



# Modeling Banks' Payment Submittal Decisions

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PAYMENT AND SETTLEMENT SIMULATION SEMINAR  
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# Orientation



- NISAC is a core partnership of Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL), and is sponsored by the Department of Homeland Security's (DHS) Information Analysis and Infrastructure Protection Directorate.
- NISAC program is charged with understanding 14 critical infrastructures and their interactions for U.S. DHS
- We depend on engaging experts who design and operate infrastructures. We've been especially fortunate in developing contacts in banking and finance
- We look for models that capture common features of many infrastructures, and are therefore more abstract than industry models



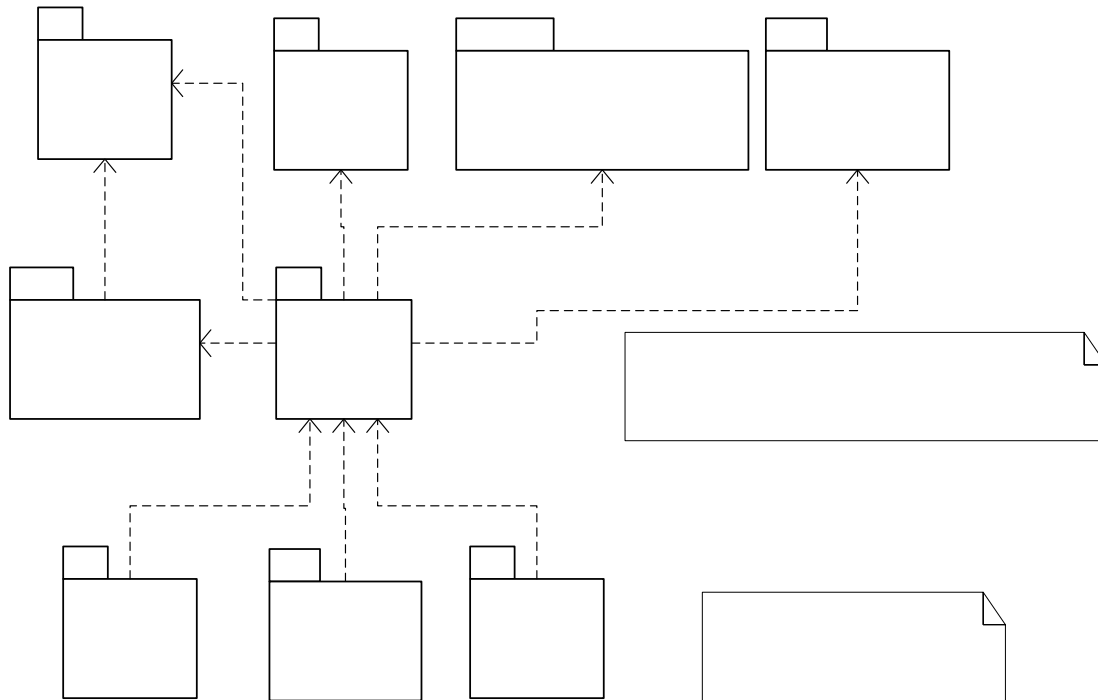
# Project Goals

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- Understand possible responses to unusual conditions
- Try to capture the complex dynamics as adaptive responses to constraints
  - Does the ability to adapt make systems more robust?
  - Are adapted states especially dependent on specific constraints or regularities?
  - Is adaptation itself a source of novel conditions?



# Polynet Model Features



- Designed to support models of diverse systems characterized by network interactions
- Defines supporting classes which can be extended and specialized
- Draws on other open libraries



