Modernizing Payments Research

Using machine learning and panel methods to help design wholesale payments systems

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These views are the views of the author and not necessarily those of the Bank of Canada

Introduction

What is a current focus of Large Value Payments Research

Typical large value payment system research has dealt with a few main problems about the *operation* of a single payment system or FMI.

- Assessing risk
  - Operational risk
  - Liquidity risk (Li [2019])
  - credit risk (Cruz [2019])
- Detecting network structures amongst participants (Soramäki et. al. 2007)

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But the focus of payment system research needs to change to *designing* payment systems

The way people pay is changing fast

The environment of payments systems has changed over the last 10 years

- New regulatory environment (Basel III, PFMIs)
- Current systems are very old
  - CHAPS (80s)
  - Fedwire (80s)
  - LVTS "new" (late 90s)
- New technologies to use in conjunction with payment systems
- Central banks modernising their wholesale payment systems

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- *Problem*: historical data were generated under different rules, behaviour of participants will surely change

Hard Problems for payment system design

- Each research team only sees one system. Causality and identification are problematic
- Richer economic models are needed. Solving the models becomes very difficult very quickly

Outline of talk

A new focus on payment system research needs new technologies

- Panel data to help design system Features
- Machine learning to design payment systems (and use payment system data)

Panel Data

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Panel data is a way to solve all this!

CPMI Expert's Group for Payment System Liquidity Efficiency

- Solution is to setup a dataset of comparable measures across many different
- For over the past year a group of central bank researchers have been working toward this goal
- Goal is to understand what the effects of different characteristics have on LVPS using a panel data set of comparable measures

Research Question

- This group's purpose is to study how different features of wholesale payment systems affect the liquidity efficiency of the system
- We intend to do this by constructing a set of aggregate measures that are both comparable and non-sensitive enough to be shareable in the group

Measures

Key is to build measures that are computable, comparable, and shareable across systems

Liquidity A measure of how many payments were made in a day relative to the liquidity available in the systems

Timing (coordination) A measure of how coordinated payments were during the day

Distribution of liquidity A measure of the "inequality" of liquidity in the system

Model

Currently we are developing a panel data model to estimate liquidity (y) as a function of system characteristics (X) controlling for behaviour (D, T)

