These slides are by courtesy of Prof. 李稻葵 and Prof. 郑捷.

# Chapter Thirty-Five

## Externalities

Ch. 35.1-4 only

# Externalities

- An **externality** is a cost or a benefit imposed upon someone by actions taken by others.
- An externally imposed benefit is a **positive externality**.
- An externally imposed cost is a **negative externality**.

# Examples of Negative Externalities

- **Air pollution.**
- **Traffic congestion.**
- **Second-hand cigarette smoke.**

# Examples of Positive Externalities

- A well-maintained house next door that raises the market value of your house.
- Improved driving habits that reduce accident risks.
- A scientific advance.

# Inefficiency & Negative Externalities

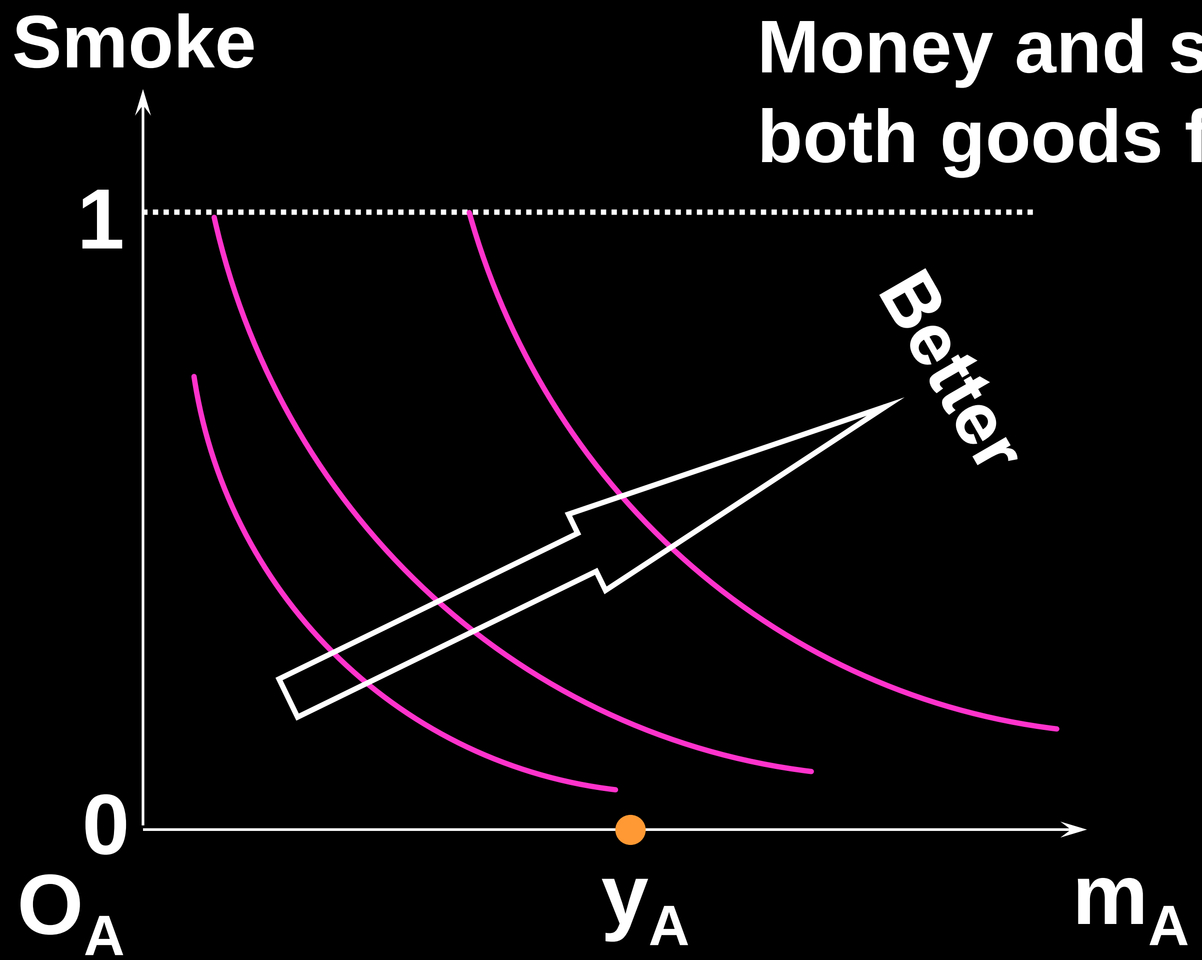
- **Two agents: A (smoker) and B (non-smoker)**
- **Two commodities: money and smoke.**
- **Both smoke and money are goods for A.**
- **Money is a good and smoke is a bad for B.**
- **The level of smoke is decided by A but it affects the welfare of B.**

# Inefficiency & Negative Externalities

- **Agent A is endowed with $$y_A$.**
- **Agent B is endowed with $$y_B$.**
- **Smoke intensity is measured on a scale from 0 (no smoking) to 1 (max smoking).**

