Labor Institutions and Market Performance
An Agent-Based Computational Economics Approach

Presenter:

Leigh Tesfatsion
Professor of Econ, Math, and Electrical and Comp. Eng.
Department of Economics
Iowa State University
Ames, Iowa 50011-1070
https://www2.econ.iastate.edu/tesfatsi/
tesfatsi@iastate.edu

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What is Agent-Based Computational Economics (ACE)?

Labor Institutions and Market Performance: What does ACE have to offer?

Illustration: (M. Pingle/L. Tesfatsion, 2003)

“Evolution of Worker-Employer Networks and Behaviors Under Alternative Non-Employment Benefits”

Trade Network Game (TNG) Lab Implementation

https://www2.econ.iastate.edu/tesfatsi/TNGHome.htm
What is Agent-Based Computational Economics (ACE)?

- Culture-dish approach to the study of decentralized market processes

- Computational study of economic processes modeled as dynamic systems of interacting agents

ACE Resource Site:
https://www2.econ.iastate.edu/tesfatsi/ace.htm

ACE Labor Market Research Site:
https://www2.econ.iastate.edu/tesfatsi/alabor.htm
ACE Modeling: Culture Dish Analogy

- Modeler constructs a **computational economic world** populated by various types of agents (economic, social, biological, & physical)

- Modeler sets **initial conditions**

- The world then **develops over time** without further outside intervention

- World driven solely by **agent interactions**
ACE Modeling: Culture Dish Analogy

Experimental Treatment Factors (Initial Conditions)
Economy Develops Over Time (Culture Dish)
Macro Regularities
Key Characteristics of ACE Models

- **Agents** are encapsulated software programs capable of:
  - *Adaptation* to environmental conditions
  - *Social communication* with other agents
  - *Goal-directed learning*
  - *Autonomy* (self-activation and self-determinism based on private internal processes)

- Agents can be situated in realistically rendered problem environments

- Behaviour/interaction patterns can develop endogenously over time
Current ACE Research Areas
(https://www2.econ.iastate.edu/tesfatsi/aappllic.htm)

- Embodied cognition
- Network formation
- Financial Economics
- Labor Markets
- Industrial organization
- Macroeconomics
- Technological change and economic growth
- Market design
- Automated markets and software agents
- Parallel experiments (real & computational agents)
- Empirical validation and verification of ACE models
- Many others...
Labor Institutions and Market Performance

Some Key Issues:

- Labor contracts typically **incomplete**

- Supplemented by government programs with **numerous eligibility restrictions**

- **Difficult to test program effects** by means of conventional analytical and/or statistical tools
Example: U.S. Programs Providing Unemployment Benefits (UB)

- UB only paid to “no fault of their own” unemployed
- UB recipients must continue to seek employment
- UB levels based on past earnings
- UB of limited duration
- UB financed by taxes imposed on employers
- Additional UB often granted when unemployment rate is abnormally high for prolonged periods

- Example: IA Unemployment Insurance Guide (29pp)
  https://www.iowaworkforce.org/ui/guide.htm
Empirical UB Findings

◆ Higher benefit level increases duration of unemployment spells.

◆ Increased benefit duration increases unemployment rate (unemployed as percentage of labor force).

◆ Evidence of other impacts of UB is considerably more mixed (endogeneity, small sample bias problems,...)
Common Approach to UB Theoretical Modeling


- Dynamic Programming (DP)
- Jobs arise and end randomly
- Unemployed receive UB
- Workers compare DP value of new job vs. current job or unemployment
- Each worker maximizes lifetime expected utility
- **Precise predictions possible, but empirical support unclear.**
Potential Contributions of an ACE Approach to Labor Research
https://www2.econ.iastate.edu/tesfatsi/alabor.htm

- Employers/workers can be modeled as autonomous interacting agents
- Matching process can be preferential (endogenous hires, quits, and firings)
- Learning can be calibrated to data (empirical, human-subject experimental)
- Evolution of behaviors/interaction networks
- Relatively easy to incorporate realistically detailed structural features (market protocols, policy rules, program eligibility requirements,...)
Illustration: An ACE Study of “Non-Employment Payments” (NEP)

Joint work with M. Pingle (U of Nevada-Reno)

Published in New Directions in Networks, 2003, Edward-Elgar volume, edited by A. Nagurney

M. Pingle and L. Tesfatsion, “Evolution of Worker-Employer Networks and Behaviors under Alternative Non-Employment Benefits: An Agent-Based Computational Economics Study”

Pre-print available at https://www2.econ.iastate.edu/tesfatsi/alabmplt.pdf

Parallel human-subject experiments conducted
ACE Labor Market Framework

Preferential job search with choice/refusal of partners: Red directed arrow indicates refused work offer.
Focus on Interaction Effects ➔ Endogenous Heterogeneity of Agents

- 12 workers with **same observable attributes** in initial period $T=0$
- 12 employers with **same observable attributes** in initial period $T=0$
- Each worker can work for at most one employer in each period $T$
- Each employer can provide at most one job opening in each period $T$
- **Worksite strategies** in initial period $T=0$ are **random and private info**
Each worker and employer has...