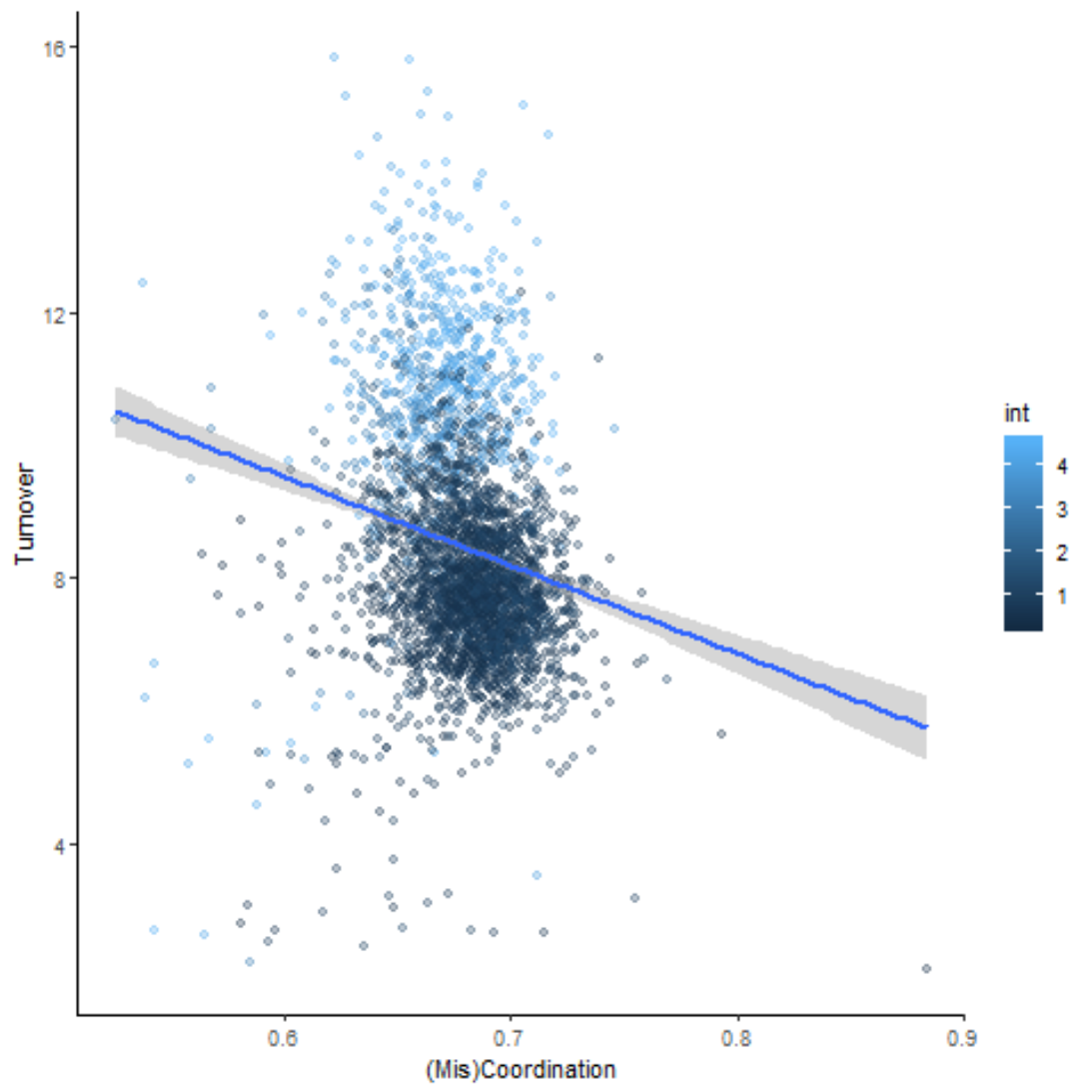
$$y_{it} = (T_{90,it} - T_{10,it})\beta_1 + D_{it}\beta_2 + X_{it}\beta_3 + \gamma_i + \epsilon_{it} \qquad (1)$$