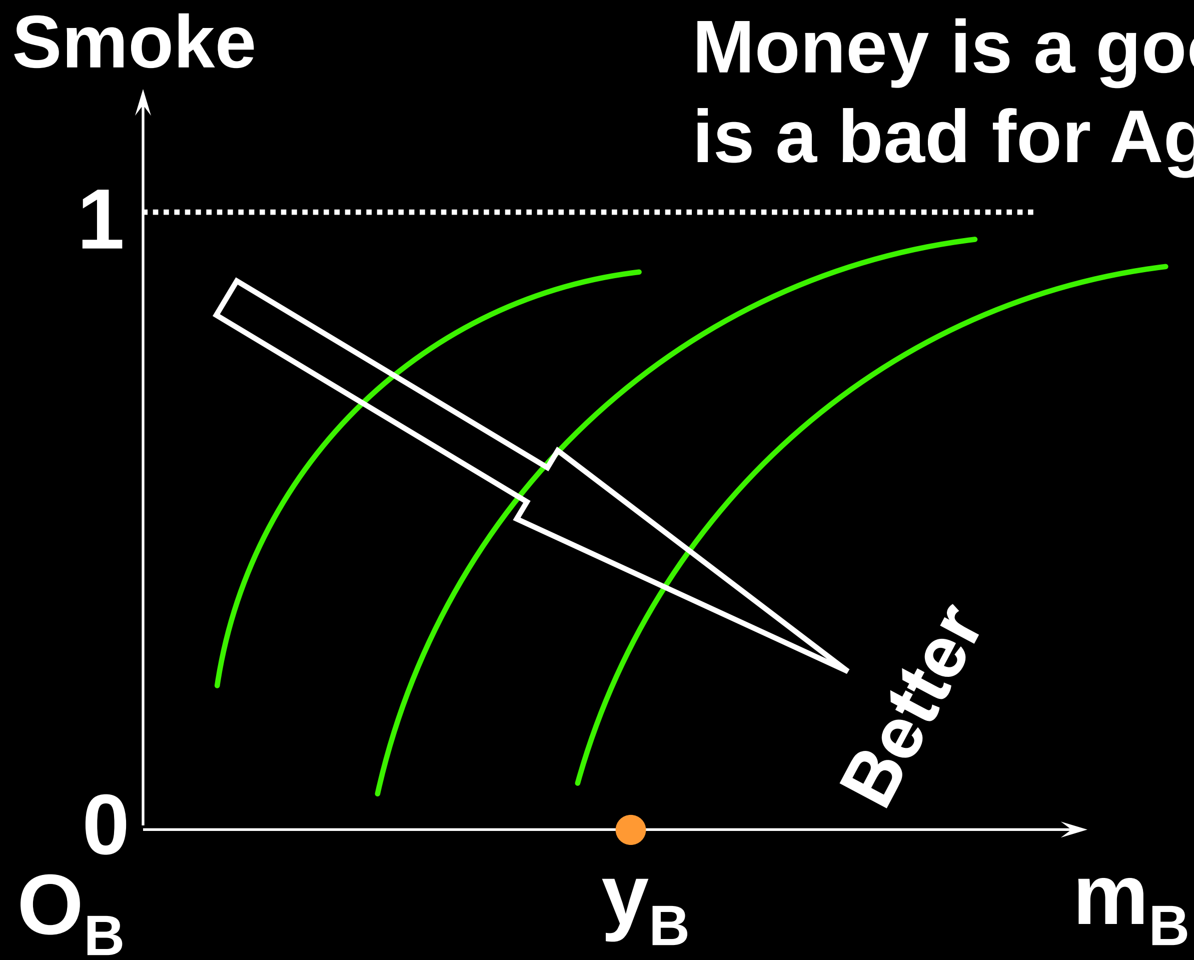
# Inefficiency & Negative Externalities

Money and smoke are both goods for Agent A.



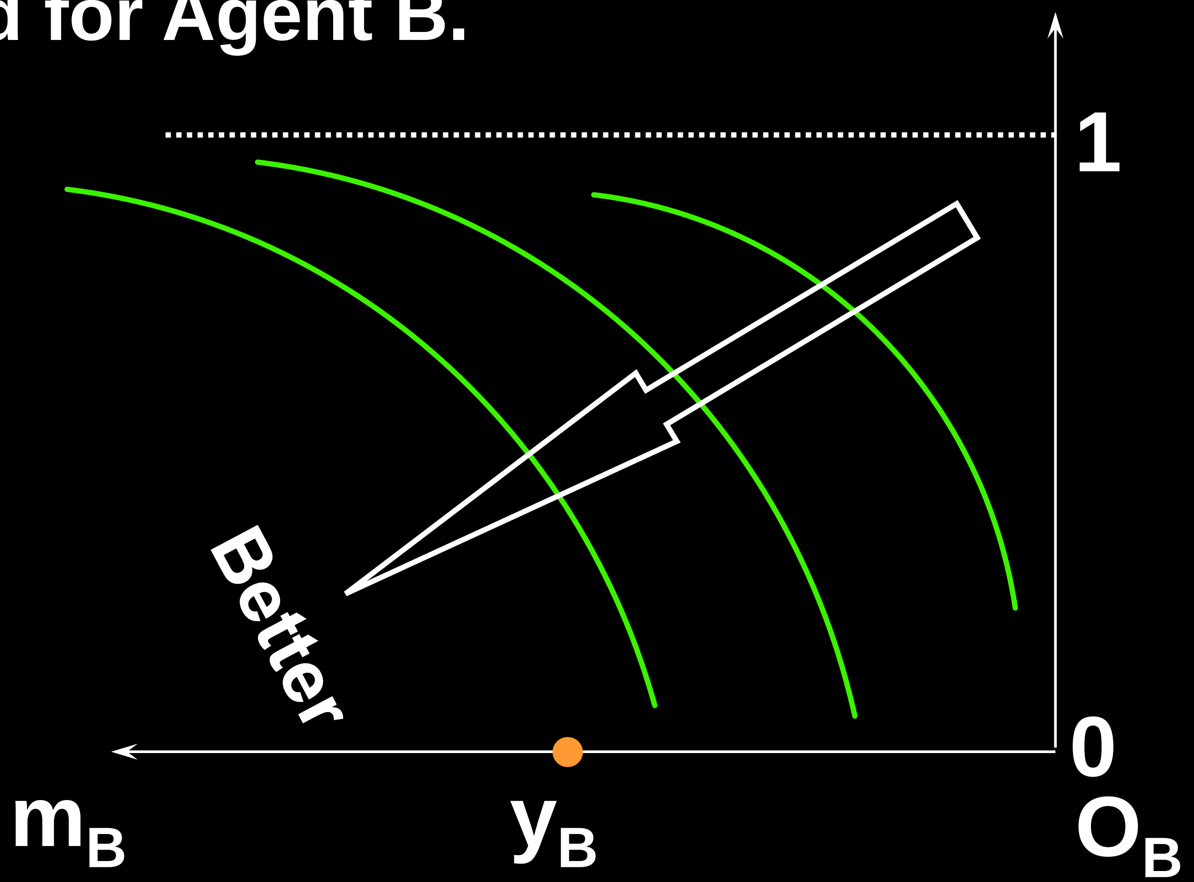
# Inefficiency & Negative Externalities

Money is a good and smoke is a bad for Agent B.



# Inefficiency & Negative Externalities

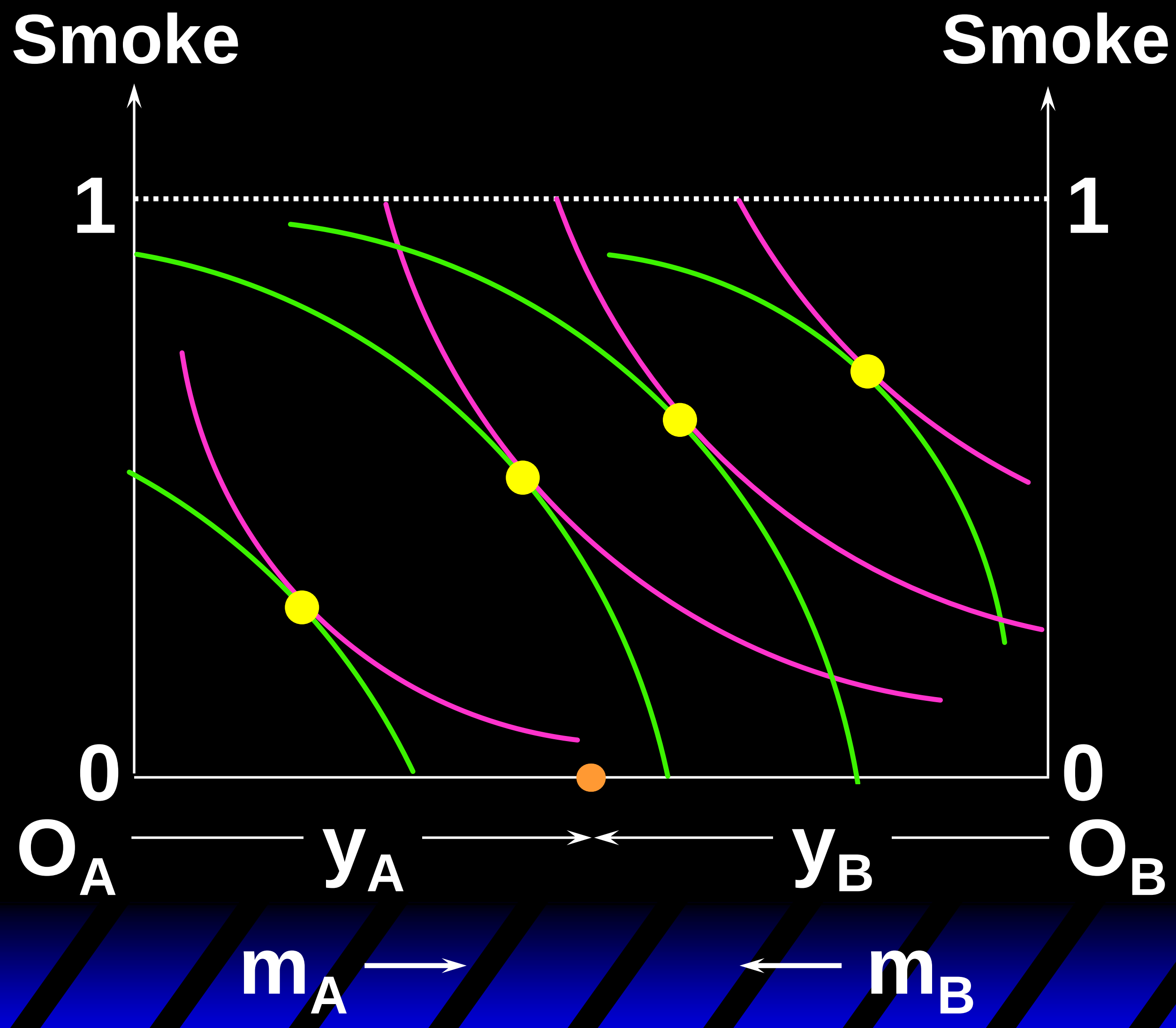
**Money is a good and smoke is a bad for Agent B.**



