# What does economics have to do with survivability?

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InfoSurv Tutorial

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# Architectural Principles (Econ)

- Decision problems are scarce resource allocation problems
- Systems are only as good as their *users* think they are

# Design problems are scarce resource allocation problems

- ✔ Decisions are choices to employ a limited resource for one purpose in lieu of others
- ✔ Including responses to disruptions
  - disruptions change absolute and relative scarcity of system resources

# Consumer Sovereignty

- Example: engineer network to fixed standards for packet loss and max delay
- Problem: Users perceive tradeoffs between loss, delay and cost
  - at some times, will prefer more or less packet loss in exchange for something else

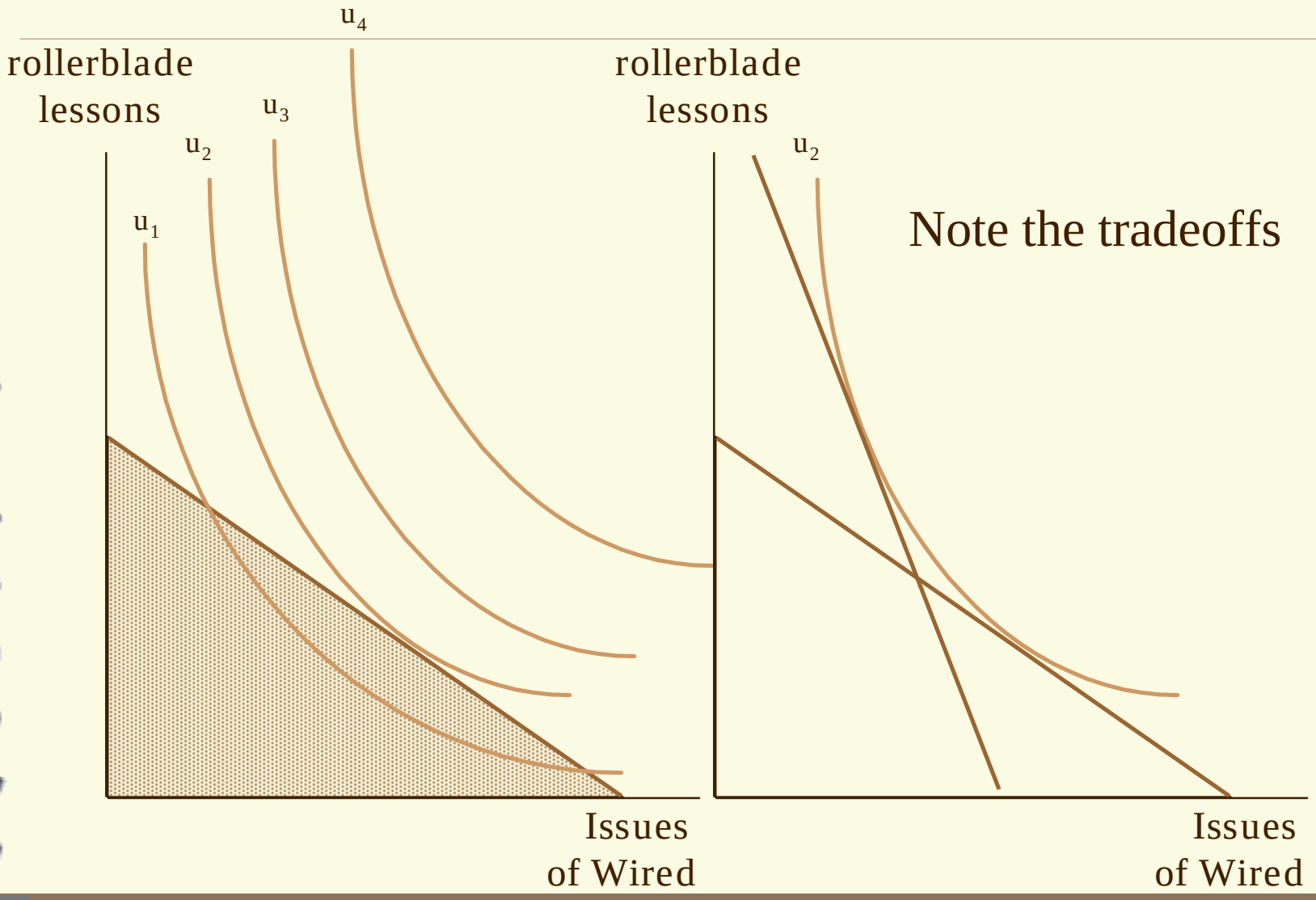
# Consumer Sovereignty II

- Example: Design service classes for specific apps (e.g., class 1 for video; class 2 for audio; best efforts for email),
