

# An Economic Theory Masterclass

## Part V: Public Goods

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February 18, 2025

# Public Goods Taxonomy

- ▶ *Rival* good: one consumer's use reduces another's benefit
- ▶ *Nonrival* good: no consumer's use reduces another's benefit
- ▶ *Excludable / nonexcludable* good: one can / cannot prevent others from jointly consuming a unit of the good

Goods	Rival	Nonrival
<b>Excludable</b>	Private good	Club good
<b>Nonexcludable</b>	Congestion public good	Pure public good



# Examples of Congestion Public Goods

## ► City roads, wifi, internet traffic, water out West

### GLOBAL APPLICATION TOTAL TRAFFIC SHARE

- 1 YOUTUBE:**  
2019: 8.69% 2020: 15.94% (+7.25%)
- 2 NETFLIX:**  
2019: 12.87% 2020: 11.42% (-1.45%)
- 3 HTTP:**  
2019: 3.61% 2020: 6.57% (-2.96%)
- 4 BITTORRENT:**  
2019: 7.75% 2020: 5.23% (-2.52%)
- 5 FACEBOOK:**  
2019: 3.37% 2020: 3.68% (+0.37%)
- 6 HTTP MEDIA STREAM:**  
2019: 13.76% 2020: 3.64% (-10.12%)
- 7 GOOGLE:**  
2019: 1.23% 2020: 2.91% (+1.68%)
- 8 WORDPRESS:**  
2019: 0.10% 2020: 2.88% (+2.78%)
- 9 INSTAGRAM:**  
2019: 2.64% 2020: 2.72% (+0.08%)
- 10 FACEBOOK VIDEO:**  
2019: 2.46% 2020: 2.29% (+0.17%)

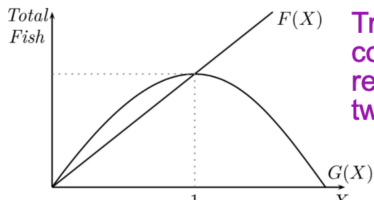
### GLOBAL APPLICATION CATEGORY TOTAL TRAFFIC SHARE

- 1 VIDEO STREAMING:**  
2019: 55.44% 2020: 57.64% (+2.20%)
- 2 SOCIAL NETWORKING:**  
2019: 8.95% 2020: 10.73% (+1.78%)
- 3 WEB:**  
2019: 10.14% 2020: 8.05% (-2.09%)
- 4 MARKETPLACE:**  
2019: 5.90% 2020: 4.97% (-0.93%)
- 5 MESSAGING:**  
2019: 3.79% 2020: 4.94% (+1.15%)
- 6 FILE SHARING:**  
2019: 8.51% 2020: 4.64% (-3.87%)
- 7 GAMING:**  
2019: 2.20% 2020: 4.24% (+2.04%)
- 8 VPN: 2.56%**  
2019: 2.46% 2020: (+0.10%)
- 9 CLOUD:**  
2019: 1.26% 2020: 1.83% (+0.57%)
- 10 AUDIO:**  
2019: 55.44% 2020: 0.39% (-0.39%)

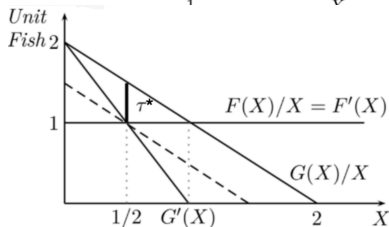
# The Tragedy of the Commons

- ▶ Public areas (e.g. air) lack property rights  $\Rightarrow$  disasters
- ▶ The commons lacks well-defined property rights (Coase fails)
- ▶ Continuum mass of fishermen each allocates hours  $X_A, X_B$  between Lakes A and B, where  $X_A + X_B = \bar{X} > 1$ .
- ▶ Lake A has constant returns:  $F(X_A) = X_A$
- ▶ Lake B has decreasing returns:  $G(X_B) = 2X_B - X_B^2$
- ▶ Every fisherman faces a binary choice: Lake A or Lake B
  - ▶ A fisherman chooses the lake with the higher expected return.
  - ▶ There is a *unique Nash equilibrium* allocation of fishermen:
  - ▶  $F(X_A)/X_A = G(X_B)/X_B \Rightarrow 1 = 2 - \hat{X}_B \Rightarrow \hat{X}_B = 1 = \hat{X}_A$ .
  - ▶ Stable dynamics equalize lake returns in the Nash equilibrium
    - ▶  $X_B > 1 \Rightarrow G(X_B)/X_B < 1 = F(X_A)/X_A \Rightarrow$  exit from Lake B.
    - ▶  $X_B < 1 \Rightarrow G(X_B)/X_B > 1 = F(X_A)/X_A \Rightarrow$  entry to Lake B.
- ▶ Social planner:  $\max F(X_A) + G(X_B)$  subject to  $X_A + X_B = \bar{X}$ 
  - ▶ FOC equates the social marginal returns:  $F'(X_A) = G'(X_B)$ .
  - $\Rightarrow 1 = 2 - 2X_B^* \Rightarrow X_B^* = 1/2 < 1 = \hat{X}$
  - ▶ The lake with diminishing returns is overfished
  - ▶ A Pigouvian tax  $\tau^*$  decentralizes this efficient allocation