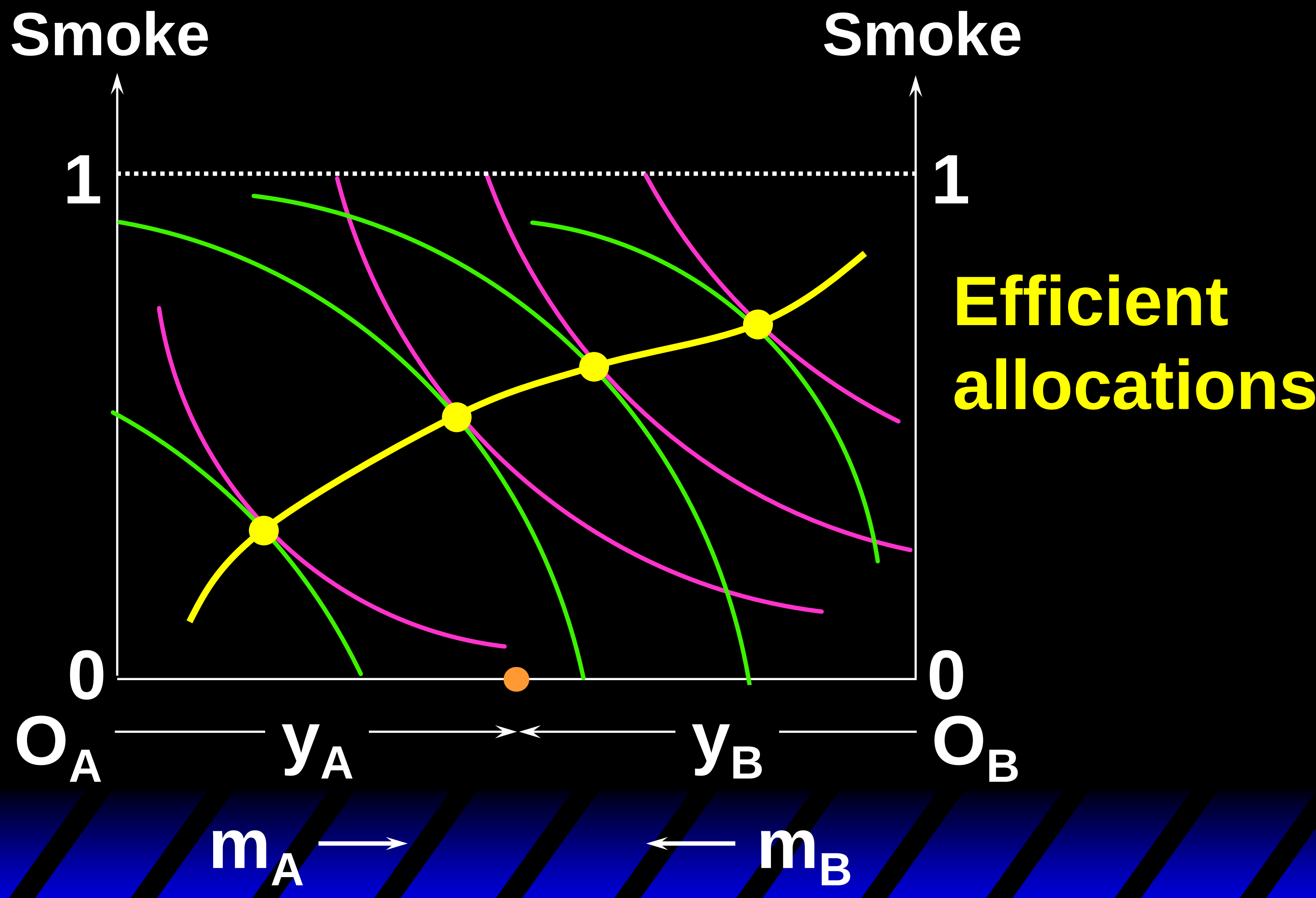
# Inefficiency & Negative Externalities

- For simplicity, let's assume that cigarette is free.
- What are the efficient allocations of smoke and money?