Current Data Set

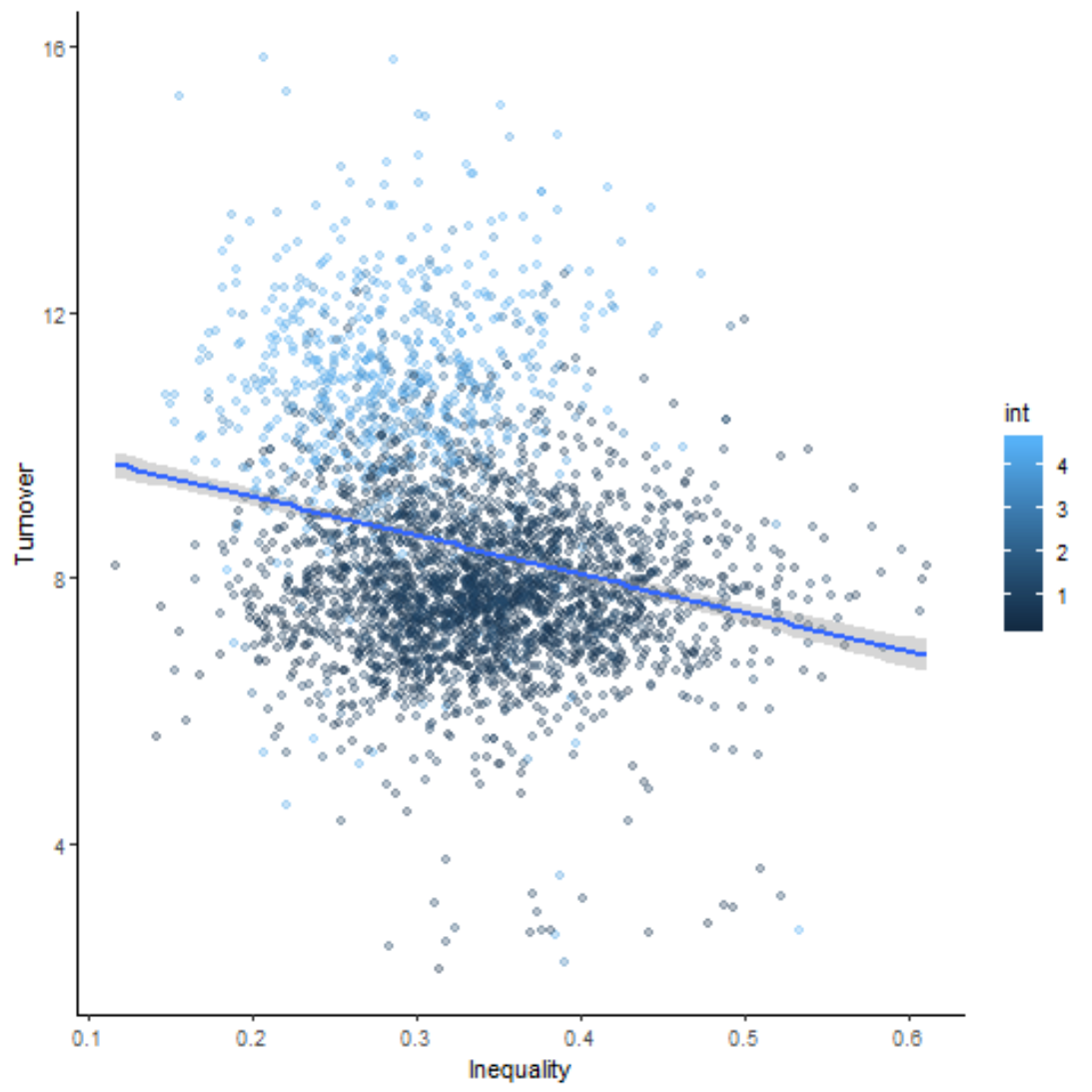
Systems we currently have data for

- Canada
- Columbia
- Denmark
- Eurosystem
- India
- Mexico
- United States
- United Kingdom
- Switzerland

LVTS: Turnover and Coordination



LVTS: Turnover and Distribution



Call for participation

- Script to calculate measures are on the Bank Payment Research's GitHub site (BOC-PaymentsResearch)
- Anyone who would like to join this project is welcome (let's talk!)
- Anyone who would like to calculate the measures for their own system is also welcome

Machine Learning

What is Machine Learning?