# The Tragedy of the Commons



Tragedy of the commons: Average returns equalize on two lakes without taxes

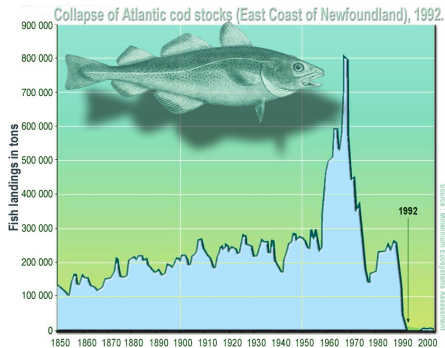


Social planner equates marginal returns on lakes

- ▶  $G(1/2)/(1/2) - \tau^* = F(1/2)/(1/2) \Rightarrow \tau^* = 1/2$
- ▶ Individual decisions are inefficient because they are governed by the social average product and not social marginal product
  - ▶ Drivers ignore the slightly increased driving time they inflict on thousands of others

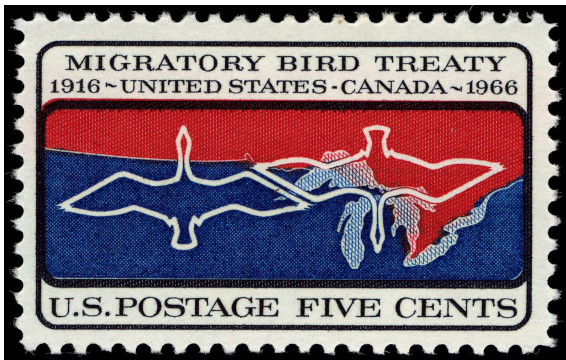
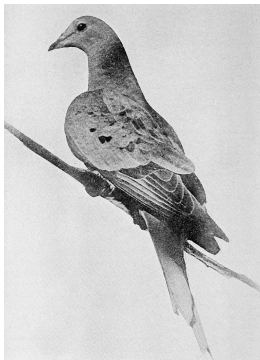
# The Fishing Tragedy of the Commons: Newfoundland

- ▶ If there is a stock variable, the tragedy can be permanent



# Migratory Birds Tragedy of the Commons Never Happened

- ▶ Martha, the last passenger pigeon, died on September 1, 1914, at the Cincinnati Zoo.
- ▶ The Migratory Bird Treaty Act, 1918 banned the possession of migratory birds for commercial purposes
  - ▶ Even casting native bird species in movies is against the law!
  - ▶ A “feather in your cap” is no longer allowed!



# Western Water Tragedy of the Commons

- ▶ California is the second-largest rice-growing state in the US!
  - ▶ Rice grows submerged in 2" of water during the growing season
- ▶ Lake Mead elevation fell from 1,220' (1941) to 1013' (2024)
  - ▶ Chinatown (the 1974 Oscar winner) was about water rights



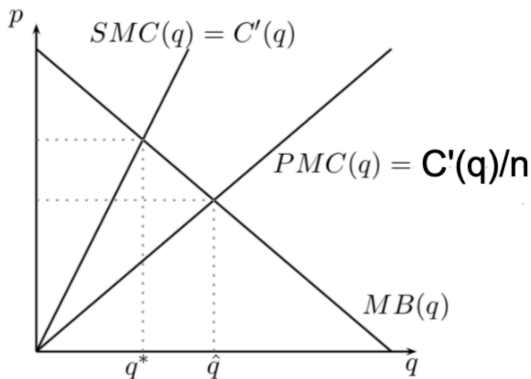


# Disinformation as Pollution

- ▶ Constitutionally guaranteed right to pollute. Implications?

