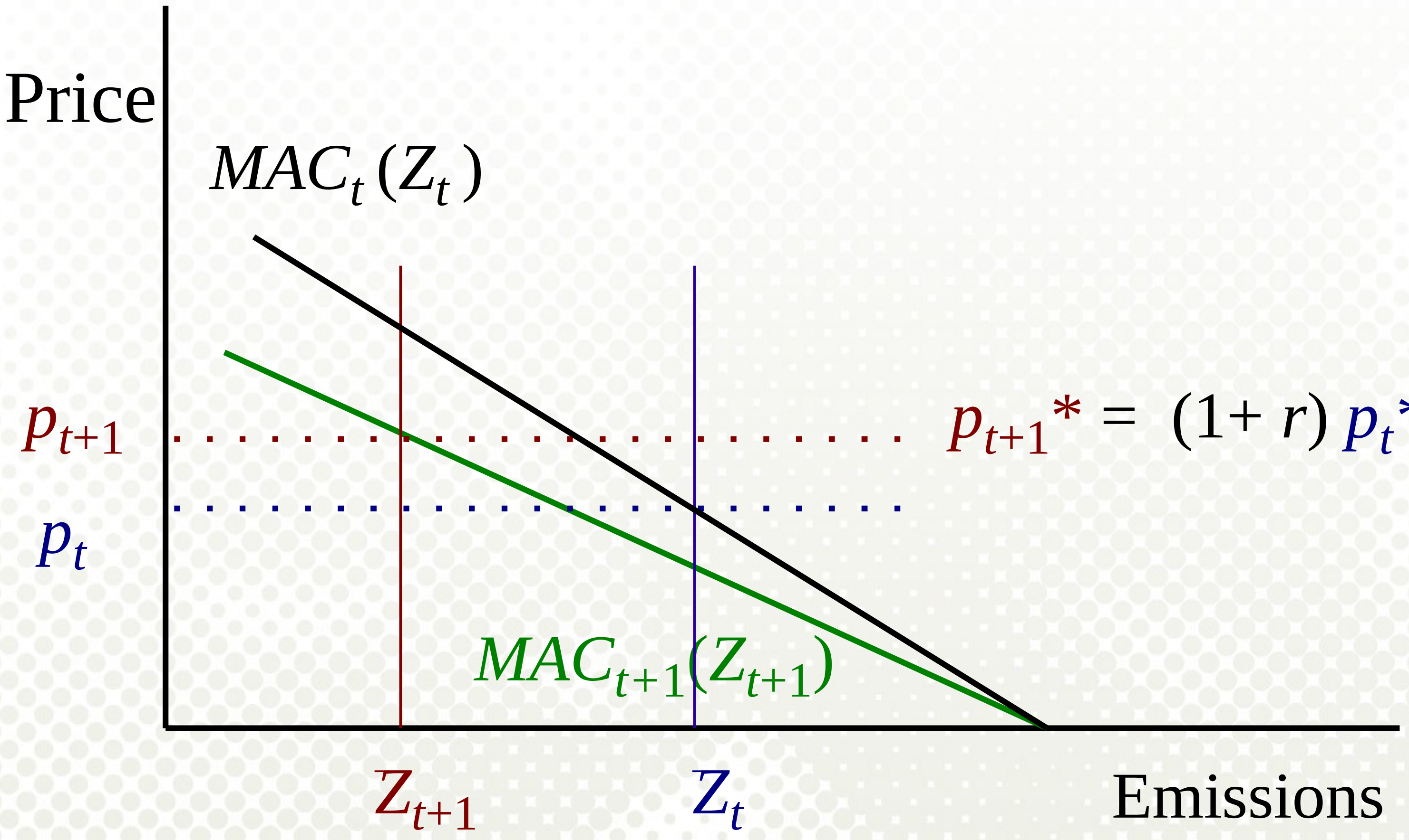
- Dynamic cost effectiveness = absence of arbitrage over time

$$MAC_{t+1}(z_{t+1}^*) = (1+r)\, MAC_t(z_t^*)$$

# … dynamic cost effectiveness (2)



# … dynamic cost effectiveness (3)



# Dynamic optimality (1)

- Static optimality:

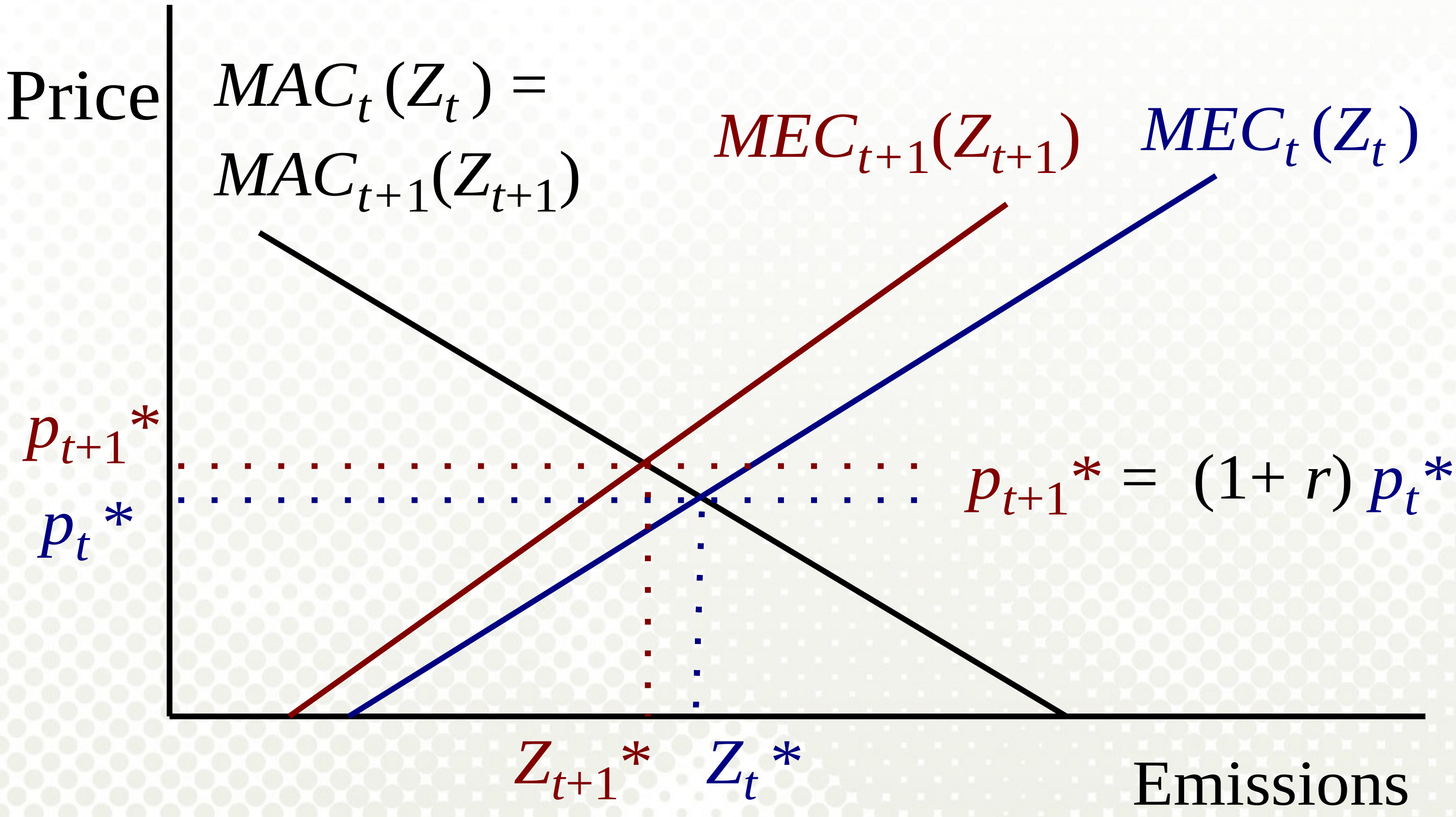
$$MAC_i(z_i^*) = MAC_j(z_j^*) = MEC(\Sigma\, z_k)$$

- Dynamic optimality:

$$MAC_t(z_t^*) = MEC_t(z_t^*) = p_t^*$$
$$MAC_{t+1}(z_{t+1}^*) = MEC_{t+1}(z_{t+1}^*) = p_{t+1}^*$$

  - What is the relationship through time?