There has been a revolution in statistics

- more data
- more computation
- more applications

Short Machine Learning Overview

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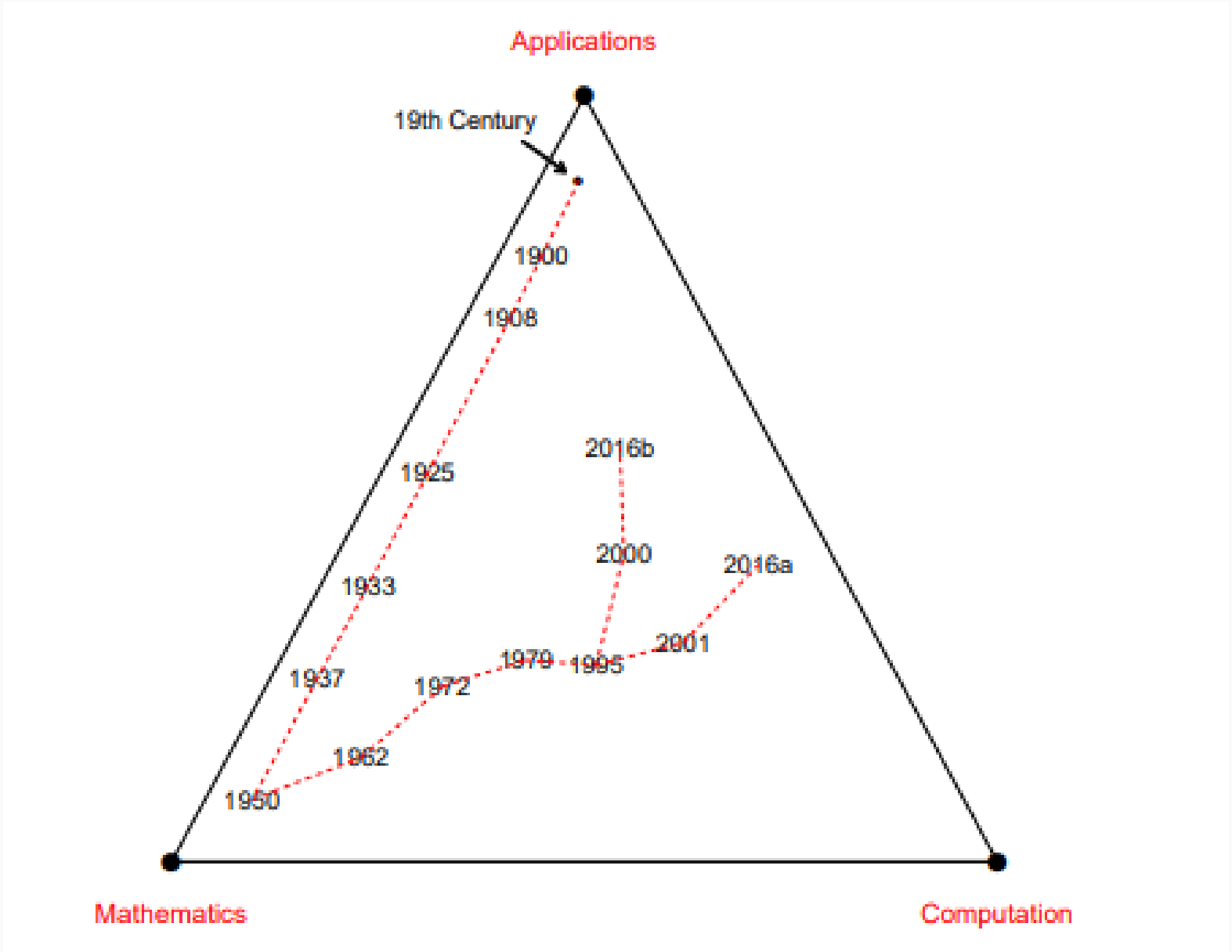
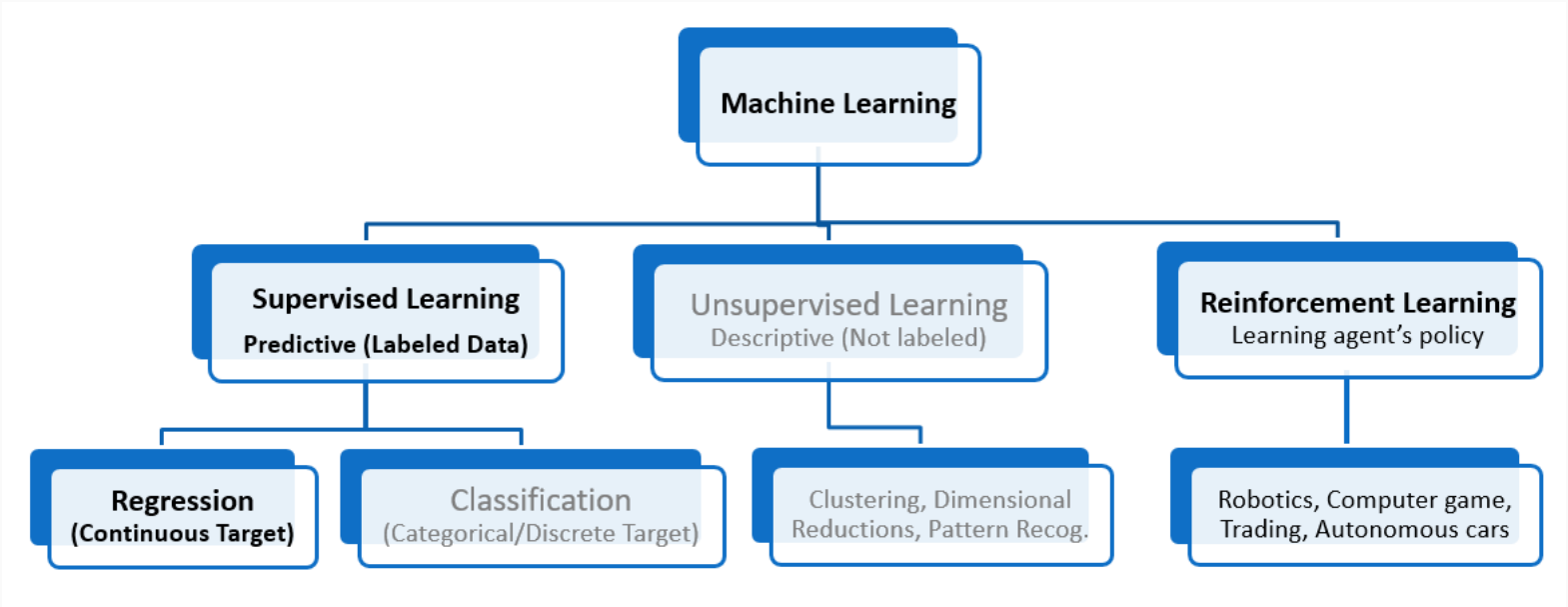
Back to the past!

