AI-driven Prices for Externalities and Sustainability in Production Markets

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- Market theory: Competitive markets will reach a **market equilibrium**
- Do not account for **negative externalities**
  - Resource depletion due to overuse, Pollution from burning fossil fuels
  - Water pollution from industrial effluents, Antibiotic resistance due to overuse of antibiotics

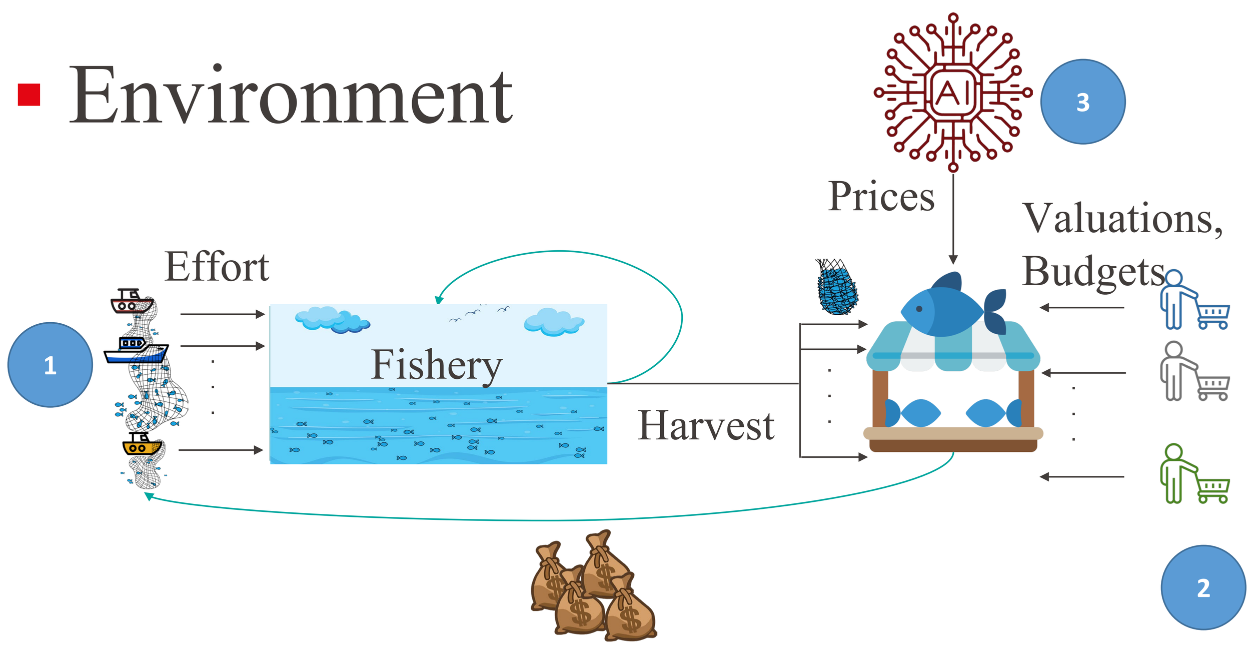
➢ Market failure

- Quantifying the appropriate intervention is quite challenging!
  - Large and complex environments, no observability, repeated interactions

Road to impact: Reinforcement Learning for *policy design*

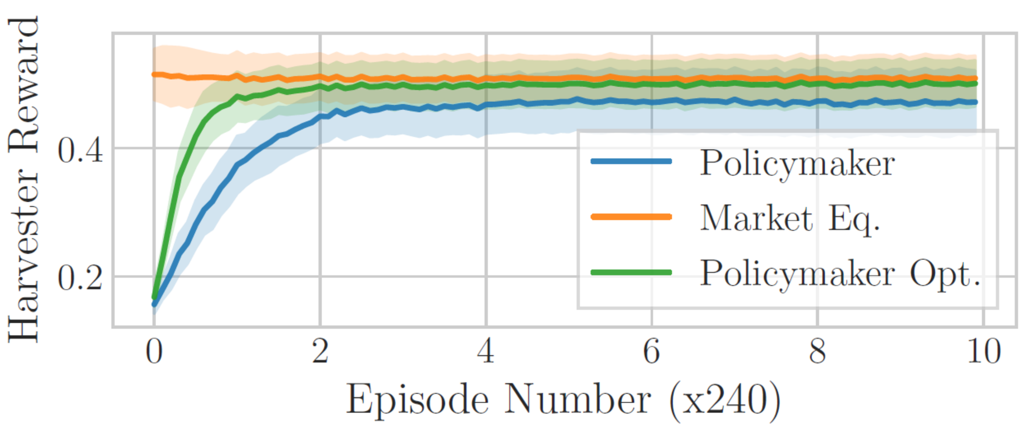
- Next field to be disrupted by AI: Economics
  - Traditionally: provably optimal solutions, but on simplified models
  - Alternatively: experimentation (via tuning of the parameters and simulating the multi-agent environment) to find the best possible policies