- **Public methods for requesting/receiving info** about various market and NEP policy protocols

- **Public communication methods**—workers and employers can talk with each other.

- **Privately stored data** that can change over time through experiences/communications

- **Private behavioral methods** that include expectation formation & learning about preferred worksite partners and worksite strategy choices
## A Worker Agent

### Public Access:

// Public Methods
- Protocols governing job search;
- Protocols governing negotiations with potential employers;
- Protocols governing non-employment payments program;
- Methods for communicating with other agents;
- Methods for retrieving stored Worker data;

### Private Access Only:

// Private Methods
- Method for calculating own expected utility assessments;
- Method for choosing/refusing employers [ learning ];
- Method for updating own worksite strategy [ learning ];

// Private Data
- Data about own self (history, utility fct., current wealth...);
- Data recorded about external world (employer behaviors,...);
- Addresses for other agents [permits agent communication]
An Employer Agent

Public Access:

// Public Methods
Protocols governing search for workers;
Protocols governing negotiations with potential workers;
Protocols governing non-employment payments program;
Methods for communicating with other agents;
Methods for retrieving stored Employer data;

Private Access Only:

// Private Methods
Method for calculating own expected profit assessments;
Method for choosing/refusing workers [learning];
Method for updating own worksite strategy [learning];

// Private Data
Data about own self (history, profit fct., current wealth...);
Data recorded about external world (worker behaviors,...);
Addresses for other agents [permits agent communication]
Flow of Activities in the ACE Labor Market

- Workers make offers to preferred employers at a small cost per offer (quits allowed)
- After batching work offers, employers accept or refuse these offers (firings allowed)
- Each matched pair engages in one worksite interaction (PD - cooperate or defect)
- After 150 work periods, each worker (employer) updates its iterated prisoner’s dilemma strategy for interactions with each potential employer (worker).
Flow of Activities in the ACE Labor Market

- **Initialization**
- **Work Period:**
  - Search/Match
  - Worksite Interactions
  - Update Expectations
- **Evolution Step:**
  - Evolve Worksite Strategies

Do 1000 Loops

Do 150 Loops
Worksite Interactions as Prisoner’s Dilemma (PD) Games

D = Defect (Shirk); C = Cooperate (Fulfill Obligations)
Key Issues Addressed

How do changes in the level of the non-employment payment (NEP) affect…

- **Worker-Employer Interaction Networks**

- **Worksite Behaviors:** Degree to which workers/employers shirk (defect) or fulfill obligations (cooperate) on the worksite

- **Market Efficiency** (total surplus net of NEP program costs, unemployment/vacancy rates,...)

- **Market Power** (distribution of total net surplus)
Experimental Design

- **Treatment Factor: NEP**
  Non-Employment Payment (NEP) paid to each unemployed worker and each employee having no workers

- **Three Tested Treatment Levels:**
  NEP=0, NEP=15, NEP=30

- **Runs per Treatment: 20**
  1 Run = 1000 Generations;
  1 Generation = 150 Work Periods Plus Evolutionary Step

- **Data Collected Per Run:** Network patterns, behaviors, and market performance (reported in detail for generations 12, 50, 1000)
Three NEP Treatments in Relation to PD Payoffs

① NEP=0 < L=10

② L=10 < NEP=15 < D=20

③ D=20 < NEP=30 < C=40

**NOTE:** Work-site PD payoffs given by:

L (Sucker)=10 < D (MutualDef) = 20
< C (MutualCoop) = 40
< H (Temptation) = 60
Market Efficiency Findings

As NEP level increases from 0 to 30...

- higher average unemployment and vacancy rates are observed; ← KNOWN EFFECT
- more work-site cooperation observed on average among workers & employers who match. ← NEW EX POST EFFECT

Note: These outcomes have potentially offsetting effects on market efficiency.
Market Efficiency (utility less NEP program costs) averaged across generations 12, 50, and 1000 for three different NEP treatments.
Efficiency Findings...

- NEP=15 yields *highest efficiency*
- NEP=0 yields *lower* efficiency
  (too much shirking)
- NEP=30 yields *lowest efficiency*
  (program costs too high – everyone too picky!)
Multiple Attractors

* Two distinct “behavioral attractors” observed for each NEP treatment...