Statistical Triangle (Hastie and Efron (2016))



Machine Learning types



Deep learning for payment system design

- Castro, Desai, Du, Garratt, and F. Rivadeneyra (In Progress) Approximate the current liquidity management rules of LVTS participants using deep reinforcement learning (RL).
- Reinforcement learning (RL) is a technique for goal-directed learning from interacting with the environment.
- Project goal: help design systems by investigating tradeoffs of alternative designs
- Current status: In a simplified two-agent setting, the objective is to learn optimal intraday payments decisions and optimal initial liquidity choices

Literature

Payments systems theory:

- Bech & Garratt (2003) liquidity management game and equilibria

Agent-based methods:

- Arciero et al. (2009) explore responses of agents to shocks in RTGS
- Galbiati & Soramäki (2011) agents choose initial liquidity to satisfy pmt demands

Reinforcement Learning

Agent

Learn by taking **actions** and evaluating rewards

Environment

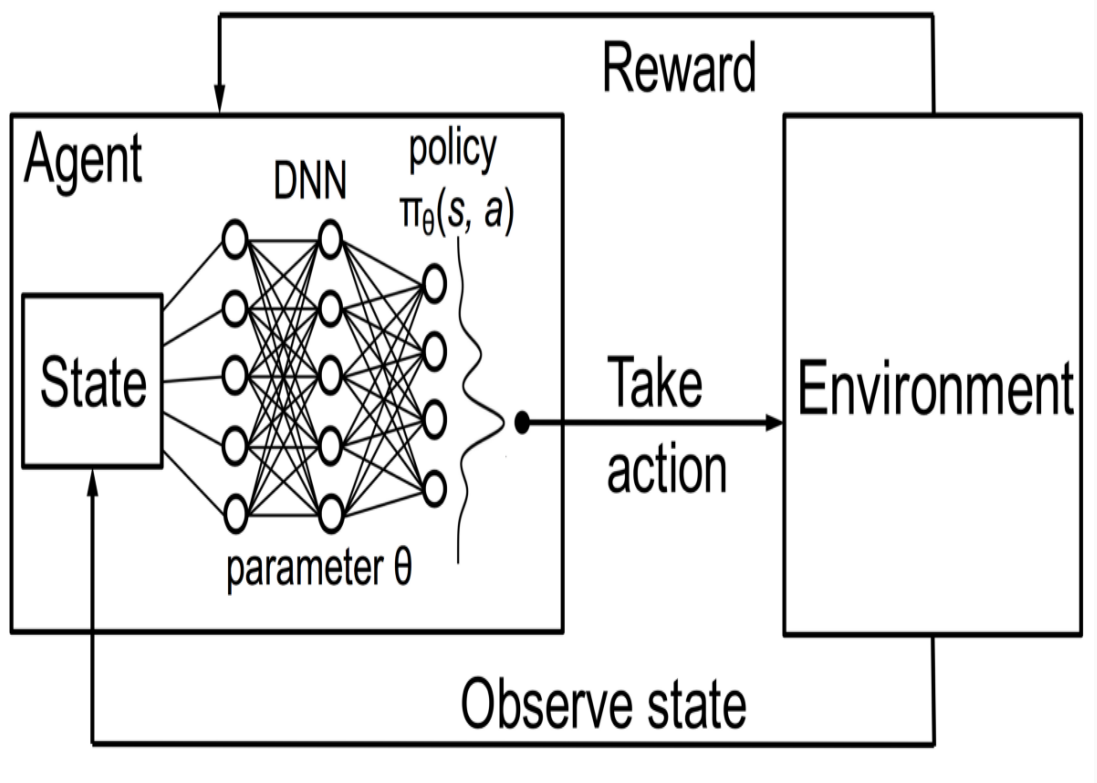
Where agent interacts

State

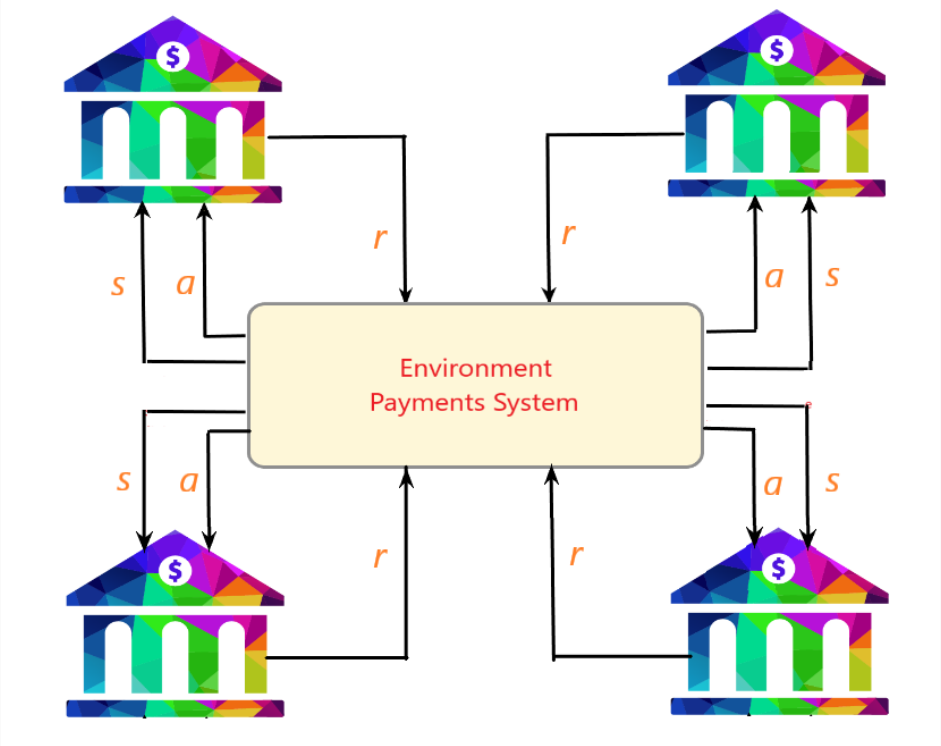
Representation of the environment

Reward

Value of actions taken



Environment



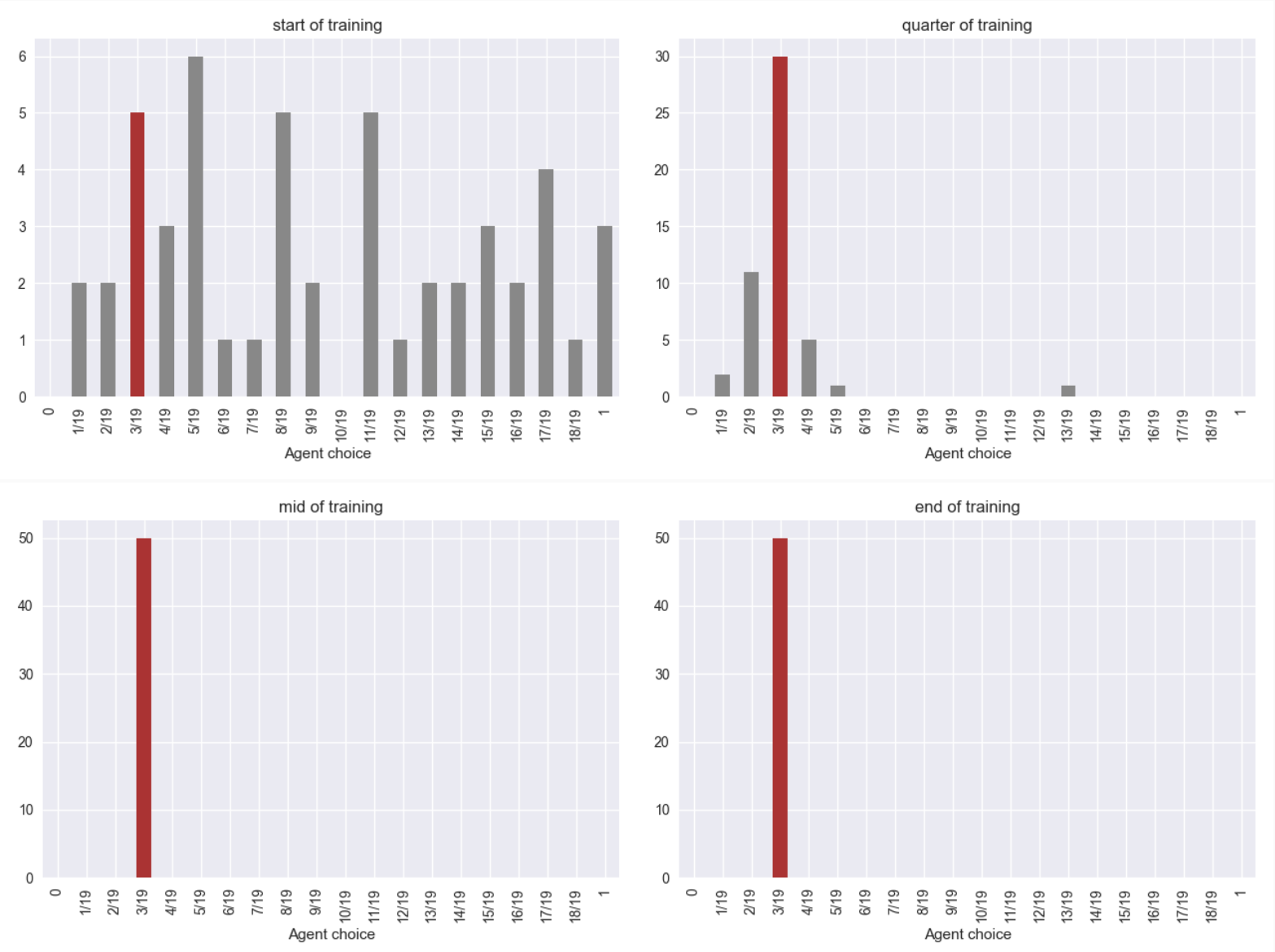
Learning initial liquidity and intraday payment rules

Strategy: tackle two simplified learning problems for which we know the optimal choice if agents have **complete knowledge** of the environment