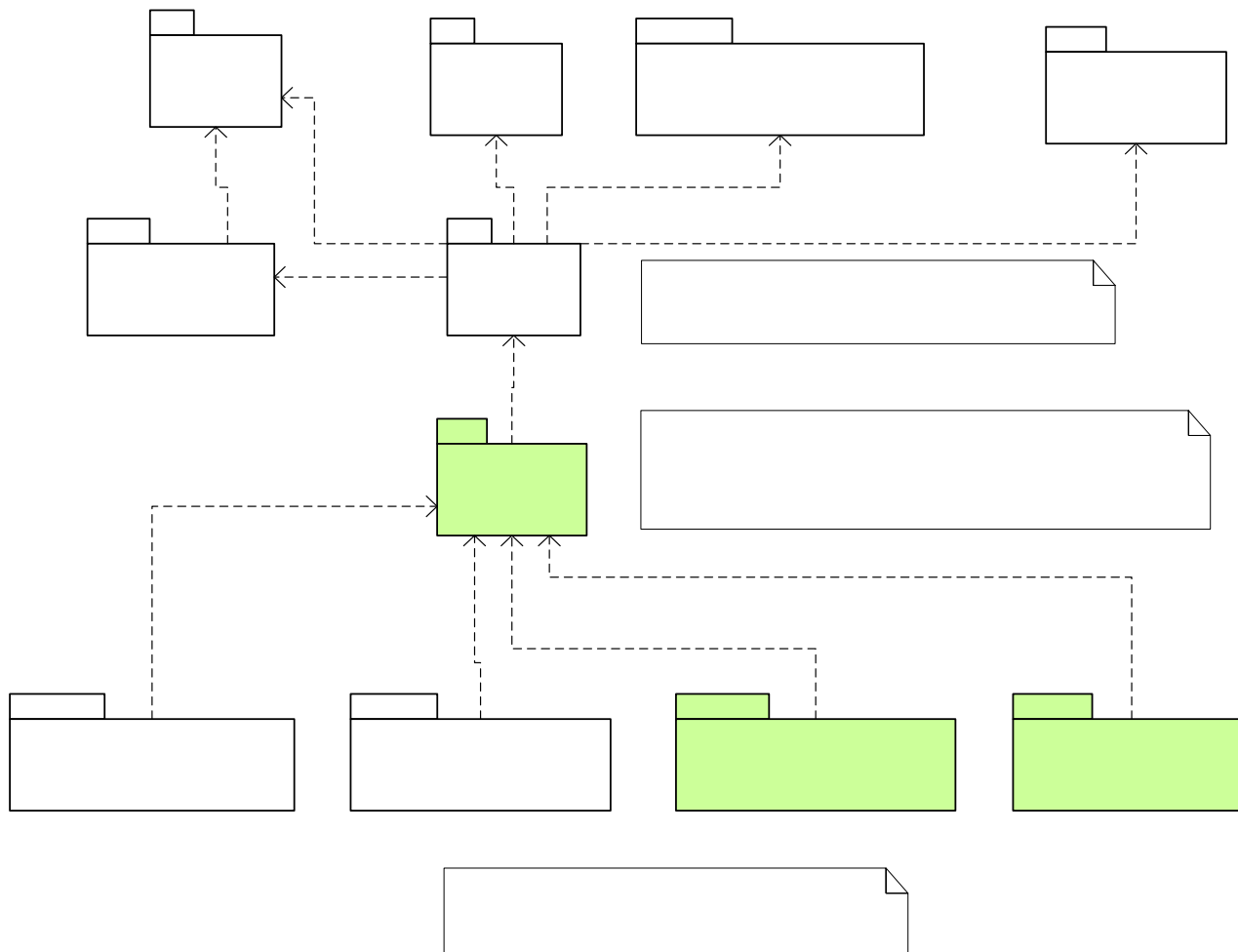
# Hypotheses

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- Adaptive banks become better over time
  - i.e. learning actually takes place. Successive iterations reduce total costs of settlement for a system consisting of adaptive banks of a type
- Adaptive banks become good in a homogenous environment
  - a system consisting of trained adaptive banks of a type has lower average total costs than systems consisting of reference banks
- Adaptive banks become good in a mixed environment
  - in a system consisting of adaptive banks of a type and reference banks of any type, adaptive banks become better over time and better than the reference banks



