An Agent-based Model of Employment, Production and Consumption

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Motivation

- Complicated $\neq$ complex (by Prof. Barkley Rosser)
- Can simplicity generate complexity?
- Can one model explain many things?

Motivation

- The idea is based on Ian Wright:
  The Social Architecture of Capitalism, Physica A, 2005
- Simulation: relation between capitalist and workers

Motivation

$\hookrightarrow$ relation of production:

A minority of firm owners employ a majority of workers in firms of various sizes, the firms produce goods and services for sale in the marketplace.

The firm owners collect revenue and workers receive a share of the revenue in the form of wages.

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- Advantages: it generates many empirical distributions within a single causal network
- Our work: keep its advantages, adjust and create new simulation rules – whether it explains more distributions, or better?

Model setting

- Initialization:
  - Economic actors $i = 1 \ldots N$ can be either Employer (E), Worker (W) or Unemployed (U) $\longrightarrow$ the total population $A = E + W + U$
  - Each actor i at $t = 0$ holds an equal amount of money m (coins)
  - A market is created with $V = 100$, changes with GDP growth rate
  - No employment relation

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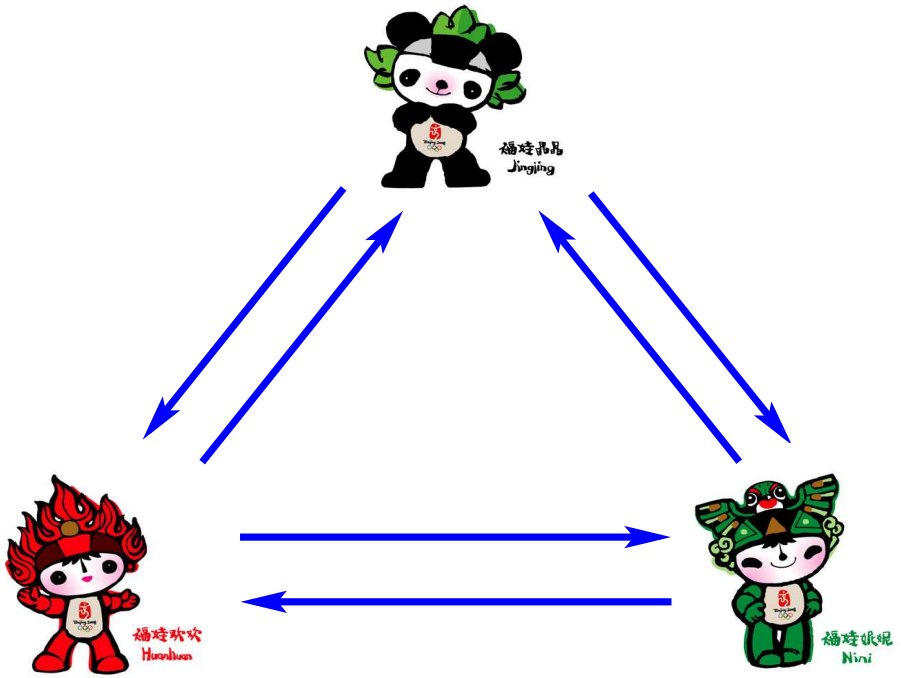
- 3 exogenous parameters:
  - total number of actors N, (N=1,000)
  - initial money for actors m (m=100)
  - wage interval $w = [w_a, w_b]$, (w=[10,90])