# Inefficiency & Negative Externalities



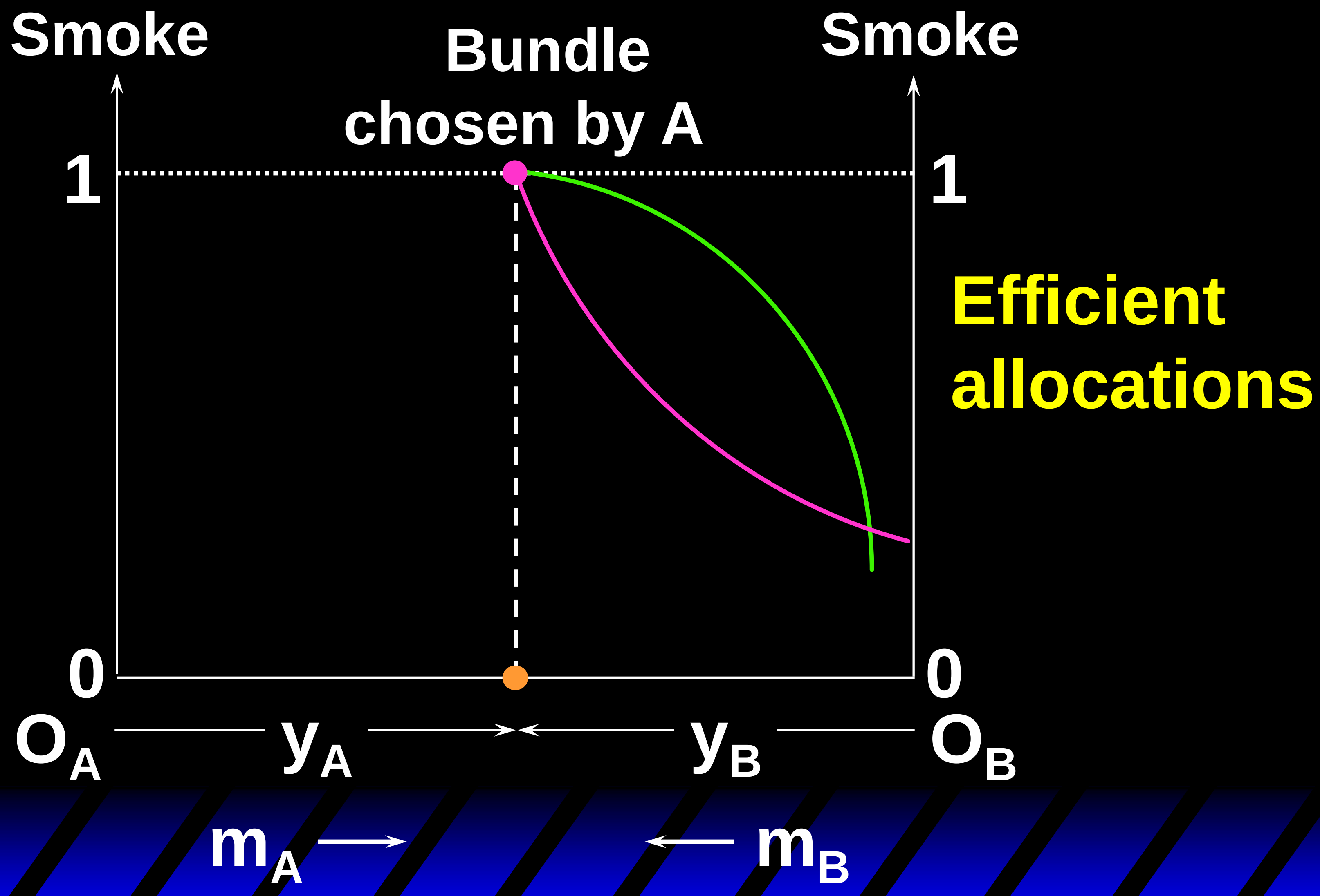
# Inefficiency & Negative Externalities



# Inefficiency & Negative Externalities

- **Suppose A and B do not negotiate over the externality:**
  - **What is the consumption bundle A will choose?**
  - **Is this allocation efficient?**

# Inefficiency & Negative Externalities



# Inefficiency & Negative Externalities

- **Without negotiation, there is too much smoke compared to its social efficiency level.**
  - **Moving to the lower-right may create Pareto improvement.**
- **As a general intuition, if a behavior has negative / positive externality, then there tend to be too much / little of that behavior.**

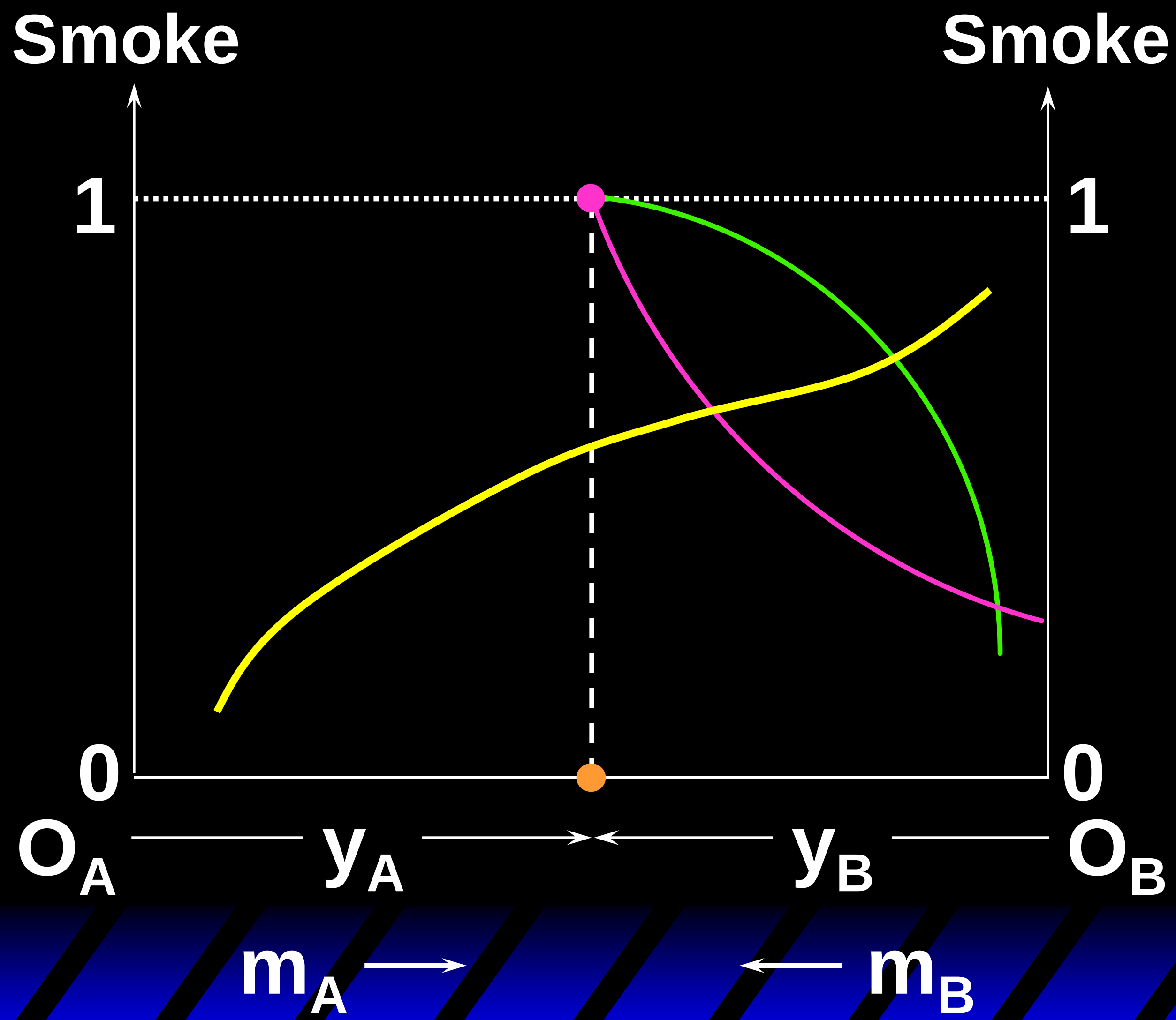
# Externalities and Property Rights

- **Ronald Coase's insight is that most externality problems are due to an inadequate specification of property rights.**