- **NEP=0 and NEP=15:**
  - First Attractor = Latched network supporting *mutual cooperation*;
  - Second Attractor = Latched network supporting *intermittent defection*

- **NEP=30:**
  - First Attractor = Latched network supporting *mutual cooperation*
  - Second Attractor = Disconnected network reflecting *total coordination failure*
The Following Diagrams Report...

1. **Two-sided (W-E) network distributions**
   - 0 = Stochastic fully connected network;
   - 12 = Latched in pairs
   - 24 = Completely disconnected

2. **Worksite behaviors that are supported by these network outcomes**
Network Distribution for NEP=0
Sampled at End of Generation 12

Network Distribution for ZeroT:12

Number of Runs

Network Distance

Intermittent Defection
Mutual Cooperation
Network Distribution for NEP=0
Sampled at End of Generation 50

Network Distribution for ZeroT:50
Network Distribution for **NEP=0**

Sampled at End of **Generation 1000**

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**Network Distribution for ZeroT:1000**

- **Network Distance**
- **Number of Runs**

**Legend:**
- **Orange Bar:** Intermittent Defection
- **Green Bar:** Mutual Cooperation
Network Distribution for NEP=15
Sampled at End of Generation 12

Network Distribution for LowT:12

Network Distance
Number of Runs
Intermittent Defection Mutual Cooperation

Network Distance
Number of Runs
Intermittent Defection Mutual Cooperation
Network Distribution for **NEP=15**
Sampled at End of **Generation 50**

Network Distribution for **LowT:50**

![Network Distribution Graph](image)

**Network Distance** vs. **Number of Runs**

- Orange bars: **Intermittent Defection**
- Green bars: **Mutual Cooperation**
Network Distribution for NEP=15
Sampled at End of Generation 1000

Network Distribution for LowT:1000

Number of Runs

Network Distance

Intermittent Defection
Mutual Cooperation
Network Distribution for **NEP=30**
Sampled at End of **Generation 12**

**Network Distribution for HighT:12**

![Network Distribution Chart]

- **Network Distance**
- **Number of Runs**
  - Intermittent Defection
  - Mutual Cooperation
  - Coordination Failure

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Network Distribution for NEP=30
Sampled at End of Generation 50

Network Distribution for HighT:50

Network Distance

Number of Runs

Mutual Cooperation

Coordination Failure

Network Distance

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Mutual Cooperation

Coordination Failure
Network Distribution for $\text{NEP}=30$
Sampled at End of Generation 1000

![Network Distribution for HighT:1000](image)

- **Number of Runs**
- **Network Distance**
- **Network Distribution for HighT:1000**

Legend:
- **Green**: Mutual Cooperation
- **Black**: Coordination Failure
Summary of Findings

- Changes in NEP **systematically** affect unemployment, vacancy, worksite behaviors, and welfare outcomes.

- Worker-employer networks tend to be either **fully latched in pairs** or **completely disconnected**.

- But... even fully latched networks support **spectral (multiple-peaked)** behavioral distributions (potential pooling problems).
Implementation via Trade Network Game (TNG) Lab:

Architecture of the TNG Lab

TNG Lab

Graphical User Interface (GUI)

TNG/COM

Supports run-time output visualizations

TNG/SimBioSys

TNG derived classes

SimBioSys class framework

Base class lib

TNG Homepage:
https://www2.econ.iastate.edu/tesfatsi/tnghome.htm
SimBioSys Class Framework
(David McFadzean, M.S. Thesis, 1995)

- Simulation toolkit
- C++ class library
- Designed for artificial life simulations (populations of autonomous interacting agents evolving in a virtual spatial world)
TNG Lab: Agent Hierarchy in Unified Modeling Language (UML)

"is a"

SimBioSys agent class library C++

TNG derived agent classes

Labor application
TNG Lab Graphical User Interface (GUI) Settings Screen
TNG Lab GUI:
Results Screen

![TNG Lab GUI Results Screen](image)
TNG Lab GUI: Chart Screen

![TNG Lab GUI Chart Screen](image-url)
TNG Lab GUI:
Network Animation Screen
TNG Lab GUI: Physics Screen
Online Software Resources

- ACE General Software and Toolkits
  https://www2.econ.iastate.edu/tesfatsi/acecode.htm

- ACE Computational Laboratories
  https://www2.econ.iastate.edu/tesfatsi/acedemos.htm

- Research Area: Development and Use of Computational Laboratories
  https://www2.econ.iastate.edu/tesfatsi/acomplab.htm

- TNG Lab Homepage
  https://www2.econ.iastate.edu/tesfatsi/tnghome.htm