  - and set prices for service by app
- Problem: Ignores essential heterogeneity in customer preferences
  - across users
  - across time

# Consumer problem

- Preferences represented by $U(x_1,x_2,\ldots,x_N)$
  - assumes preferences are:
    - complete, transitive, continuous
    - other useful assumptions: local nonsatiation and convexity (diminishing marg. rates of substitution)
- Solve: max u(x) over $x \geq 0$
  - subject to $F(x) \leq 0$
  - F(X) are constraints: budget ($p'x \leq m$)
  - and technology (e.g., $x_1 \leq 24$, for $X_1$ calling hours/day)

# Consumer problem



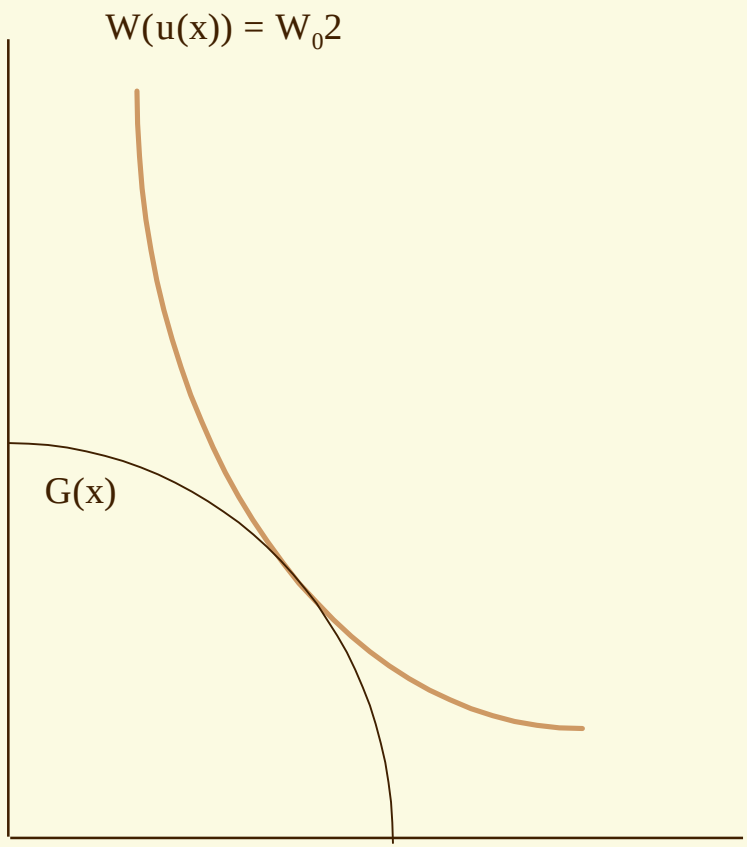

Note the tradeoffs

# Social Welfare Maximization

- How to aggregate individual utilities, and evaluate overall system performance?
- SWF = $W(u_1,u_2,\ldots,u_T)$
  - W allows for central evaluator's weighting of different individuals, and nonlinearities or interactions between them
- max $W(u_1,u_2,\ldots,u_T)$
  - subject to $G(x) \leq 0$
  - G(x) are constraints (technology and budget)