- Intelligent actors: being reactive, proactive and social

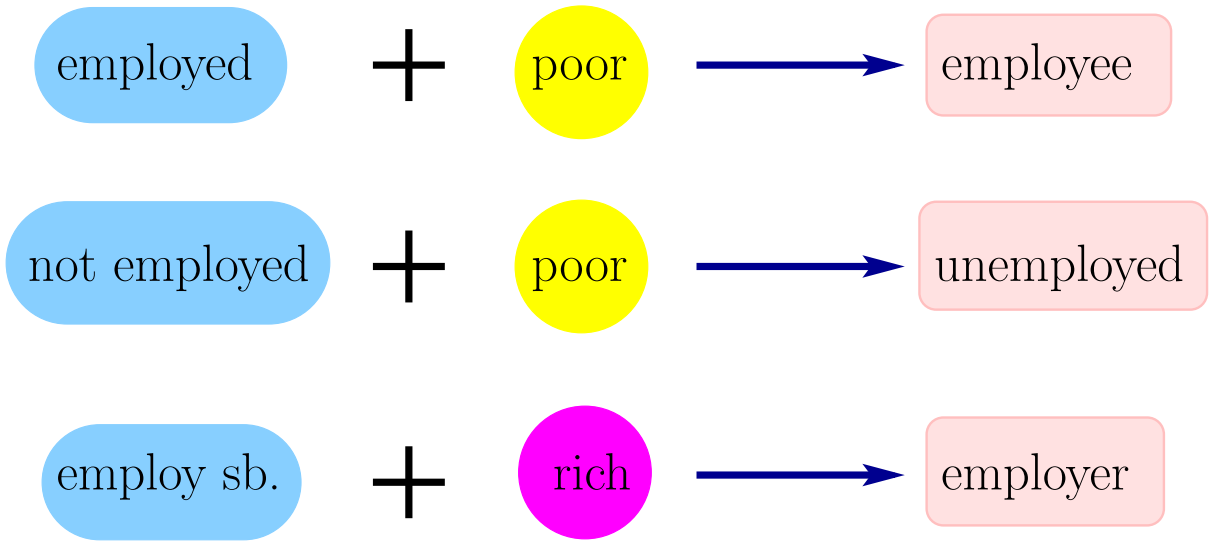


Actors interact,

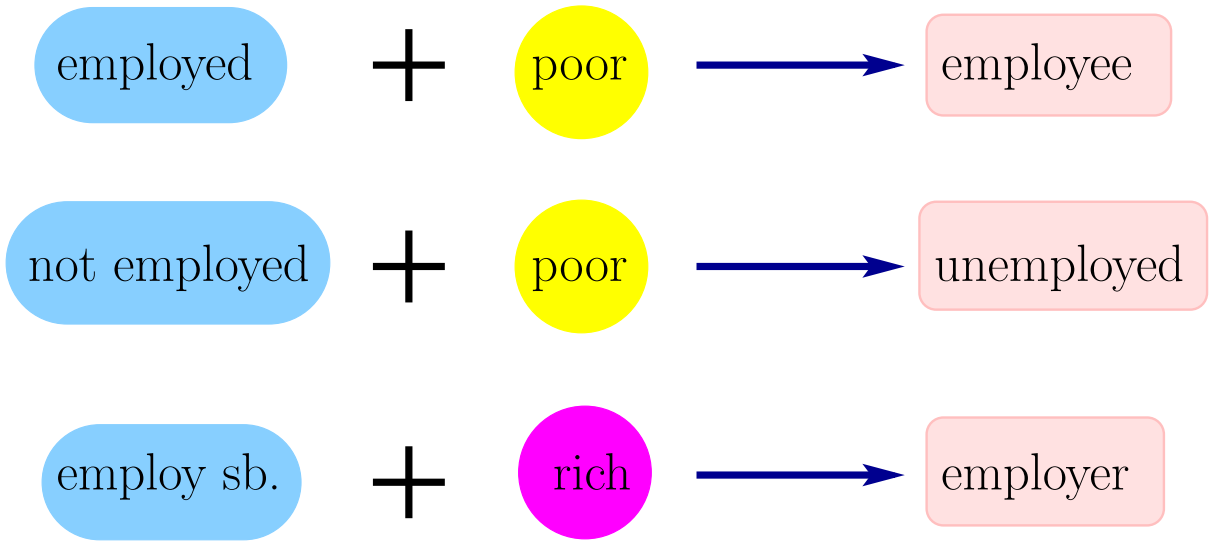
change states,

and exchange money

- Identify an actor by his employment state and money holding



- Identify an actor by his employment state and money holding



- Assign 100 coins to each actor, and starts the program

Simulation Rules

1. Actor Selection Rule

actor **a**

(select by order)

...

A

shuffle play order before every iteration

2. Hiring Rule

If  is unemployed ← hired ← Employer (E), Unemployed (U)

$$H = E \cup U$$

actor **a**

Choose  according to $P(c) = \frac{m_c}{\sum_{x \in H} m_x}$

actor **c**

 hires  if $m_c > \overline{w}$, $\overline{w} = (w_a + w_b)/2$

3. Revenue Rule

If  **is not unemployed**

actor a

- **Employer** → **Revenue**
- **Employee** → **Revenue**

→ **Gain revenue** $m \in [0, V]$ **(triangular)**

- $V \downarrow$ **by** m
- $m_c \uparrow$ **by** m

Simulation Rules

If  **an employer,**

actor a

4. Firing Rule

Determine number of workers to fire: $u = max\left(|W_a| - \left[\frac{m_a}{\overline{w}}\right], 0\right)$