# Structure Supports Diverse Models of Decision Making



**jaxb**



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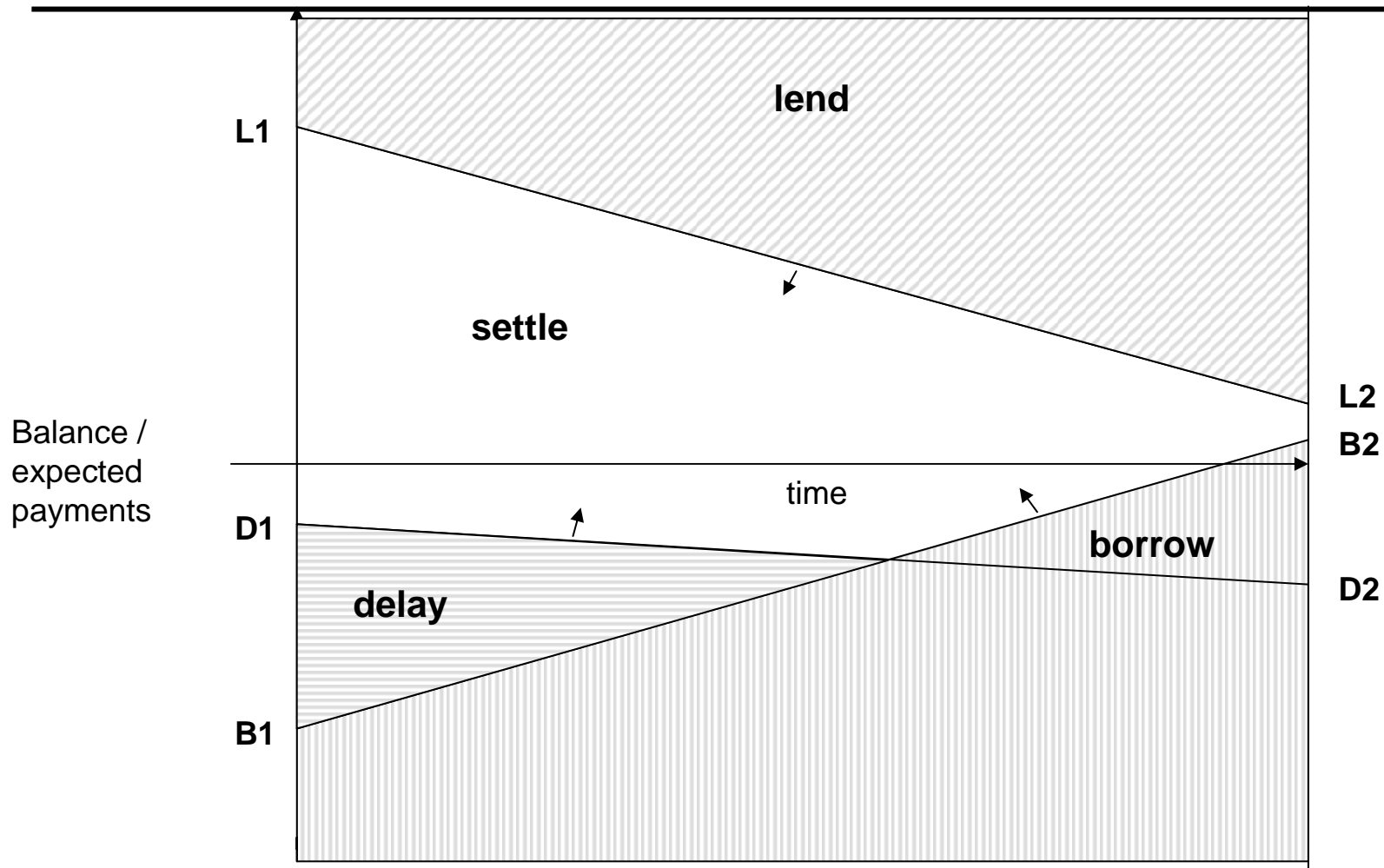


# Strategies

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- Adaptive strategies (learning takes place)
  - GENETICBANK is a bank learning through the process of a genetic algorithm
  - CLASSIFIERBANK is a bank learning through a classifier system
  - HEURISTICBANK is a bank that follows the heuristic rules described
- Static reference strategies (no learning)
  - DELAYBANK is a bank following a pure strategy of delaying all payments and settling them at the end of the day (with end-of-day funding/defunding)
  - ODBANK is a bank that follows the pure strategy of settling all payments immediately (with end-of-day funding/defunding)
  - TITFORTATBANK is a bank that sends its first payment immediately and always delays subsequent payments until the time it receives funds (with end-of-day funding/defunding).

# Heuristic Bank Decision making







# Rules for settlement

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- Banks settle arriving payments immediately if balance is above line D1-D2 and no payments are in queue
- Banks settle queued payments in FIFO order if balance is above line D1-D2
- Banks place arriving payments at the end of the queue if balance is below line D1-D2



# Borrowing and lending

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- Rules for borrowing and lending
  - banks post a bid to borrow if balance is below line B1-B2
  - banks post an offer to lend if balance is above line L1-L2
  - the amount posted is  $|\text{balance-threshold}|$  rounded up to the next million
  - once a bid or offer is made, the bank cannot participate in the market for a given time-interval\*
  - banks withdraw all unmatched bids and offers if a payment arrives first (and make a new decision as above)
- Initially bids and offers are given on a fixed interest rate
- Subsequently
  - The price will be something the banks learn and adapt to
  - Bids and offers will be matched to form a payment or a series of payments
  - Unmatched bids and offers will stay on the board until matched or withdrawn

\* to prevent too many transactions and at the same time allow for continuous decision making