# … dynamic optimality (2)



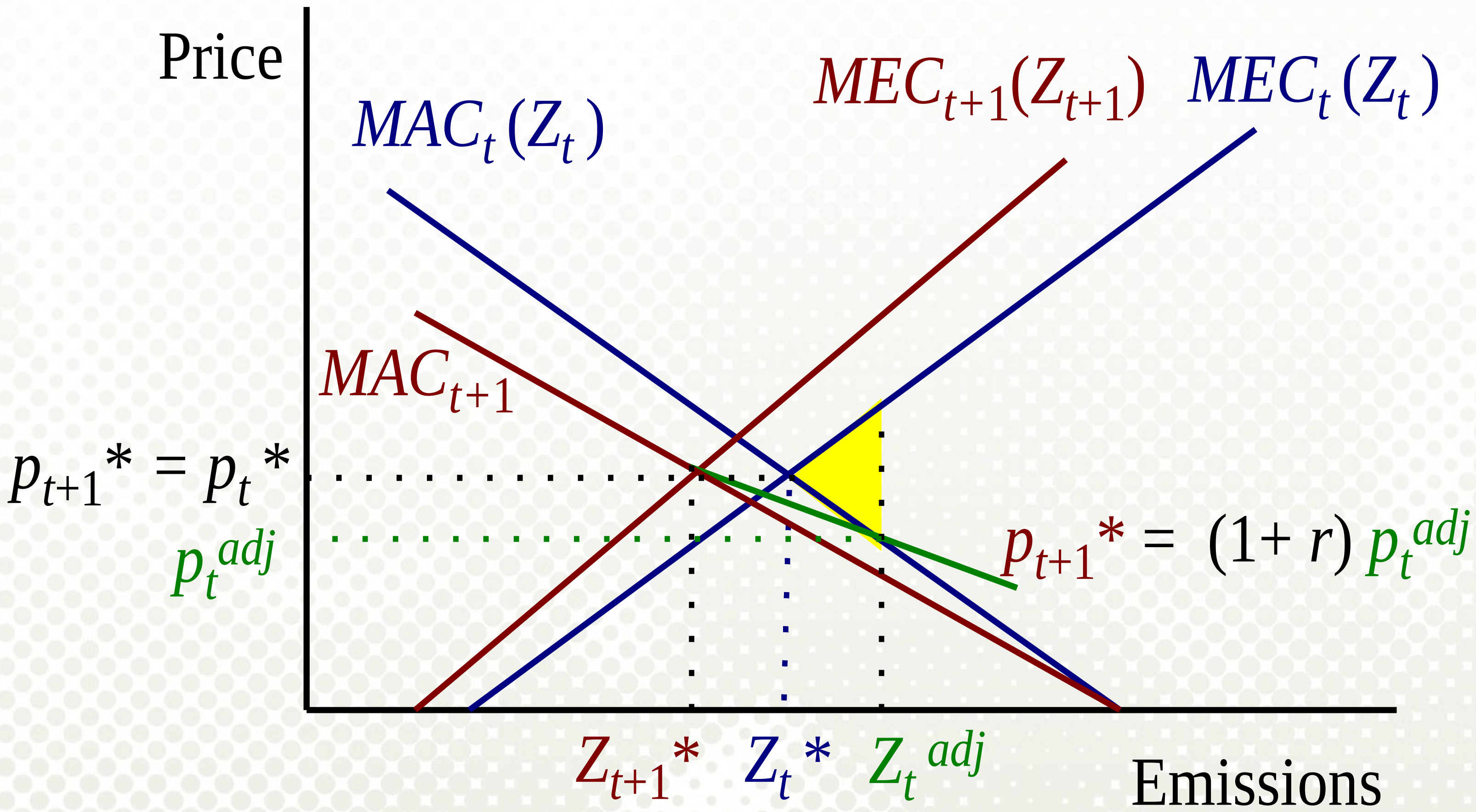
# … dynamic optimality (3)

- Strange coincidence if the sequence of static optimal emission levels over time would follow the Hotelling price path

$$p_{t+1}^* = (1+r)^t \, p_0^*$$

- How to trade off time preference (given by the Hotelling price path) and the sequence of static optima?

# … dynamic optimality (4)



# … dynamic optimality (5)

- Decision problem: maximize discounted social welfare (net benefits) from emissions reductions ($q_t$) over time

- Complicating features
  - future benefits and costs of emissions reductions not known
  - exp. benefits: ${}_{t\text{-}1}E\ [B_t(q_t^*)] < {}_{t\text{-}1}E\ [B_{t+1}(q_{t+1}^*)]$ (stock effect)
  - exp. costs: ${}_{t\text{-}1}E\ [C_t(q_t^*)] > {}_{t\text{-}1}E\ [C_{t+1}(q_{t+1}^*)]$ (technological progress)