## Group Dining Dilemma

- Assume an agreement or protocol to divide the check equally. can enforce a tragedy of the commons:  $SMC > MC$



- Everyone then equates  $MB = MC$ , the *private marginal cost*.
- FOC is  $MC = C/n < SMC$ , the *social marginal cost*
- Pigouvian tax is “Going Dutch” (paying for their own meal)  
 $\Rightarrow MC = SMC \Rightarrow$  people buy efficient smaller meal  $q^* < \hat{q}$ .



# Electromagnetic Spectrum of Public & Club Goods

**ELF** Extremely Low Frequency  
 Frequency: 3 KHz to 30 KHz  
 Wavelength: 100 km to 10 km

**LF** Low Frequency  
 Frequency: 30 KHz to 300 KHz  
 Wavelength: 10 km to 1 km

**MF** Medium Frequency  
 Frequency: 300 KHz to 3 MHz  
 Wavelength: 1 km to 100 m

**HF** High Frequency  
 Frequency: 3 MHz to 30 MHz  
 Wavelength: 100 m to 10 m

Maritime radio, navigation



Maritime radio, navigation

AM radio, Aviation radio, navigation



Amateur radio, NFC, aviation, weather broadcast

**VHF** Very High Frequency  
 Frequency: 30 MHz to 300 MHz  
 Wavelength: 10 m to 1 m

**UHF** Ultra High Frequency  
 Frequency: 300 MHz to 3 GHz  
 Wavelength: 1 m to 100 mm

**SHF** Super High Frequency  
 Frequency: 3 GHz to 30 GHz  
 Wavelength: 100 mm to 10 mm

**EHF** Extremely High Frequency  
 Frequency: 30 GHz to 300 GHz  
 Wavelength: 10 mm to 1 mm

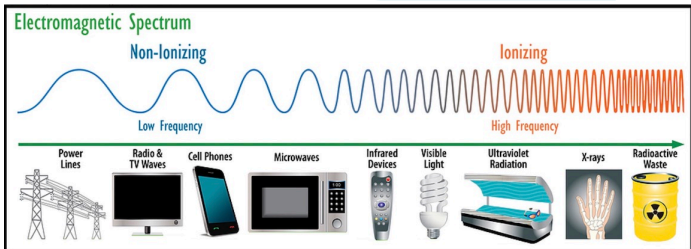
FM radio, VHF television



Mobile, Wi-Fi, GPS, 4G, UHF television

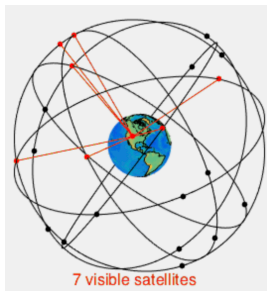


Satellite, 5G, Wi-Fi, Radio astronomy



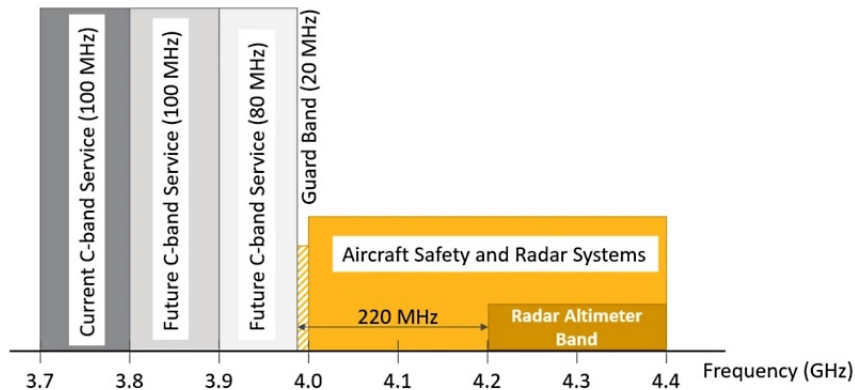
## Examples of Club Goods

- ▶ Fancy golf courses, toll bridges and roads, satellite radio, etc.
- ▶ GPS transitioned from club to public good in May, 2000: government stopped degrading civilian GPS accuracy
- ▶ '78: NAVSTAR Global Positioning System satellites launched.
  - ▶ They circle the Earth at an altitude of 20,000 km and complete two orbits daily (not in a geostationary orbit)
  - ▶ 24 satellites ensure that  $\geq 8$  satellites can be simultaneously seen at any time from almost anywhere on Earth.