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# Cost Components



- Delay - proportional to time between arrival and execution using an implicit interest rate that reflects customer displeasure
- Intraday Overdraft - charged continuously at a specified rate
- Failure - charged at a specified rate for all payments remaining at the close
- Overnight Overdraft - charged at a specified rate for any negative balance
- Borrowing - paid at a specified funds rate plus a spread and a fixed transaction cost
- Lending - received at a specified funds rate minus a spread plus a fixed transaction cost

# Costs and remedies

Cost		Parameter					
		L1	L2	B1	B2	D1	D2
delays	intraday	↑	↑	↑	↑	↓	↓
	overnight	↑	↑	↑	↑	↓	↓
borrowing	intraday CB	↑	↑	↑	↑	↑	↑
	overnight CB	↑	↑	↑	↑	↑	↑
	overnight market	↑	↑	↓	↓	↑	↑
lending	overnight CB	↑	↑	↑	↑	↑	↑
	overnight market	↓	↓	↑	↑	↑	↑
	funds transaction	↑	↑	↓	↓		

↓ reduce value    ↑ increase value

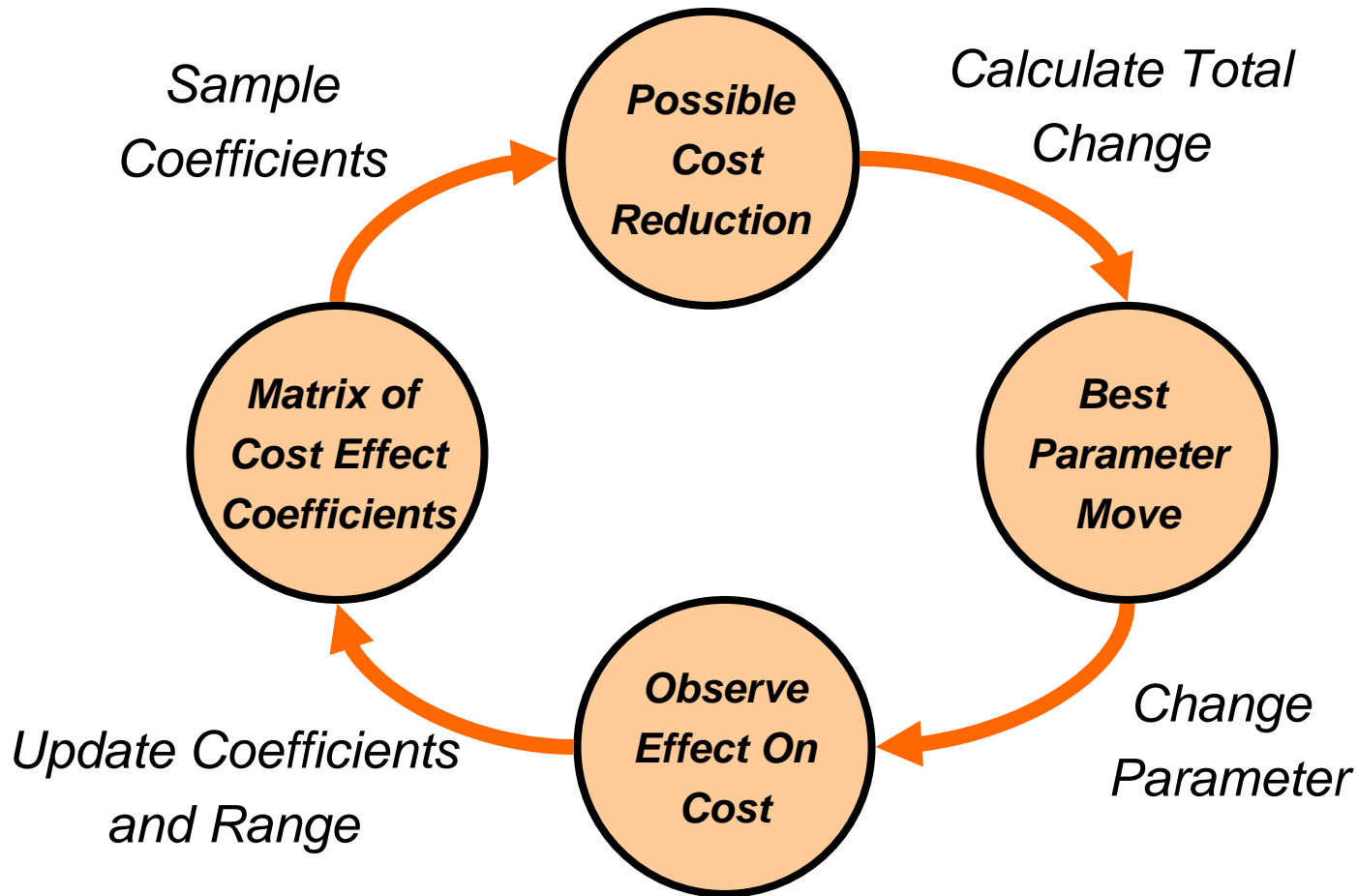
The direction a parameter should be moved in order to decrease a cost