$\longrightarrow$ **Select** u **from** W_a **(uniform)**

5. Wage Payment Rule

Pay $w \in [w_a, w_b]$ **(triangular) to each employee,**

If $m_a < w$**, select** $w^* \in [w_a, m_a]$ **(triangular)**

If $m_a < w_a$**, pay** m_a **to worker and goes bankrupt**

6. Expenditure Rule

actor **a**

A

Select expenditure amount $m \in [0, m_a]$ **(triangular)**

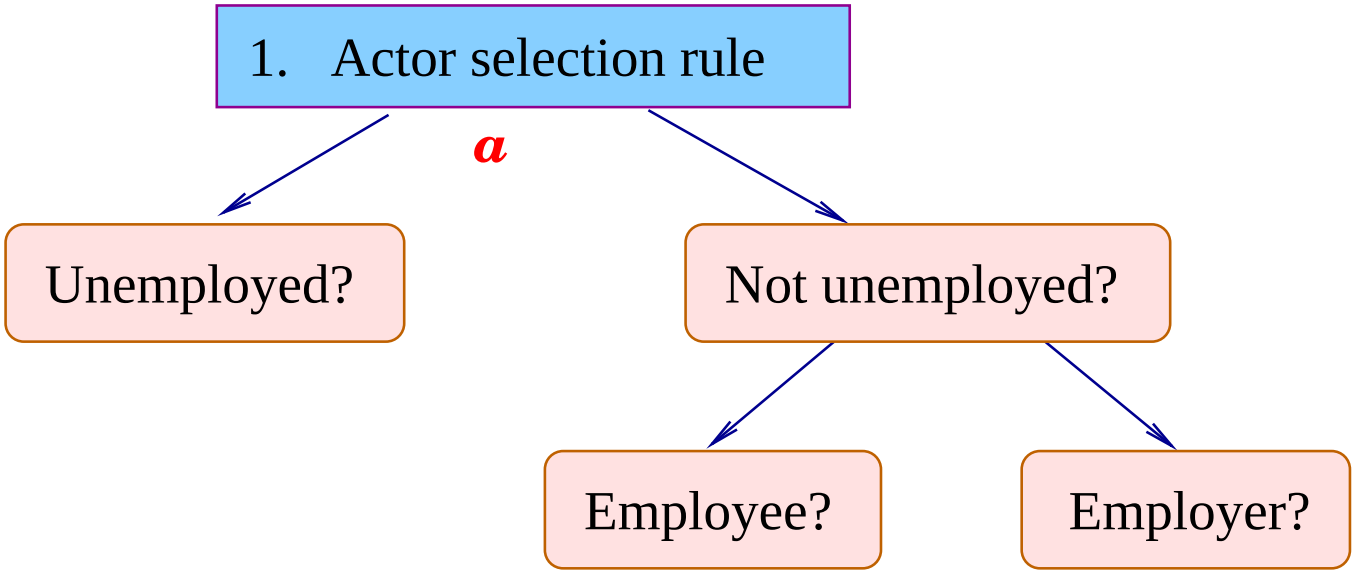
- $V \uparrow$ by m
- $m_a \downarrow$ by m

