DISSERTATION PROPOSAL

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"Dynamic Market Design in Environmental and Energy Economics"

Friday, November 14, 2025
2:30pm
Tepper 4219

Electricity and carbon policies unavoidably confront intertemporal trade-offs: carbon accumulates into stocks, permits can be banked across periods, and discharging batteries today limits tomorrow's capacity. Yet many policy instruments treat these dynamic problems with static, uniform rules. In this dissertation, I study three questions: How should international climate agreements be designed when emissions create stock externalities? How does initial allocation design affect trading behavior when firms can bank permits intertemporally? And do capacity markets that compensate storage identically to conventional generators distort dispatch and reduce efficiency?

Chapter 1: Optimal Climate Agreements as Delegation with Externalities: The Case of Dynamic Carbon Production (*joint with Ali Shourideh*)
International climate agreements must delegate emission decisions to countries with private preferences while managing global environmental costs that accumulate over time. We characterize optimal dynamic climate agreements using mechanism design theory with a continuum of heterogeneous countries and stock externalities. Building on Harstad's (2012) framework, we establish two main results. First, optimal agreements exhibit a cutoff structure where high-emission countries bunch at period-specific caps while low-emission countries receive flexibility. Second, we derive necessary and sufficient conditions for when simple "total carbon budget" mechanisms achieve optimality: only when emissions either do not accumulate across periods or when discount factors satisfy a specific relationship with accumulation rates. Outside these conditions, optimal agreements require period-by-period caps rather than flexible multi-year budgets. Our analysis identifies when international climate frameworks should impose annual emission limits versus flexible carbon budgets, directly informing ongoing policy debates about Paris Agreement architecture.

Chapter 2: Free Allocation, Trading Frictions, and Market Efficiency in Emission Markets *(joint with Robert A. Miller)*
The EU ETS initially gave 90% of carbon permits free to incumbents but is now transitioning to full auctioning. We study whether free allocation reduces efficiency by discouraging trading and creating thin markets. Using EU ETS transaction data, we show that firms receiving free permits trade less frequently, concentrating activity among financial intermediaries who account for over half of transactions despite no compliance obligations themselves. We develop a dynamic structural model of production, banking, and trading decisions under participation costs to estimate efficiency losses from misallocation across heterogeneous emitters. Simulating full auctioning counterfactuals, we quantify whether eliminating free allocation improves welfare by expanding liquidity or whether transaction frictions prevent efficiency gains. This tests whether initial allocation matters under Coasean bargaining with non-trivial trading costs, informing market design for spectrum, water rights, and resource allocation broadly.

Chapter 3: Compensating Flexibility: How Capacity Markets Distort Battery Storage Dispatch
As grids transition to renewable energy, battery storage plays an increasingly important role, yet capacity markets compensate batteries identically to conventional generators despite fundamental differences. Unlike coal or gas plants that can produce whenever called upon, batteries have limited stored energy and

must optimize when to discharge. Current capacity markets pay batteries fixed amounts for being available during peak hours, ignoring this intertemporal constraint. Using operational data from Great Britain, I study whether this uniform compensation causes batteries to withhold discharge during high-value periods and to miss opportunities to absorb excess renewable generation. I develop a structural model of battery dispatch under energy capacity constraints to estimate how capacity rules distort behavior and simulate alternative payment designs including performance-based and time-differentiated compensation. This research tests whether treating resources with different capabilities uniformly reduces efficiency when intertemporal constraints matter.