# … dynamic optimality (6)

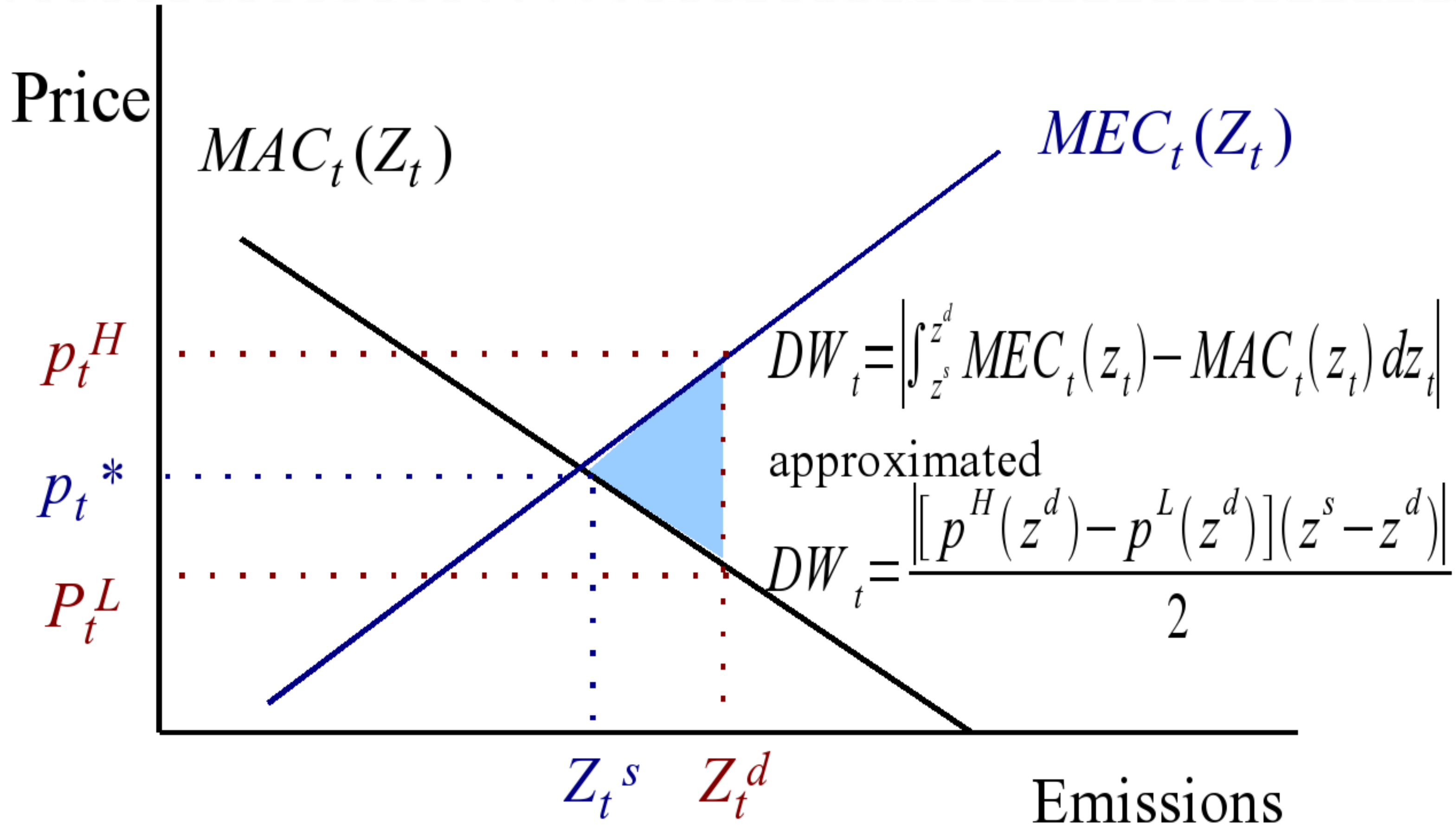
- Max $\Sigma_{t=1} (1+r)^{-t} \{ {}_{t-1}E [B_t(q_t^*)] - {}_{t-1}E[C_t(q_t^*)]\}$ $\{q_t^*\}$

- Nature of the solution depends on
  - expectations of future benefits and costs
  - relative slope of expected benefits and costs :: Pfizer ('99): expected benefits flatter than expected costs for climate

    $\Rightarrow$ most likely trade-off: postpone reductions

    $\Rightarrow$ $q_t^* < q_{t+1}^*$ as $(1+r)\, p_t^* > p_{t+1}^*$ but could also be $q_t^* > q_{t+1}^*$ when $(1+r)\, p_t^* < p_{t+1}^*$

# Loss when using dynamics – an outline



# Loss when using statics – an outline

- Sequence of static optimal prices $\{ p_t^s \}$ differ from the optimal dynamic prices $\{ p_t^d \} \Rightarrow$ deviation from