Simulation Rules

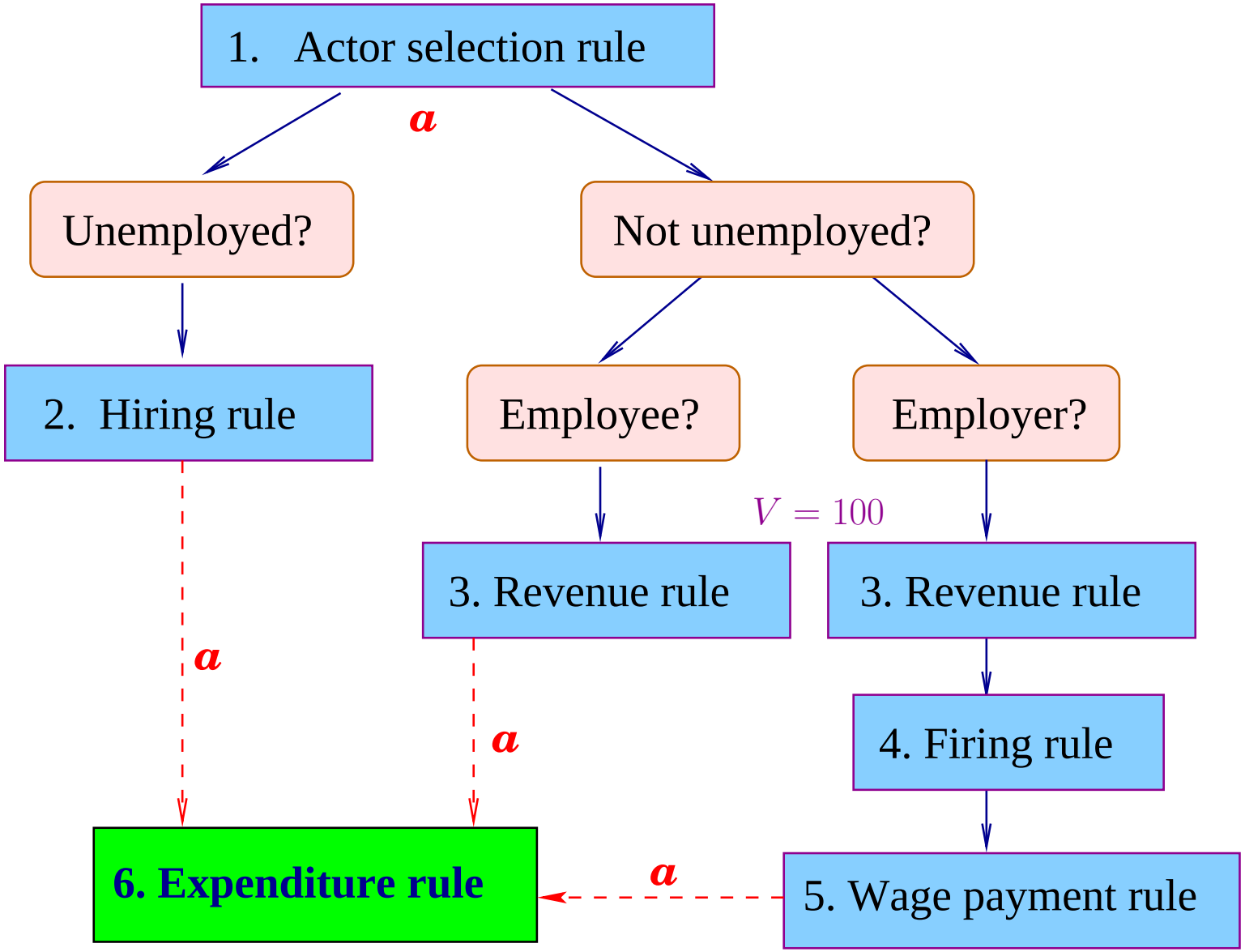
1. Actor selection rule

a

Simulation Rules

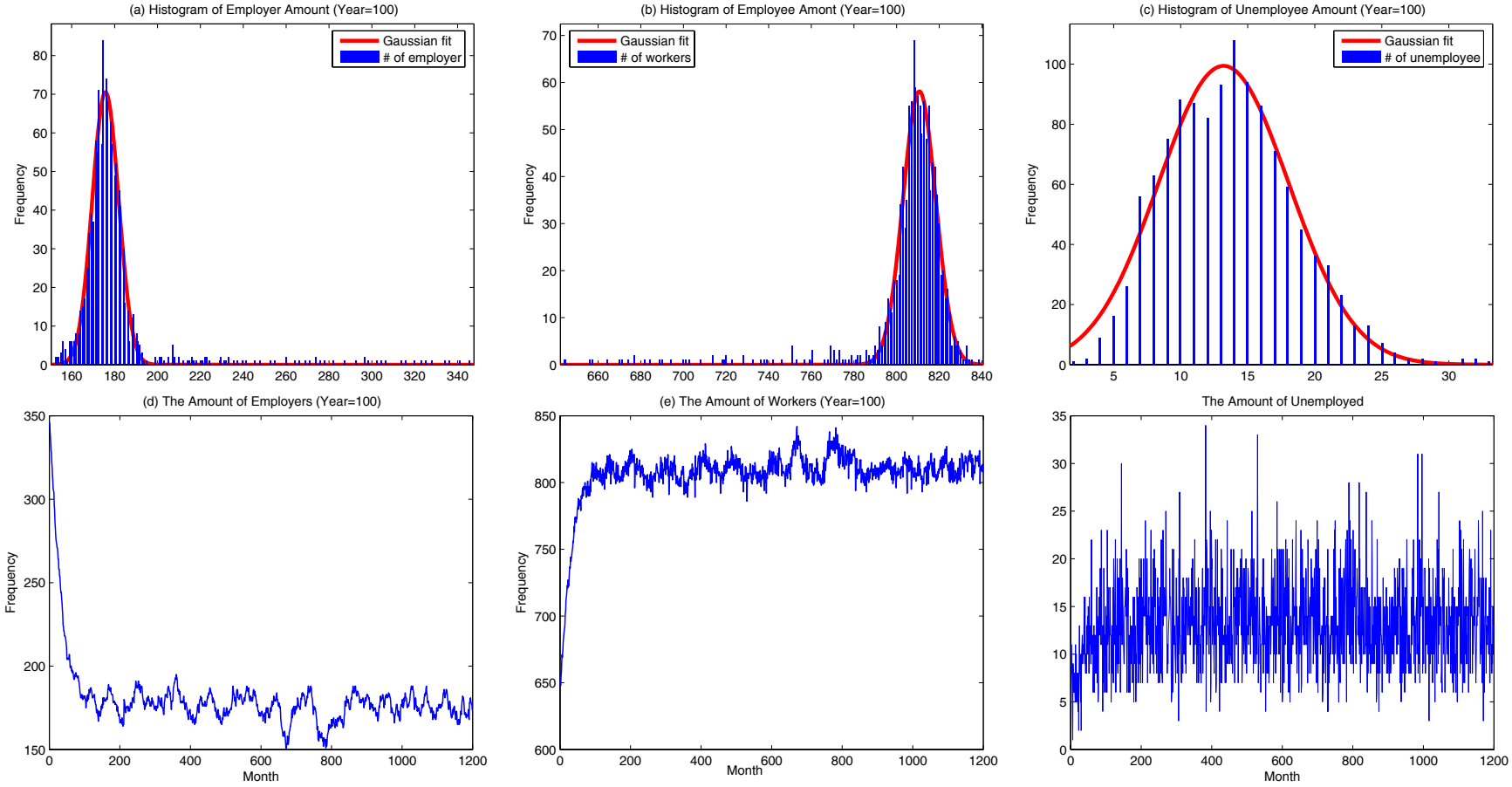


Simulation Rules