**Only effective if lending occurred**

**Only effective if borrowing occurred**

**Only effective if payments were delayed**

# Adaptive Process





# Limitations on Adaptation



- Nothing but balance governs decisions
- Response size is fixed and does not depend on cost gradient
- Uncertain environment rich with feedbacks; effects of parameter changes are difficult to discern amid the noise
- Response based on local sensitivities
- Learn on recent experience but forget past

- Simple system with:
  - 9 banks
  - 1500 payments per bank per day
  - Lognormal payment size, mean = 1, sigma = 1

<i><b>Funding Mechanism</b></i>	<i><b>Rate</b></i>	<i><b>Period</b></i>
Daylight overdraft	0.36%	Duration of overdraft
Overnight overdraft	5%	24 hours
Delay	0.18%	Duration of delay
Failure	6%	24 hours
Federal funds	4.5%+transaction fee	24 hours

- Comparison of reflexive strategies with adaptation
- Comparison of adapted strategies across banks



# Performance of Reflexive Strategies



## Percentages

		<i>Contributors</i>			
Strategy	Total Cost	Delay	Intraday OD	Transaction	Funding
Delay	<b>0.0018</b> <b>(0.0022)</b>	21%	<1%	7%	72%
Pay	<b>0.0014</b> <b>(0.0022)</b>	<<1%	2%	8%	90%
Tit-for-Tat	<b>0.0018</b> <b>(0.0022)</b>	20%	<1%	7%	73%