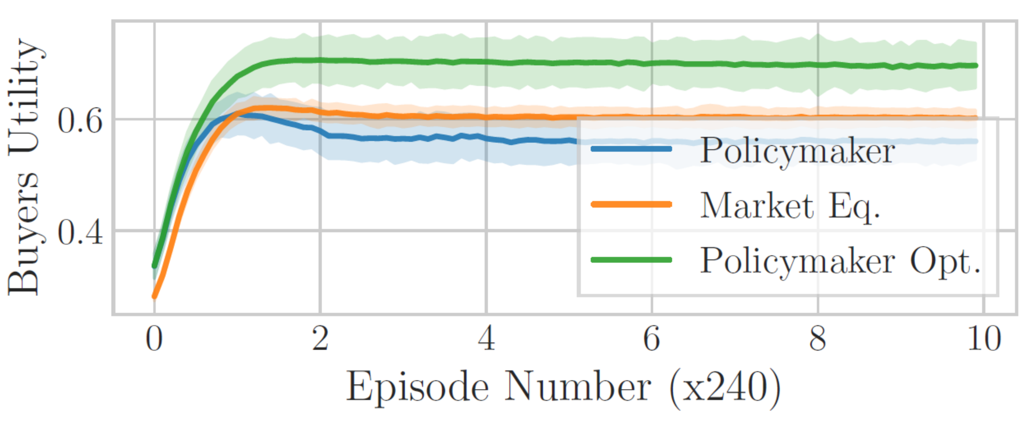
- Environment

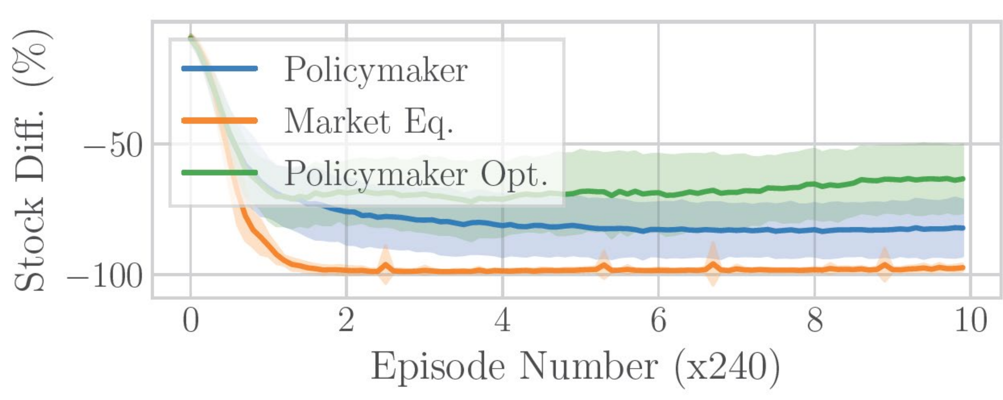


- Theorem: If the **budget is large enough**, market equilibrium prices can irrefutably lead to the **depletion** of the resource, under **optimal harvesting**.
  - No closed form expression for optimal harvesting.
  - Preventing depletion requires knowledge of the max/min budgets.
  - Motives use of RL instead!

- Results







- **Policymaker Architecture**
  - Observations (obfuscated): effort, stock, budgets, valuations
  - Output: vector of prices
  - Multi-objective optimization

$$w_h \frac{1}{|\mathcal{N}|}\sum_{n\in\mathcal{N}} \boldsymbol{u}_{n,t}(\cdot) + w_b \frac{1}{|\mathcal{B}|}\sum_{b\in\mathcal{B}} \boldsymbol{u}_{b,t}(\cdot) + w_s \min_{r\in\mathcal{R}}\left(\min(s_{r,t} - S_r^{eq}, 0)\right) + w_f Fair(\mathbf{x})$$

- **Robust** & **scalable**!
  - Cumulative harvest per resource
  - Split buyers into classes

- Policymaker is about 7% on average worse than the market eq. prices
  - Optimizing specifically for social welfare closes the gap!
- **Significantly** and **consistently** more **sustainable** harvesting strategies
  - Up to **35% improvement** compared to the market equilibrium prices (MEP)
  - MEP deplete the resources in ≈10% of the episodes, while the policymaker depletes the resources in ≈2% of the episodes

- **Full paper / Code:**

- **Acknowledgement:**

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