Simulation Results
Class distribution — Gaussian

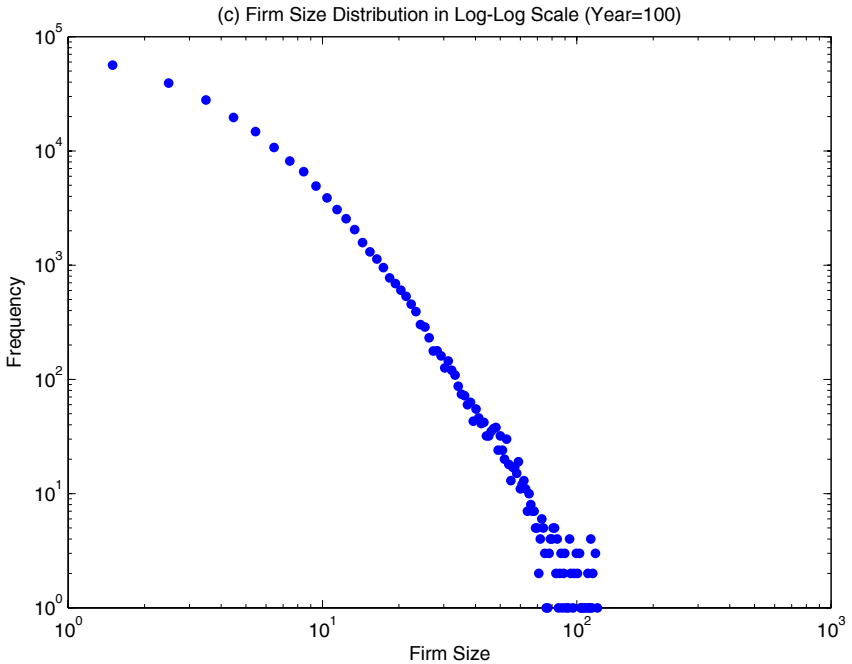
- Class size measure: After each month, count each class