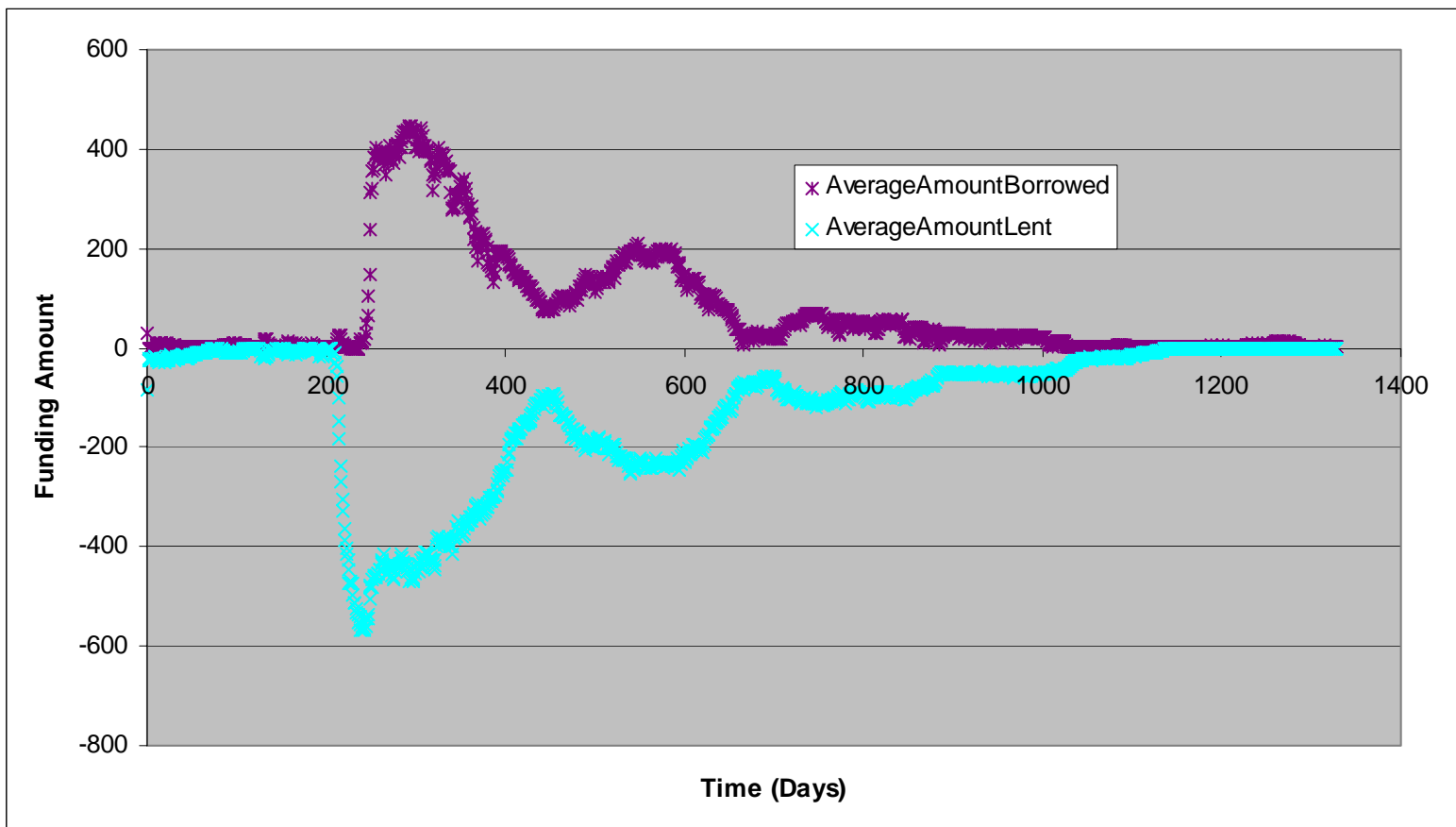
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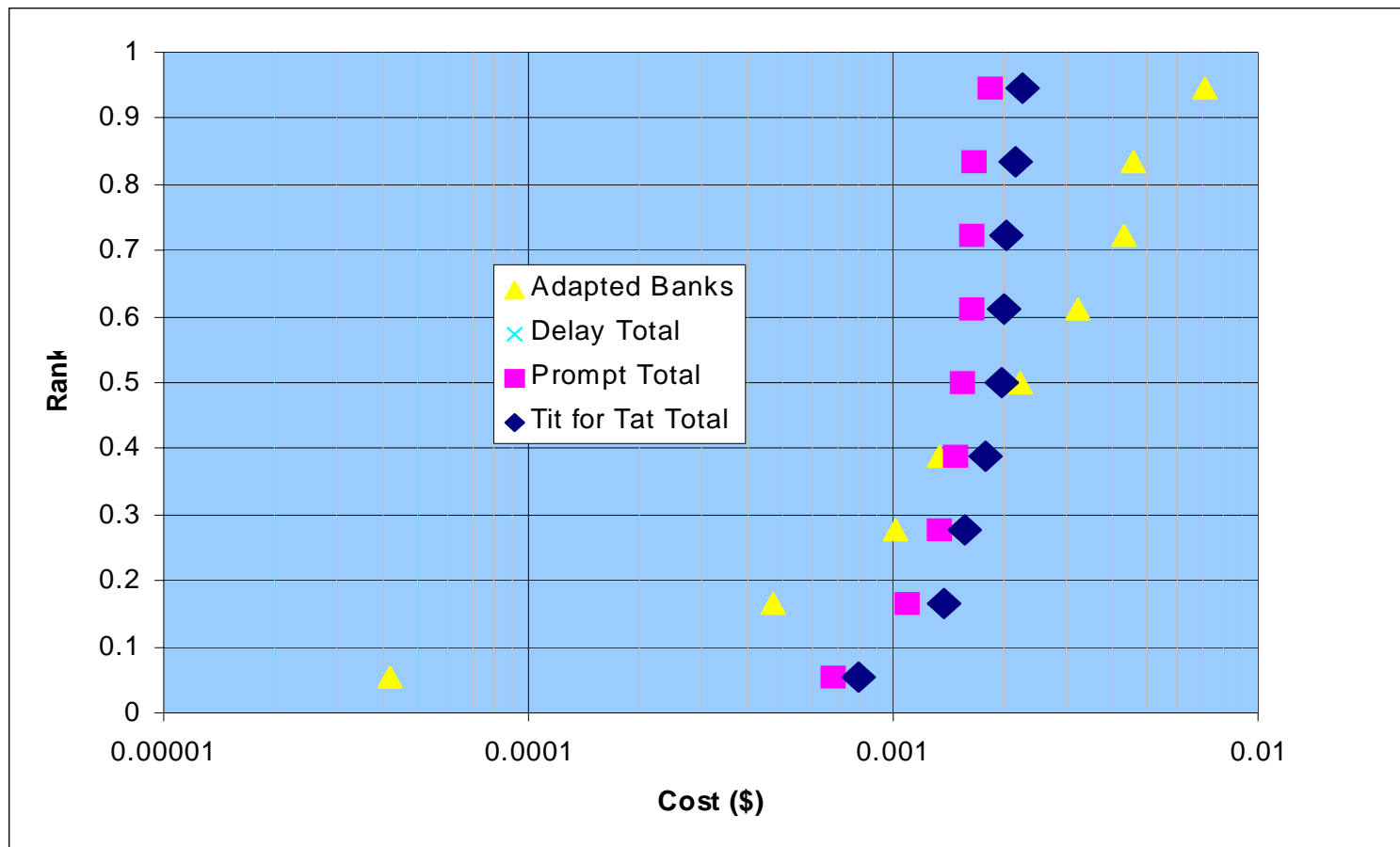