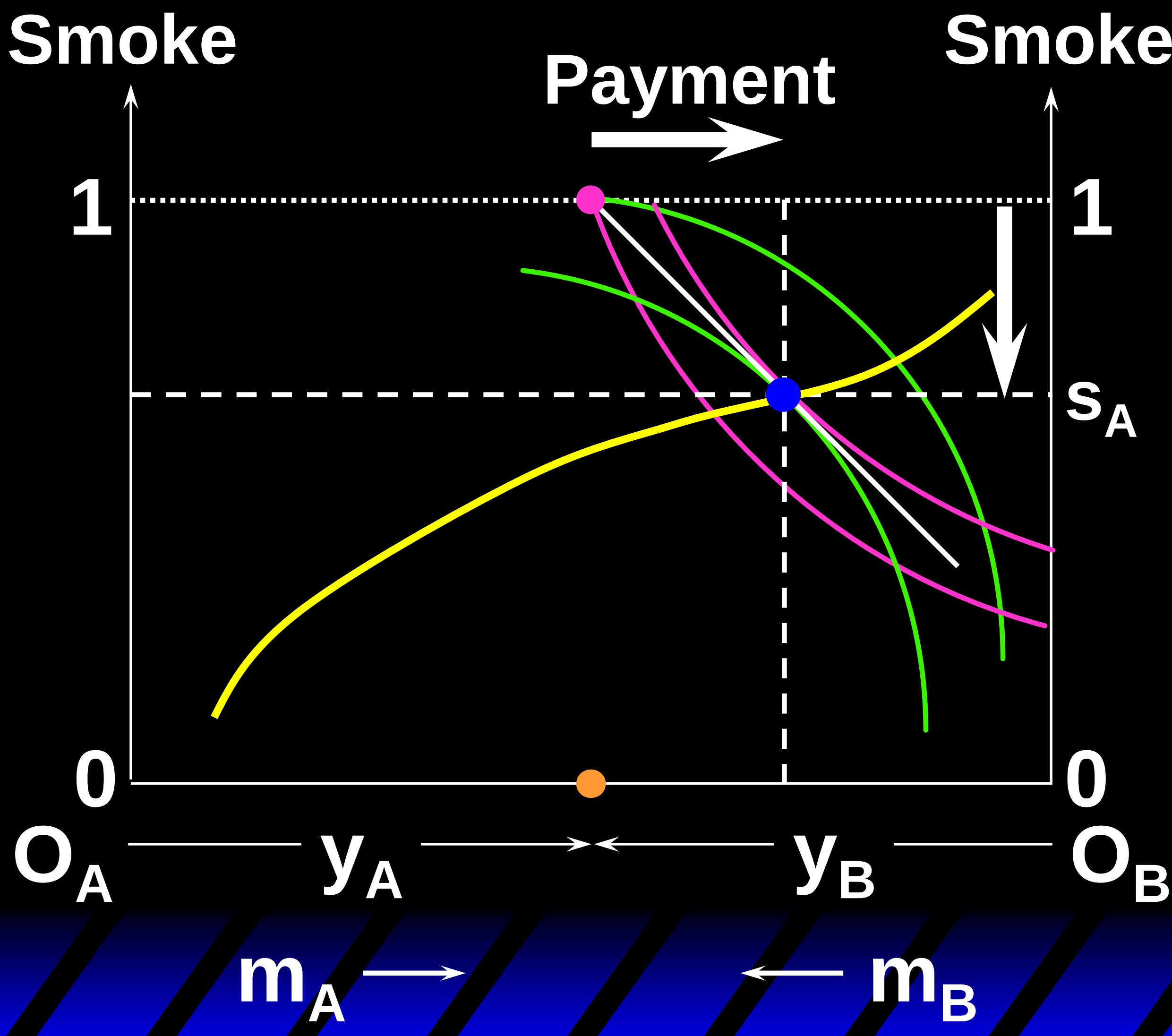
# Externalities and Property Rights

- Suppose that the government introduces a commodity: smoking licenses (total amount = 1)
  - The law says that a smoker's consumption of smoke cannot exceed the amount of licenses he/she owns.
- Let's assign property right:
  - Suppose the government gives all licenses to A.

# Externalities and Property Rights



# Externalities and Property Rights



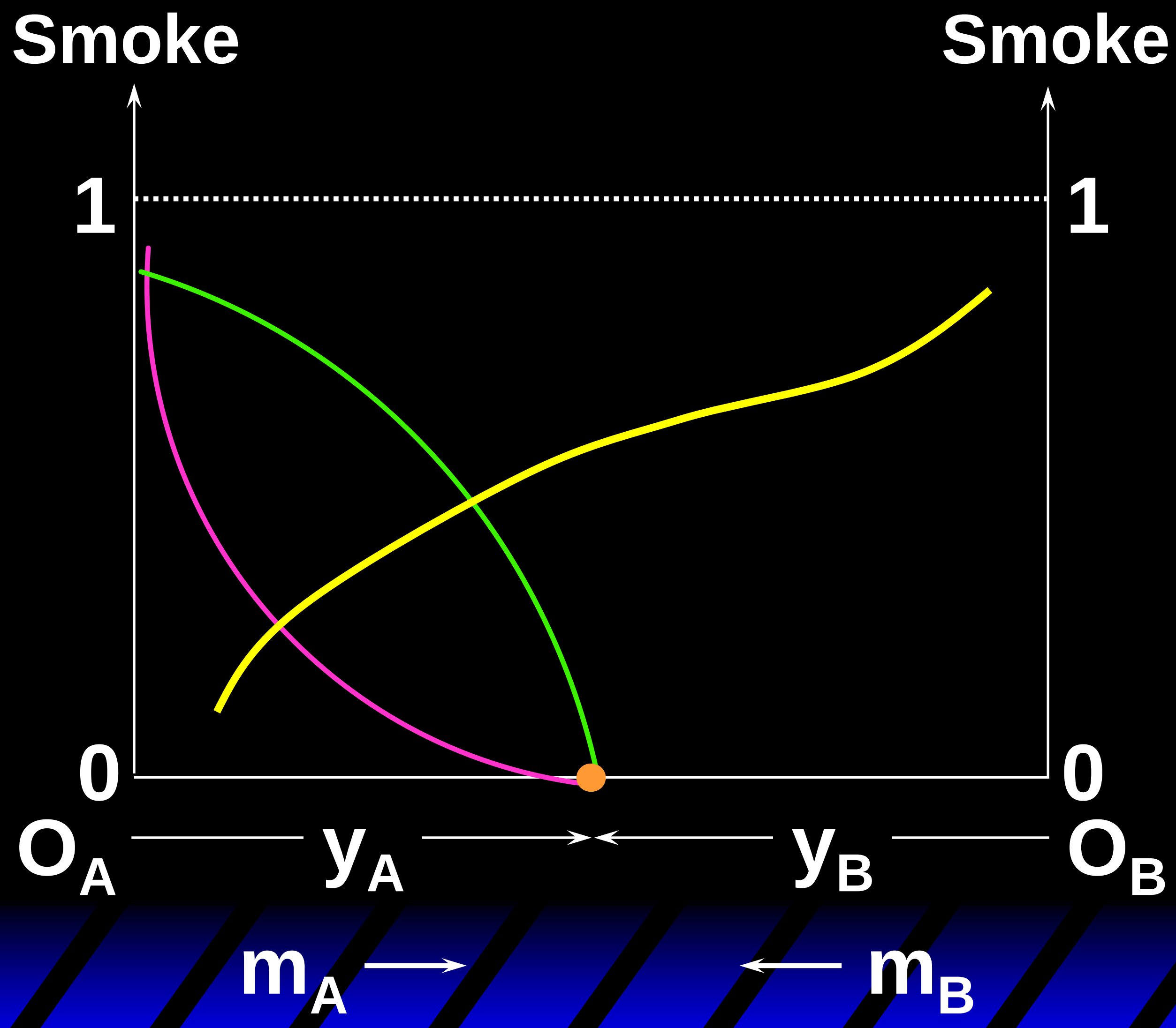

B buys some licenses from A, and both agents gain from trade.