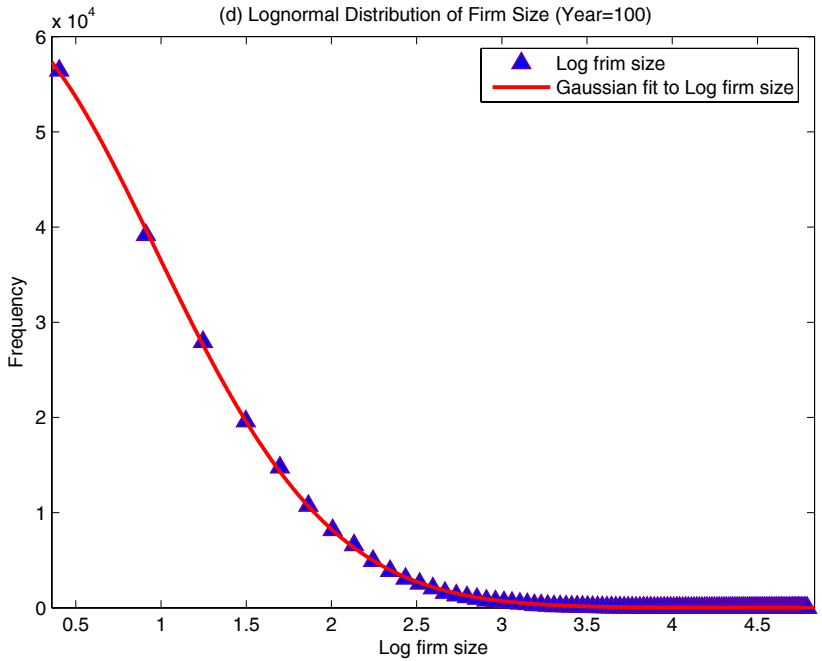


- Gaussian classes: 18% employer, 80% employee, 2% unemployed

Simulation Results
Firm size distribution — Lognormal

- Firm size measure: After each month, count employees in each firm

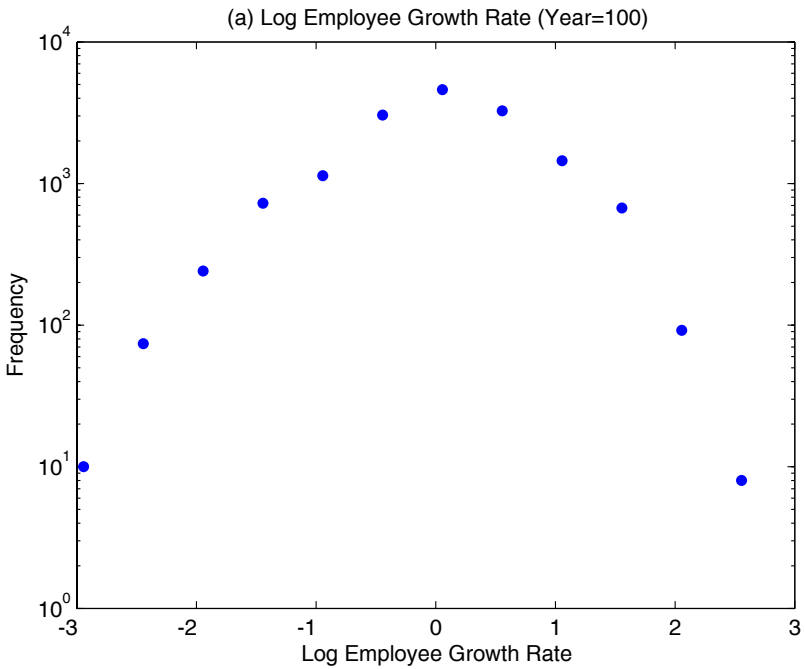


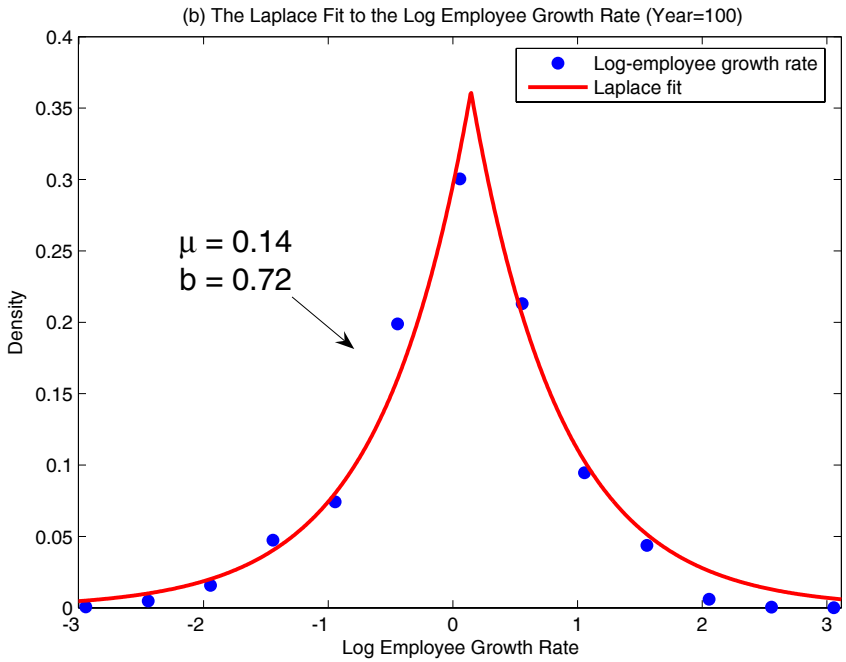


- Lognormal firm size: small firms are majority,
  largest firm employs $< 10\%$ total labor

Simulation Results
Firm growth distribution — Laplace

- Firm growth measure: Calculate the yearly firm size by employee numbers, s_t, the growth rate is s_t/s_{t-1}