# Good Results for A Single Learner

## Funding

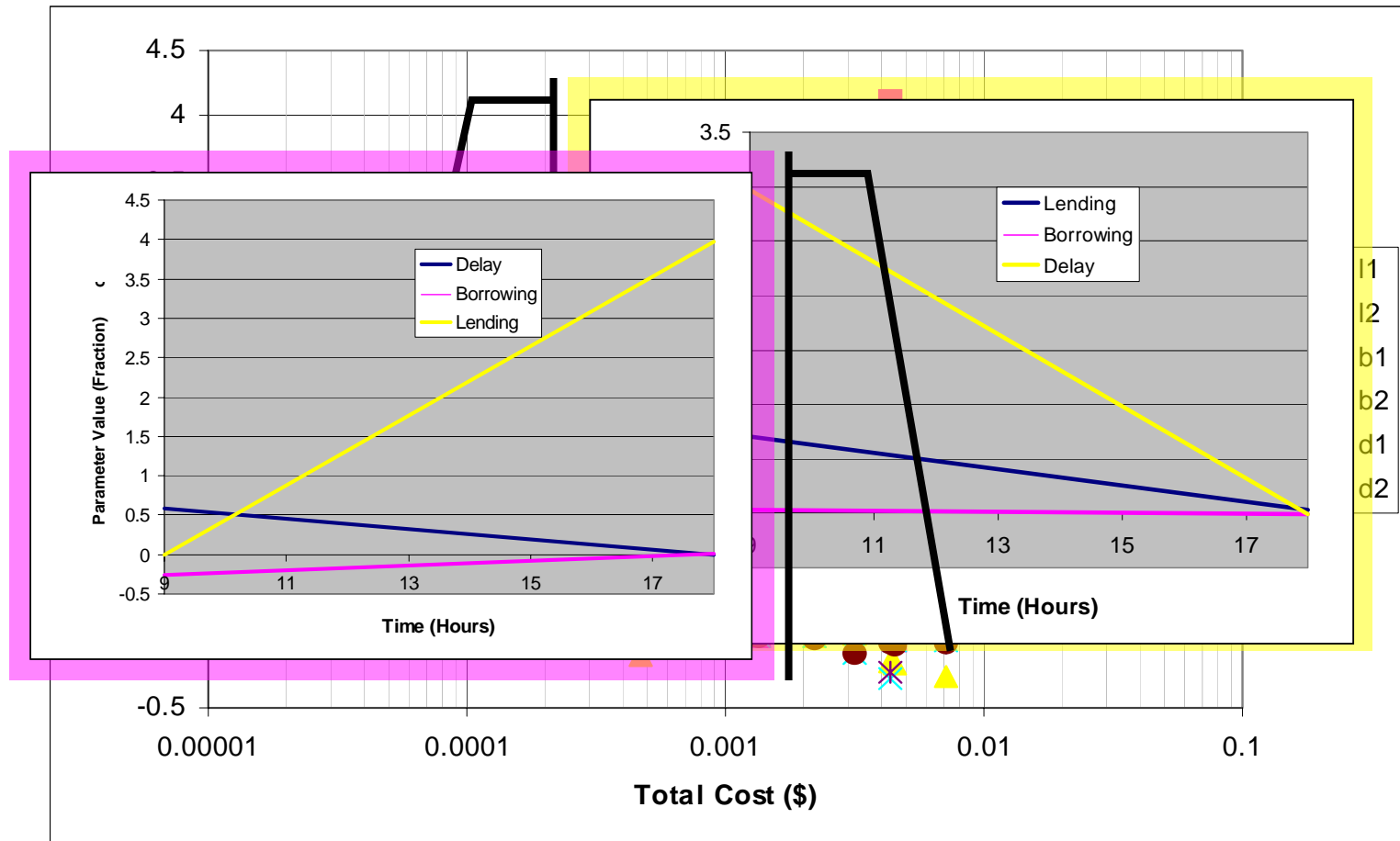


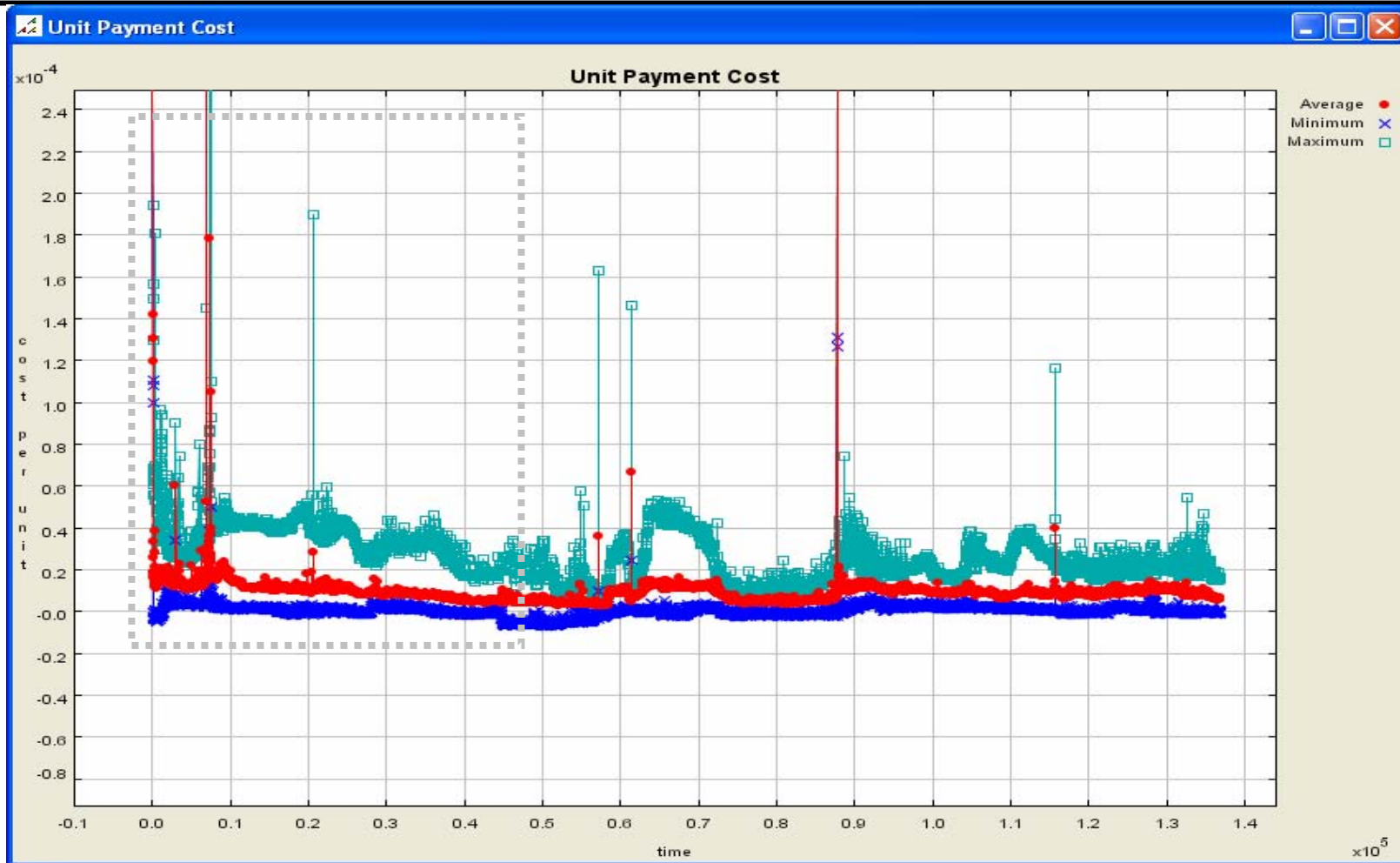
# Final Cost Distributions





# Comparison of Adapted Strategies







# Preliminary Conclusions

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- Cost matrix must be complete and responses should be monotonic, considering all side effects. Deficiencies will be discovered and exploited
- Cost function strongly depends on behavior of correspondents
- Gradient following is unlikely to lead to a good solution. A more robust search is likely to perform better. Neural networks are appealing because they can shift among modes, and this strategy complements other adaptive methods we have implemented
- Simultaneous parameter changes (e.g. raising L2 and lowering B2) may be needed to reduce costs. The current implementation cannot discover these moves
- Current balance information alone may not be enough to inform a cost-minimizing decision





# Next Steps

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- Heuristic model
  - Constrain parameter values to narrow the search and better align with cost gradients
  - Experiment with alternative search strategies including multiple parameter changes and slower response times
  - Distinguish counterparties and provide for performance awareness
- Include simple funds market
- Evaluation of less intuitive decision formulations (genetic algorithm, classifier system, etc.)