Equilibrium is efficient.

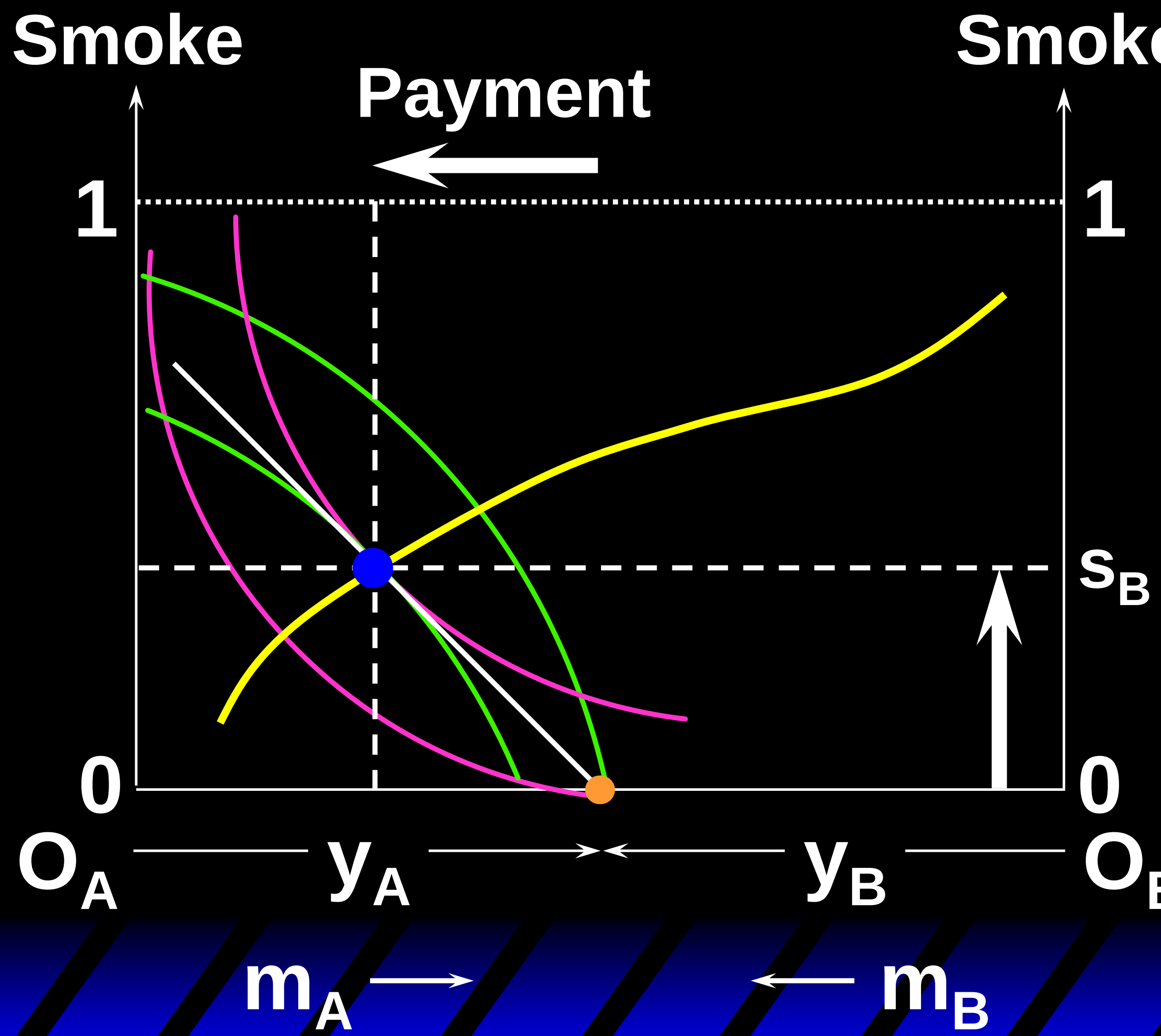
# Externalities and Property Rights

- **Let's assign property right the other way:**
  - **Suppose the government gives all licenses to B.**