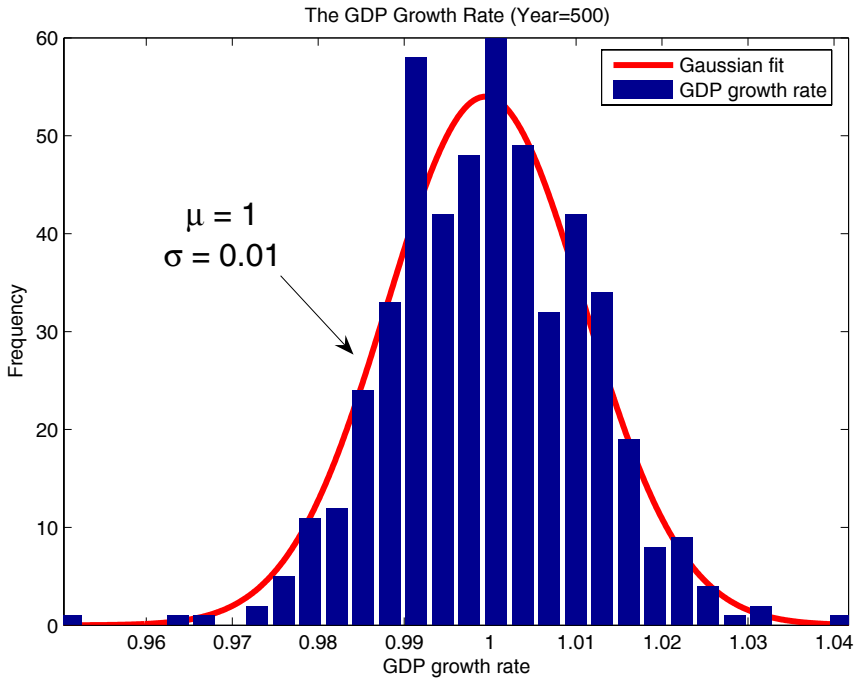


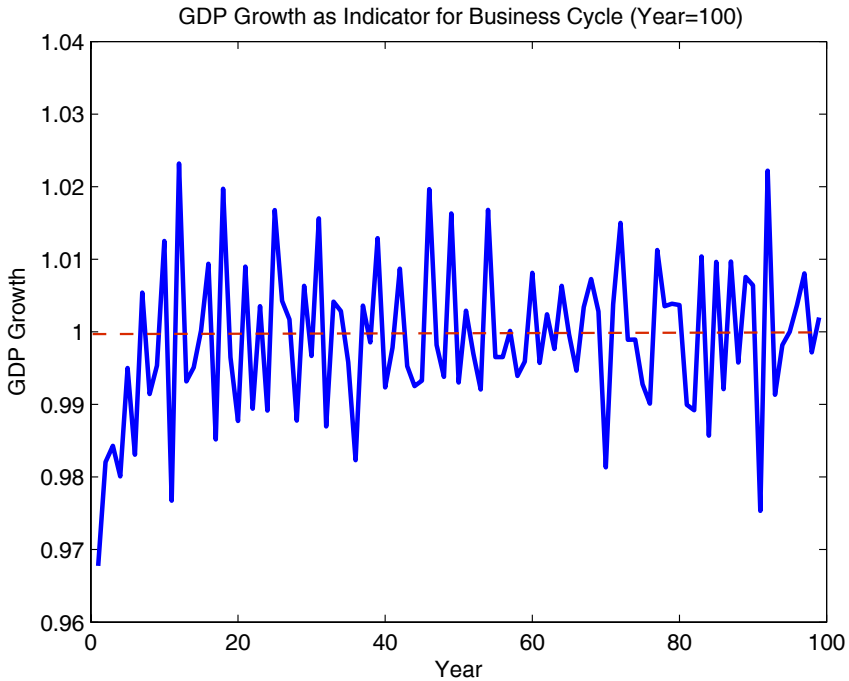


- Laplace firm growth: firm growth rates depend negatively on size, small firms tend to experience either rapid growth or rapid decline

Simulation Results
GDP growth distribution — Gaussian

- GDP growth measure: Calculate firm revenues by the end of year as GDP, R_t, GDP growth rate $= R_t/R_{t-1}$