  Hotelling price path: $p_t = p_0 (1 + r)^t$

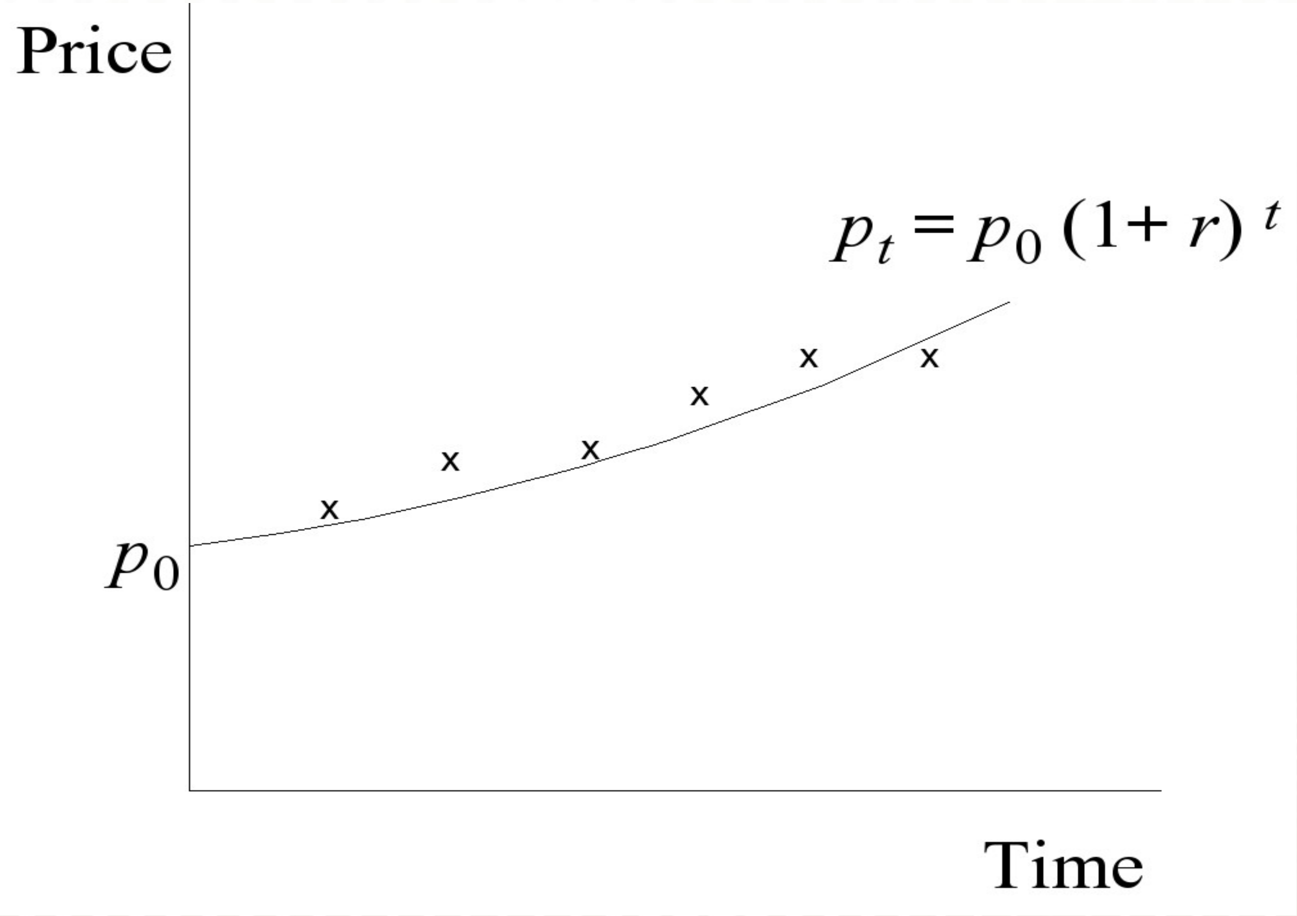
- $\Rightarrow$ loss of dynamic efficiency

  (= trade-off between time periods)

# Optimal solution – an outline (1)

- Minimize the discounted losses caused by the two perspectives
  - dynamic (DW-losses from the statically optimal prices) and
  - statics (deviation from the Hotelling price path compared to the dynamically optimal prices)

# … optimal solution – an outline (2)



# Concluding remarks

- Sequence of static optima and dynamic optimality do not generally coincide
  - $q_t^* < q_{t+1}^*$ :: an intuitive (climate) result due to tech.progress changing more than stock effect on marginal damages
  - increased early abatement reduces stock effect ⇒ “old” result less likely
  - emissions and stocks “same” damage ⇒ $MC_t(q^*) = MC_t(\text{reduced stocks}^*)$ :: REDD

- Work in progress