The Tradeoff of the Commons Under Stochastic Use

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Contents

Research Question

How should renewable common pool resources be allocated?

Why is this important?

Optimal resource allocation is the fundamental goal of welfare maximization

Renewable vs Exhaustive - Background Info

Renewable Resource

Ex: fisheries, bandwidth, seats on an airplane, solar energy

Exhaustible Resource

Ex: oil, coal, metallic ores

*with renewable the goal is to maximize value of usage subject to preventing overuse

Introduction - Background Info

Tragedy of the Commons

- traditional solution is to assign property rights

Common Pool Resource - Background Info

Definition

Good is typically costly to make excludable

Use of good deteriorates quality for the rest of society

(overfishing leads to less fish for everyone in the future)

Common Pool Resource - Background Info

	Excludable	Non-Excludable
Rivalrous	**Private Goods** Food, clothes, cars and other consumer goods	**Common Goods** Fish, timber, coal
Non-Rivalrous	**Club Goods** Cinemas, private parks, satellite TV	**Public Goods** air, national defence

Previous Research - Background Info

McAfee and Miller (2012)

Result is that private ownership is not always the welfare maximizing method to resolve tragedy of commons.

Free use dominates depending on structure of values, costs, and probability of usage intensity.

Coase: Both regimes are efficient under low transaction costs and tradable property rights

Background Info

How is this paper different than McAfee and Miller (2012) ?

Demand for resource given from a distribution vs stochastic demand

Previous model is concerned with loss from coordination failure

Scheduling is impractical - too costly

Problem Statement/Hypothesis

How should renewable common pool resources be allocated?

Model will calculate welfare

Model

N potential users

M resource capacity $M < N$ (implies scarcity)

Individual utility $x(\alpha)$ where α is blocking probability (quality of service)

Q is usage intensity across network, probability usage = 1 (exogenous)

Ex: usage of network checking email vs video conference

Model

Individual Utility:

Xi(α) = A - α - f(N)ε Epsilon st all potential individuals have positive utility

G is inverse normal distribution

Relationship between n and α : as n rises α rises => maximum acceptable α creates n

$$n = \frac{M}{q} - \frac{1}{2q}\left[G(1-\alpha)\sqrt{4M(1-q) + G^2(1-\alpha)(1-q)^2} - G^2(1-\alpha)(1-q)\right].$$

Model

Consider 3 structures

Commons - Allocation of resource is random, equal probability of use regardless of utility

Monopoly - Profit maximizing price those whose utility exceed price become customers (price = pm)

Regulation - Same structure as monopolist with regulation profit = 0

(price = pr)

Model

Social Welfare Equation Under Commons

n(α f) equilibrium # of people

Expected Value

$$W^f(\alpha^f) = \frac{1}{l}\sum_{i=1}^{l} z_i = \frac{1}{l}\sum_{i=1}^{l}\frac{n(\alpha^f)l}{N}x_i(\alpha^f) = \frac{n(\alpha^f)}{N}\sum_{i=1}^{N}x_i(\alpha^f)$$

$$= n(\alpha^f)\left(A - \alpha^f - \frac{\sum_{i=1}^{N} f(i)\epsilon}{N}\right)$$

Model

From: $max_{\alpha^m}(p^m - v)n - K$

st $\alpha^m \leq \alpha^f$

$x_i(\alpha^m) \geq p^m,$

Social Welfare Equation Under Monopoly

Fixed cost: K Variable cost: V

$$W^m(\alpha^m) = \sum_{i=1}^{n(\alpha^m)} x_i(\alpha^m) - [vn(\alpha^m) + K] = \sum_{i=1}^{n(\alpha^m)} (x_i(\alpha^m) - v) - K$$
$$= \sum_{i=1}^{n(\alpha^m)} (A - \alpha^m - f(i)\epsilon - v) - K.$$

Payment from customer to monopolist is cancelled out

Model

Social Welfare Equation under regulated firm

Same maximization problem with Profit = 0 constraint

$$W^r(\alpha^r) = \sum_{i=1}^{n(\alpha^r)} x_i(\alpha^r) - p^r n(\alpha^r) = \sum_{i=1}^{n(\alpha^r)} (x_i(\alpha^r) - v)$$
$$- K \sum_{i=1}^{n(\alpha^r)} (A - \alpha^r - f(i)\epsilon - v) - K.$$

Propositions - Tradeoff

Prop1

N regulated > N monopoly

Welfare regulated > Welfare monopoly

Propositions

Prop 2: Low Intensity → High LHS

$$\frac{\partial}{\partial \alpha} \ln n(\alpha) > \frac{1}{x_N(\alpha) - v}$$

Condition for

Quantity effect > Quality effect

How tolerant customers are to degradation and variable cost

Propositions

Prop 3

When costs (V&K) are high free use is more socially efficient than priced regime

If costs are neither too high or low, (αf) determines structure dominance.

αf = Maximum acceptable degradation

Low degradation favors free use

Extensions - Complicate the model

Frequency Reuse

Channel Bonding

Mixed Service

Bertrand Competition

Extensions - Reuse Frequency

Wireless Spectrums:

Macro cells - 4G

Micro cells - Wifi (Θ # of cells)

N/Θ $N(\alpha r)$ $N(\alpha f)$ How these three numbers relate determines optimal regime

Conditions to make free use bandwidth optimal are easier under micro architecture (less blocking)

Extensions - Channel bonding

Under licensed structure (no free use)

Take unused bandwidth and combine it into a aggregate unit for free use

Additional users will increase more than linearly

Economies of Scale

Ex: Cognitive Radio

Extensions - Mixed

Suppose it is possible to split resource.

Half with minimum degradation for payment and half free use no quality guarantee

$$W^{MS} = \left(A - \alpha^r - \frac{(N^* - 1)\epsilon}{2}\right) N^* - \nu N^* - K + n(\alpha^f)\left(A - \alpha^f - \frac{(N^* + N - 1)\epsilon}{2}\right)$$

When optimized the mixed is never worse than regulation

Mixed VS free use depends on v

V also determines portion of resource for each structure

Extensions - Competition

Under Bertrand competition profit will be zero but fixed cost will be paid more than once

A regulated Monopolist is more efficient than bertrand competition

^given quantity effect dominates (regulated monop > pure monop)

*With simple cost mechanisms (no production)

Conclusion

The usage pattern and resource characteristics determine the optimal structure to resolve the tragedy of the commons

Conclusion

1 If costs of implementing a pricing mechanism are large free use is better

2 If likelihood of service degradation is low free use is also better

Conclusion

When privatization is better the choice between monopolist and regulation

Hinges on which effect dominates the quality or quantity effect.

Light usage and small service cost make quantity effect more powerful and make regulation better.

Implications

Wireless architecture infrastructure - bluetooth, wifi, radio

The correct property structure is different based on suitability of different spectrums

Most spectrum is the result of fragmented licensing over many years and likely suboptimal in hindsight

References

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