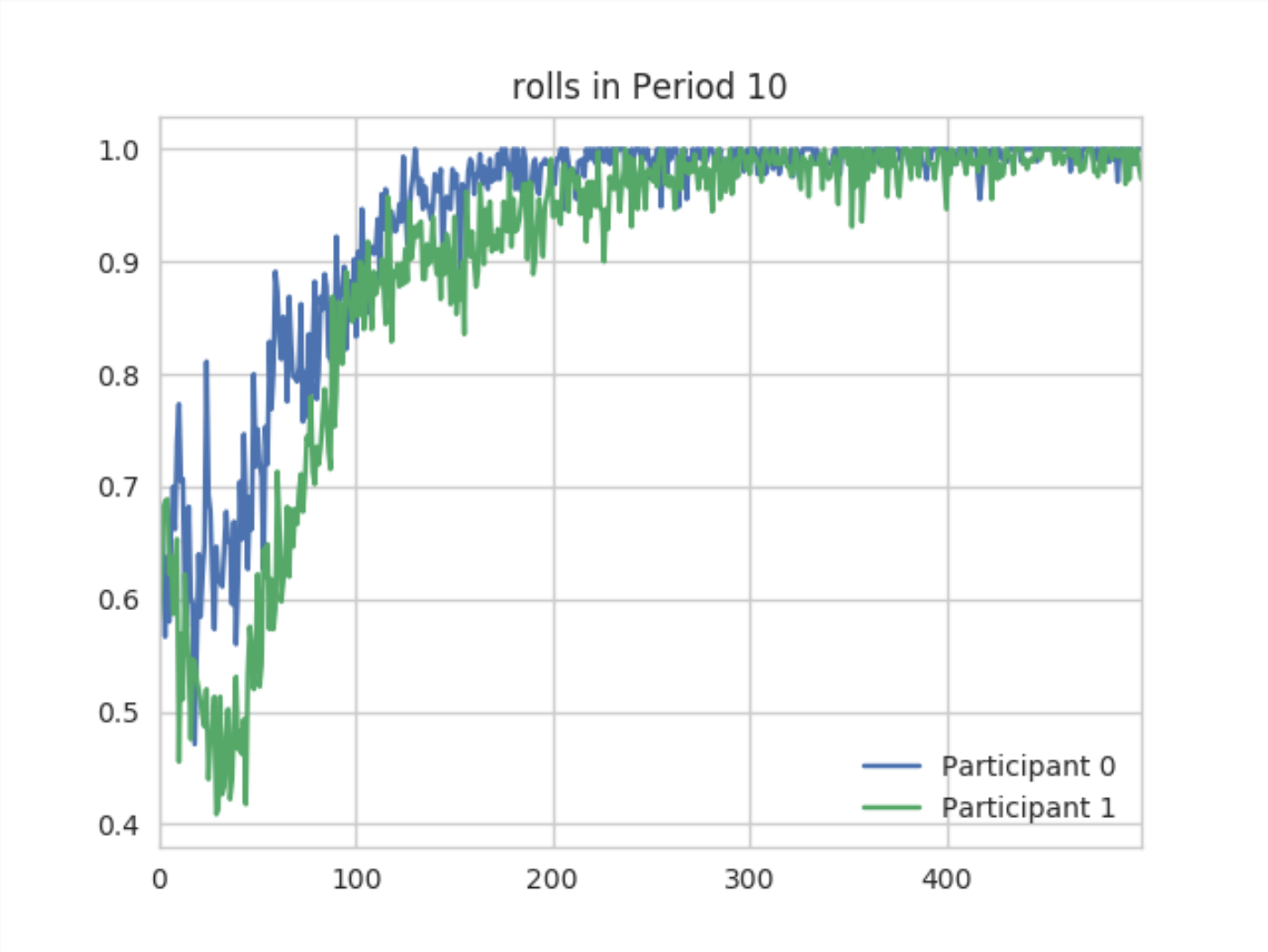
1. **Intraday payment decision**: without incentives for delay, agent must learn to send as much as it can every period

2. **Initial liquidity choice**: given the above rule, learn to choose the initial liquidity that minimizes the cost of processing all payments

Result: Example 1: agent A choice of initial liquidity



Intraday payment decision results



Key Points to date from Deep Learning Exercise

- In the simplified two-player settings, RL agents demonstrate optimal learning behaviour in both intraday payments decision and initial liquidity choices problems
- In complicated game settings, it is hard to verify if agents have learned optimal behaviour
- Learning in multi-agent RL setting is very challenging
- From the implementational perspective, optimistic start but there are three levels of challenges:
  - creating a correct environment
  - selecting the right learning algorithm
  - neural network architecture

Successes of Machine Learning for Payment System

- ML techniques handle nonlinear problems really well
- ML for nowcasting can find non-obvious patterns (Nowcasting of Chapman and Desai (2019))
- ML for payment system design can potentially solve complex decision problems (Castro et. al.)

Conclusion

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- Payment system design research is needed and should be a focus going forward
- New data sets comparable across systems can help understand institutional variation
- New techniques can help solve models that are rich but analytically intractable

Thank You!