# Externalities and Property Rights



# Externalities and Property Rights



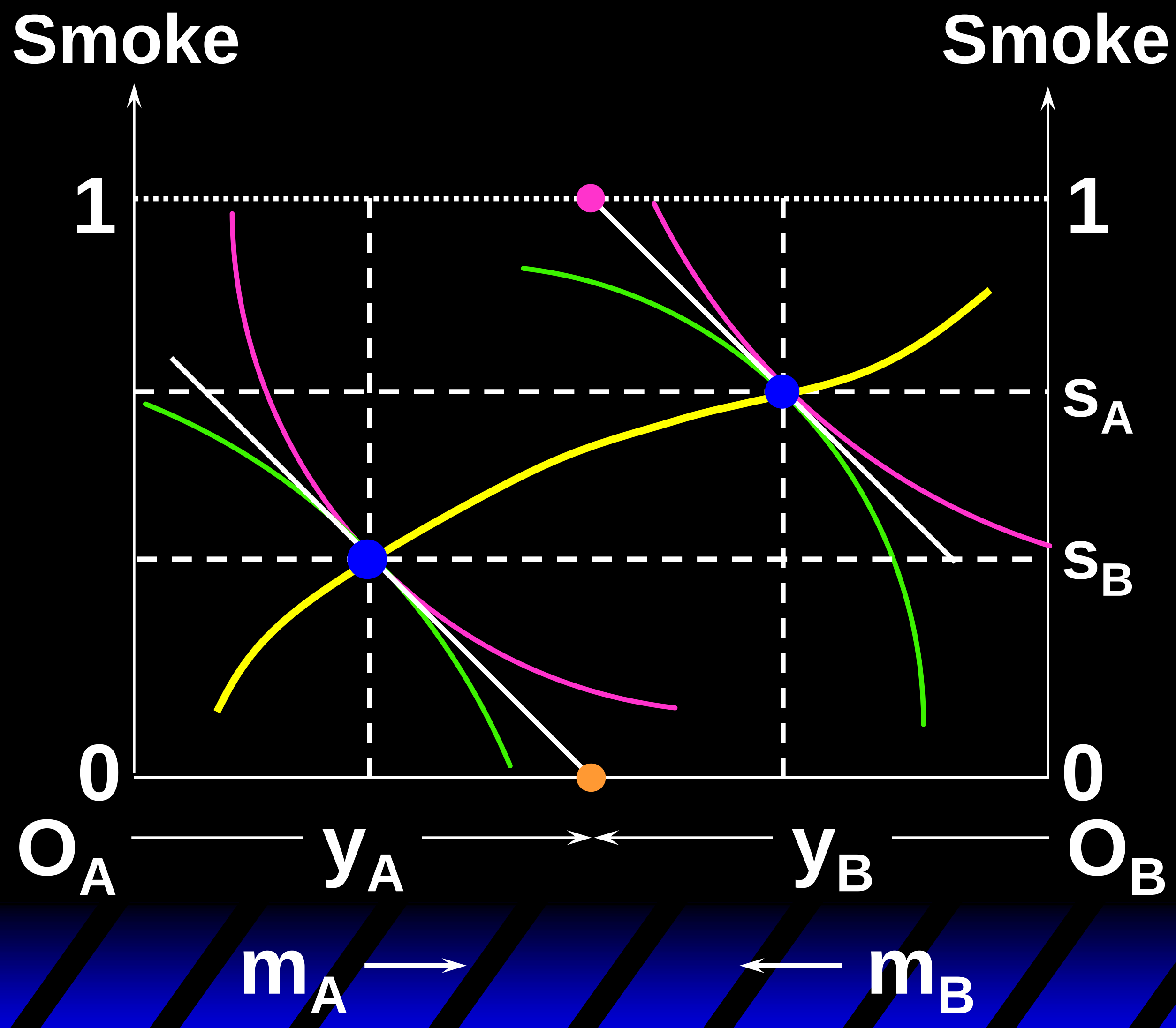

A buys some licenses from B, and both agents gain from trade.

Equilibrium is efficient.

# Externalities and Property Rights

- **Notice that**
  - **How the government specifies the property right affects the welfare of the two agents.**
  - **In general, it also affects the amount of smoking that occurs in equilibrium.**

# Externalities and Property Rights

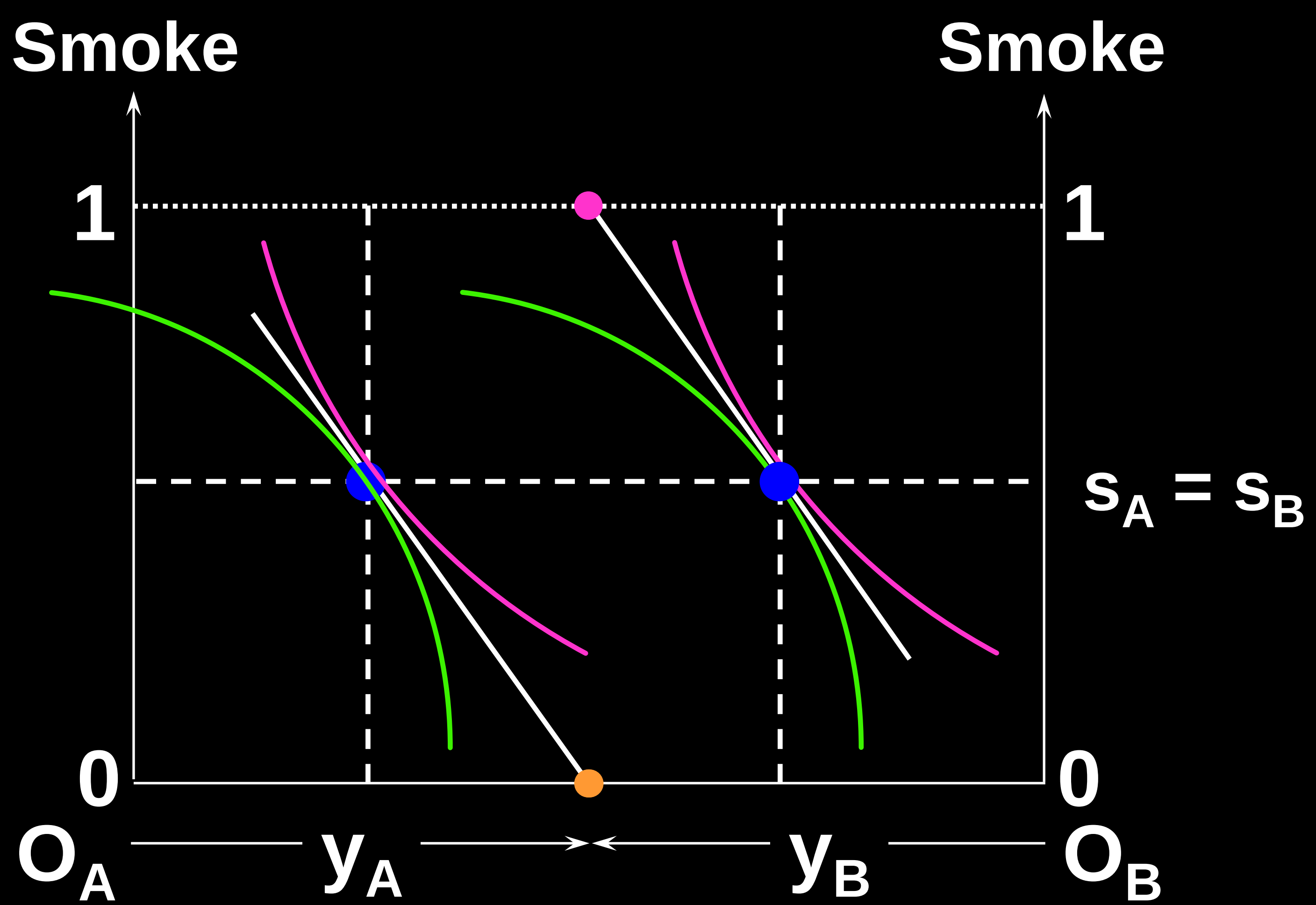



$s_A \neq s_B$

# Externalities and Property Rights

- **However, in the special case with utility functions quasi-linear in money, the same amount of smoking occurs in equilibrium regardless how property right is specified.**

# Externalities and Property Rights




**Two agents' utility is of the form: $u(y,s) = y + v(s)$.**

# Coase's Theorem

- **Coase's Theorem: If all agents' preferences are quasilinear in money, then the same efficient level of the externality generating behavior will be performed, no matter how property right is assigned.**

# Production Externalities

- A steel mill produces steel and pollution.
- The pollution adversely affects a nearby fishery.
- Both firms are price-takers.
- $p_S$ is the market price of steel.
- $p_F$ is the market price of fish.

# Production Externalities

- $c_S(s,x)$ is the steel firm's cost of producing s units of steel jointly with x units of pollution.
  - Assumed to be increasing in s, U-shaped in x.
- The steel firm's profit function is

$$\Pi_S(s,x) = p_S s - c_S(s,x)$$

# Production Externalities

Steel firm's problem:

$$\max_{s,x} \Pi_s(s,x) = p_s s - c_s(s,x).$$

The first-order profit-maximization conditions are

$$p_s = \frac{\partial c_s(s,x)}{\partial s} \quad \text{and} \quad 0 = \frac{\partial c_s(s,x)}{\partial x}.$$

# Production Externalities

E.g. suppose $c_S(s,x) = s^2 + (x - 4)^2$ and $p_S = 12$. Then

$$\Pi_S(s,x) = 12s - s^2 - (x-4)^2$$

and the first-order profit-maximization conditions are

$$12 = 2s \quad \text{and} \quad 0 = -2(x-4).$$

$s^* = 6$, $x^* = 4$

# Production Externalities

**The steel firm's maximized profit level is**

$$\Pi_s(s^*, x^*) = 12s^* - s^{*2} - (x^* - 4)^2$$

$$= 12 \times 6 - 6^2 - (4 - 4)^2$$

$$= \$36.$$

# Production Externalities

- The cost to the fishery of catching f units of fish when the steel mill emits x units of pollution is $c_F(f,x)$.
  – Increases in x; i.e. the steel firm inflicts a negative externality on the fishery.