# Social Welfare Max II

- Focus on tradeoffs:
  - between resource users: reallocate until taking ε from me to give you hurts me more than it helps you (wtd. appropriately)
  - between resources: transform $x_1$ into $x_2$ until incremental user benefit from more $x_2$ just less than user loss from less $x_1$



# Survivability as a social welfare maximization problem

- **Survivability is not 100% fault tolerance**
  - ignores the cost -- generally users will be willing to accept some faults in exchange for cost savings
  - resources *will* be lost or degraded from time to time
- **Ideal system** is configured so that at any given instant, it provides the **best allocation** of resources
- Survival response is to move sufficiently quickly to **new best allocation** for reduced resource set

# Survivability II

- Note: “best allocation” must be measurable as a function $W(u_1,u_2,\ldots,u_T)$
- Note: Focus is on making trade-offs: doing the best possible with whatever is left

# What do market mechanisms have to do with SW-max?

- Suppose individual $U^i(y,x) = y + u(x)$, where y is "money remaining"
- max $y + u(x)$  s.t. $y + px = m$
- or, max $u(x) + m - px$
- FOC: $u'(x) = p$
- MARKET: "Take more of x, until incremental cost (p) is greater than incremental benefit"

# SW-max: Case of Pareto Efficiency

- Pareto Welfare Criterion: Cannot make any agent better off without reducing utility of at least one other agent
- Suppose allocating fixed (x,y) between 2
- max $y + u_1(x_1)$
  - subject to: $u_2(x-x_1) + (y-y_1) = u_2^0$
- FOC: $u_1'(x_1) = u_2'(x_2)$
- NB: Individuals optimizing in market set $u_1'(x_1) = p_x = u_2'(x_2)$

# SW-max II

- So, if it exists, a competitive equilibrium is Pareto efficient
- And, monotonicity and $u_1'(x_1) = u_2'(x_2)$ imply there is a p* that implements any PE as a competitive equilibrium
- These results generalize: 1st and 2nd Welfare Theorems
- Distribution of endowments determines which PE allocation is selected

# SW-max in General

- What if PE is necessary, not sufficient for SW-max?
  - By monotonicity of $W(u_1,u_2,\ldots,u_T)$, any W* must be PE
  - *So, every SW-max is a competitive equilibrium for some distribution of endowments*
- So, first step towards static SW-max is to ensure allocation is a competitive equilibrium (don't have to use market to find)

# Implications for Survivability

- The comp. equilib. prices are the Kuhn-Tucker multipliers (shadow values) of the SW-max problem
- A disruption changes the resource constraints
  - solve for new $\lambda^*$ (shadow values)
  - set $p_{new} = \lambda_{new}^*$ and reallocate accordingly

# What do we gain from markets?

- In part, have so far said SW can be stated as a math programming problem, and then the optimal allocation can be found by direct solution
  - Why use markets?

# What do we gain II?

- Central solution requires:
  - full knowledge of each u()
  - full info on local prodn. or tech. Constraints
  - huge computation and low latency communications burden
- Competitive markets:
  - distributed intelligence approach for solving SW-max problems
  - local info
  - local optimization

# Our Tasks

- ✔ Specify our problem(s) as (static?) competitive allocations
  - agents
  - resources
  - mechanisms
- ✔ Introduce dynamics
  - time dimension for resources
  - time dimension for agent preferences
  - dynamic mechanism: getting from one state to another

# Some problems

- Dimensionality of resource vector
  - time granularity
  - multiple quality dimensions
- Resource transformations
  - e.g., do comms users buy services, or buffers and bandwidth at each node?
- Strategic behavior
  - market power
  - asymmetric information

# More problems

- Transaction costs
- “Secret Agents”

# Architectural suggestions

- ✔ Let agents & market decide when to make new markets.
- ✔ No scarce resources should be given for free.
- ✔ Convexity, competition, complete info