# Club Goods in Conflict: 5G vs. Aircraft Altimeters

- ▶ Two parties thought they had property rights!



# Efficient Provision Nonrival Discrete Public/Club Goods

- ▶ Individuals  $i = 1, 2, \dots, n$  have utility  $U^i(G, m)$  increasing in amount  $G$  of public good and  $m$  of private good (money)
- ▶ Extensive margin exercise: Build a pyramid  $G=1$  or not  $G=0$
- ▶ Pareto Efficiency rule:  $G = 1$  if  $\exists$  transfers  $t_1, \dots, t_n$  from consumers paying for it ( $\sum_i t_i \geq c$ ), such that
  - everyone is weakly better off:  $U^i(1, m_i - t_i) \geq U^i(0, m_i)$
  - some  $j$  is strictly better off:  $U^j(1, m_j - t_j) > U^j(0, m_j)$
- ▶ Pareto efficiency is often a very weak social objective
  - ▶ Vilfredo Pareto (1848–1923)  $\Rightarrow$  fascist? If so, **social efficiency**



# Efficient Provision Nonrival Continuous Public Goods

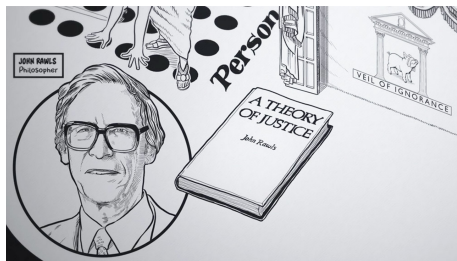
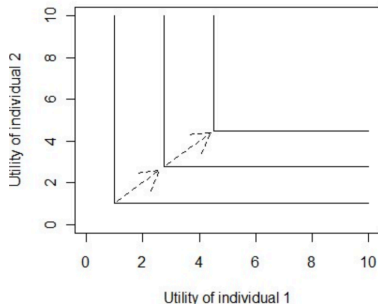
- ▶ We now consider the question of how big to build the pyramid
- ▶ *Pareto efficiency is an ordinal social welfare measure*
- ▶ We need a cardinal social welfare measure to trade off consumers' gains with an intensive margin
- ▶ A social planner, or “society”, derives welfare from utilities  $u^1, \dots, u^n$  like a consumer gets utility out of consumed goods
- ▶ **social welfare function** (SWF)  $W(u^1, \dots, u^n)$  is increasing and quasi-concave



# Rawlsian Social Welfare

- ▶ John Rawls (1921–2002) considered the extreme case of perfect complements SWF:  $W(u^1, \dots, u^n) = \min(u^1, \dots, u^n)$ .

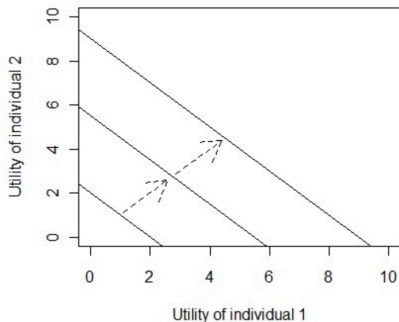
**Rawlsian Social Welfare**



# Utilitarian Social Welfare

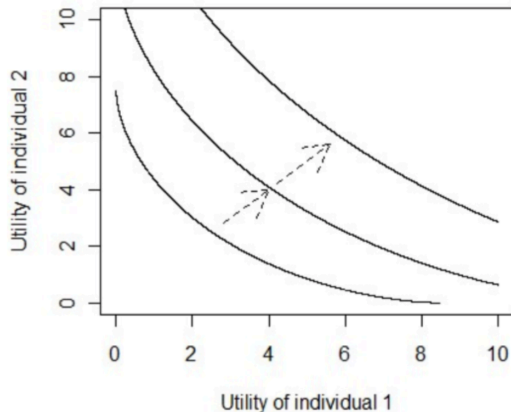
- ▶ Jeremy Bentham (1748–1832): “the greatest happiness of the greatest number is the foundation of morals and legislation”
- ▶ Perfect substitutes SWF:  $W(u^1, \dots, u^n) = u^1 + \dots + u^n$

Utilitarian Social Welfare



# Smooth Strictly Convex Social Welfare

## Strictly Quasi-Concave Social Welfare Function



- ▶ We will assume this case, with smoothness.

WHY ECONOMICS IS  
SO DARN SUCCESSFUL



**ECONOMIC THEORY**