# Production Externalities

Fishery's problem:

$$\max_{f} \Pi_F(f;x) = p_F f - c_F(f;x).$$

The first-order profit-maximization condition is $$p_F = \frac{\partial c_F(f;x)}{\partial f}.$$

# Production Externalities

**E.g. suppose $c_F(f;x) = f^2 + xf$ and $p_F = 10$.**

**The fishery's profit function is thus**

$$\Pi_F(f;x) = 10f - f^2 - xf$$

# Production Externalities

$$\Pi_F(f;x) = 10f - f^2 - xf$$

FOC:

$$10 = 2f + x.$$

So, given a pollution level x inflicted upon it, the fishery's profit-maximizing output level is

$$f^* = 5 - \frac{x}{2}.$$

# Production Externalities

Since the steel firm chooses x* = 4, the fishery's profit-maximizing output level is **f* = 5 - x*/2 = 3.**
The fishery a maximized profit level:

$$\Pi_F(f^*;x) = 10f^* - f^{*2} - xf^*$$
$$= 10\times 3 - 3^2 - 4\times 3 = \$9.$$

# Production Externalities

- Are these choices by the two firms efficient?
  - The two firm's profits is \$36 + \$9 = \$45.
  - Is \$45 the largest possible total profit that can be achieved?

# Merger and Internalization

- **Suppose the two firms merge to become one. What is the highest profit this new firm can achieve?**

$$\Pi^m(s,f,x) = 12s + 10f - s^2 - (x-4)^2 - f^2 - xf.$$

- **What choices of s, f and x maximize the new firm's profit?**

# Merger and Internalization

$$\Pi^m(s,f,x) = 12s + 10f - s^2 - (x-4)^2 - f^2 - xf.$$

The first-order profit-maximization conditions are

$$\frac{\partial \Pi^m}{\partial s} = 12 - 2s = 0$$

$$\frac{\partial \Pi^m}{\partial f} = 10 - 2f - x = 0.$$

$$\frac{\partial \Pi^m}{\partial x} = -2(x-4) - f = 0.$$

The solution is

$$s^m = 6$$

$$f^m = 4$$

$$x^m = 2.$$

# Merger and Internalization

And the merged firm’s maximum profit level is

$$\Pi^m(s^m, f^m, x^m)$$
$$= 12s^m + 10f^m - s^{m^2} - (x^m - 4)^2 - f^{m^2} - x^m f^m$$
$$= 12 \times 6 + 10 \times 4 - 6^2 - (2 - 4)^2 - 4^2 - 2 \times 4$$
$$= \$48.$$

This exceeds \$45, the sum of the non-merged firms.

# Merger and Internalization

- **Merger has improved efficiency.**
- **On its own, the steel firm produced $x^*$ = 4 units of pollution.**
- **Within the merged firm, pollution production is only $x^m$ = 2 units.**
- **So merger has caused both an improvement in efficiency and less pollution production. Why?**

# Merger and Internalization

**The steel firm's profit function is**

$$\Pi_s(s,x) = 12s - s^2 - (x-4)^2$$

**so the marginal cost of producing x units of pollution is** $MC_s(x) = 2(x-4)$

# Merger and Internalization

In the merged firm the profit function is

$$\Pi^m(s,f,x) = 12s + 10f - s^2 - (x-4)^2 - f^2 - xf.$$

The marginal cost of pollution is

$$MC^m(x) = 2(x-4) + f > 2(x-4) = MC_s(x).$$

The merged firm's marginal pollution cost is larger, because it faces the social cost of its pollution.

So less pollution is produced by the merged firm.

# Merger and Internalization

- **Merger internalizes the externality and so causes an efficient outcome.**

- **How else might cause efficiency?**

# Coase and Production Externalities

- Suppose that the government introduces a commodity: pollution licenses (total amount = 4)
  - The law says that the steel firm's pollution level cannot exceed the amount of licenses it owns.
- Let's assign property right:
  - Suppose the government gives all licenses to the fishery.

# Coase and Production Externalities

- The fishery may sell some of the licenses, in a competitive market, at $\$p_x$ each.
- The fishery's profit function becomes

$$\Pi_F(f,x) = p_f f - f^2 - xf + p_x x.$$

- Note that x is now a choice variable for the fishery.

# Coase and Production Externalities

$$\Pi_F(f,x) = p_f f - f^2 - xf + p_x x.$$

The profit-maximum conditions are

$$\frac{\partial \Pi_F}{\partial f} = p_f - 2f - x = 0$$

$$\frac{\partial \Pi_F}{\partial x} = -f + p_x = 0$$

and these give $f^* = p_x$ (fish supply)

$x_S^* = p_f - 2p_x.$ (license supply)

# Coase and Production Externalities

- **The steel firm must buy one unit of licenses for every unit of pollution it emits so its profit function becomes** $$\Pi_S(s,x) = p_s s - s^2 - (x-4)^2 - p_x x.$$

# Coase and Production Externalities

$$\Pi_S(s, x) = p_s s - s^2 - (x - 4)^2 - p_x x.$$

The profit-maximum conditions are

$$\frac{\partial \Pi_S}{\partial s} = p_s - 2s = 0$$

$$\frac{\partial \Pi_S}{\partial x} = -2(x - 4) - p_x = 0$$

and these give $s^* = \frac{p_s}{2}$ (steel supply)

$x_D^* = 4 - \frac{p_x}{2}$. (license demand)

# Coase and Production Externalities

In a competitive market for pollution licenses, the price $p_x$ must adjust to clear the market. So, at equilibrium,

$$x_D^* = 4 - \frac{p_x}{2} = p_f - 2p_x = x_S^*.$$

The market-clearing price for pollution licenses is

$$p_x = \frac{2p_f - 8}{3}$$

and the equilibrium quantity of licenses traded is

$$x_D^* = x_S^* = \frac{16 - p_f}{3}.$$

# Coase and Production Externalities

$$s^* = \frac{p_s}{2};\ \ f^* = p_x;\ \ x_D^* = x_S^* = \frac{16 - p_f}{3};$$

$$p_x = \frac{2p_f - 8}{3}.$$

**So if $p_s = 12$ and $p_f = 10$ then**

$$s^* = 6;\ \ f^* = 4;\ \ x_D^* = x_S^* = 2;\ \ p_x = 4.$$

**This is what the merged firm does and it is the efficient outcome.**

# Is this Example Correct?

- No. The fishery didn't maximize its profit. Its profit function is not concave, and therefore FOC didn't give us maximization.
- In fact, the equilibrium for the license market does not exist in this example.
- See my note for details, where a correct example was provided.

# Coase and Production Externalities

- **Alternatively, the government may assign all licenses to the steel firm.**
  - **The fishery must buy some licenses from the steal firm to reduces pollution.**

# Coase and Production Externalities

- We may write down the two firm's problems and solve for the competitive equilibrium.
  - Still, the same efficient outcome will occur
  - Firms' profit will be different.

# Summary

- The concept of externality
- Coase theorem and property rights
- Production externality