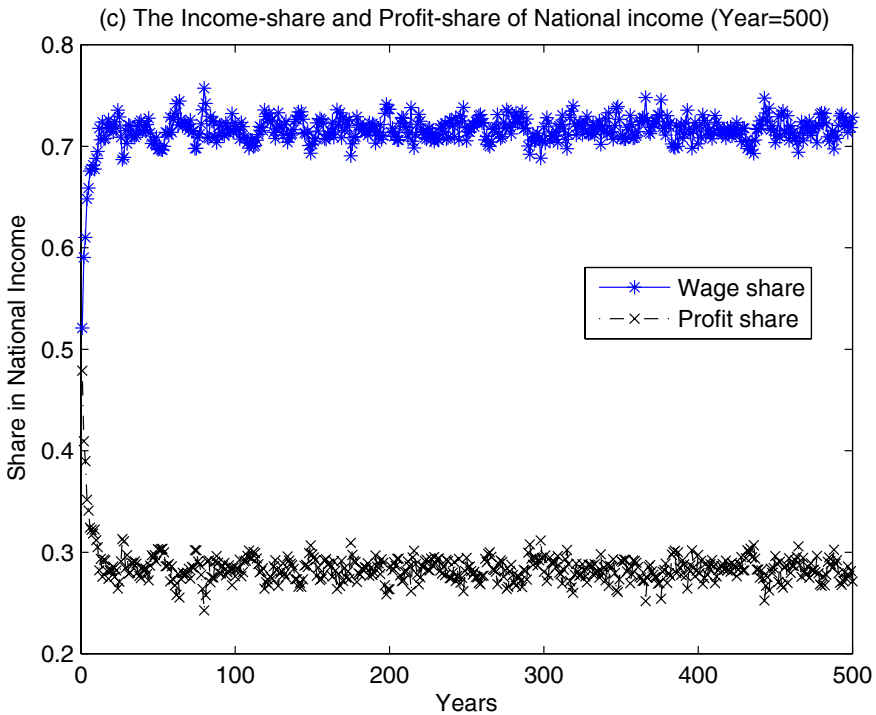


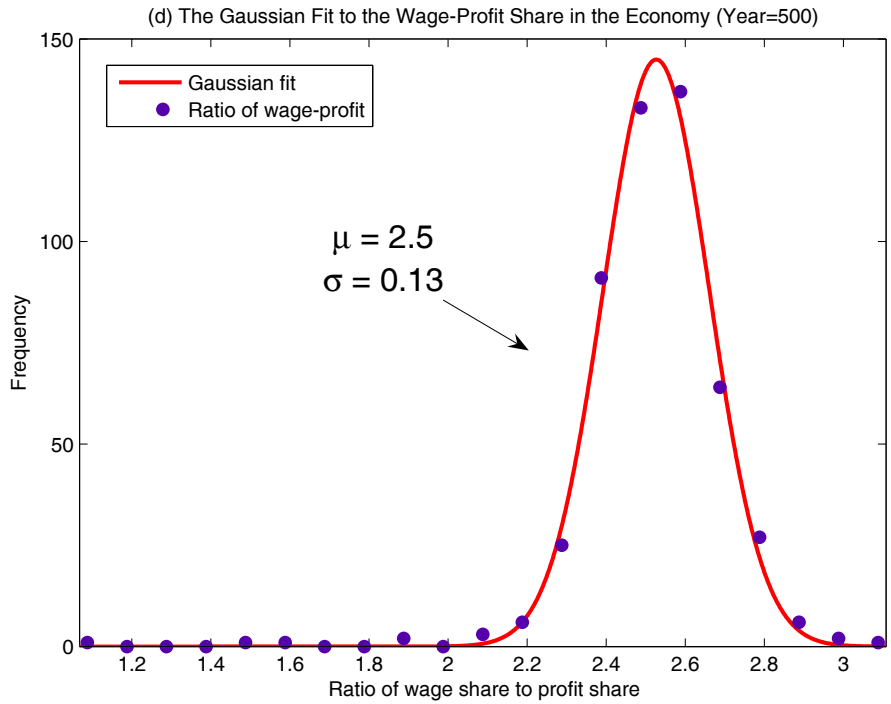


- Gaussian GDP growth rates cluster around μ with very small σ^2

Simulation Results
Wage-Profit Share — Gaussian

- Income shares measure: Wage share = wages paid to the workers in GDP; Profit share = $1-$ wage share.

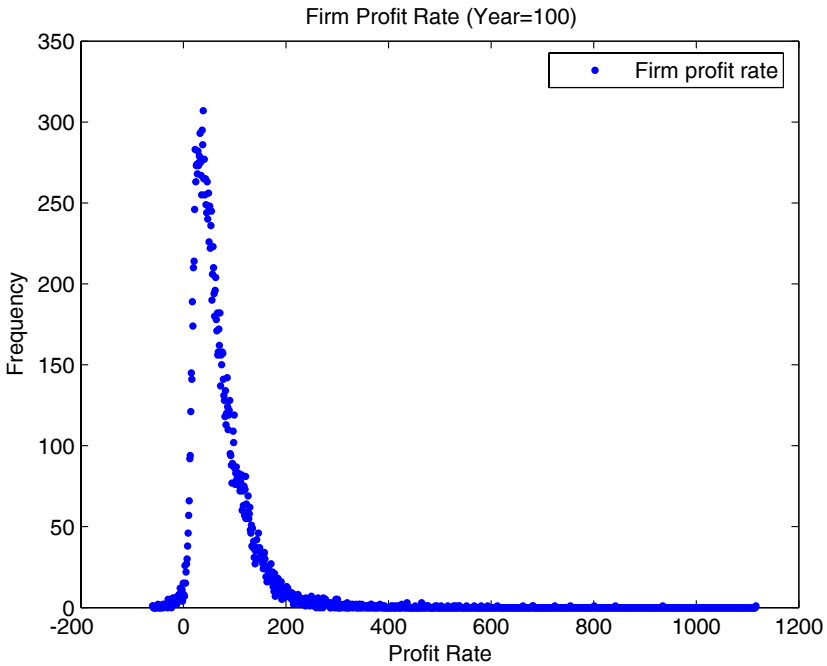


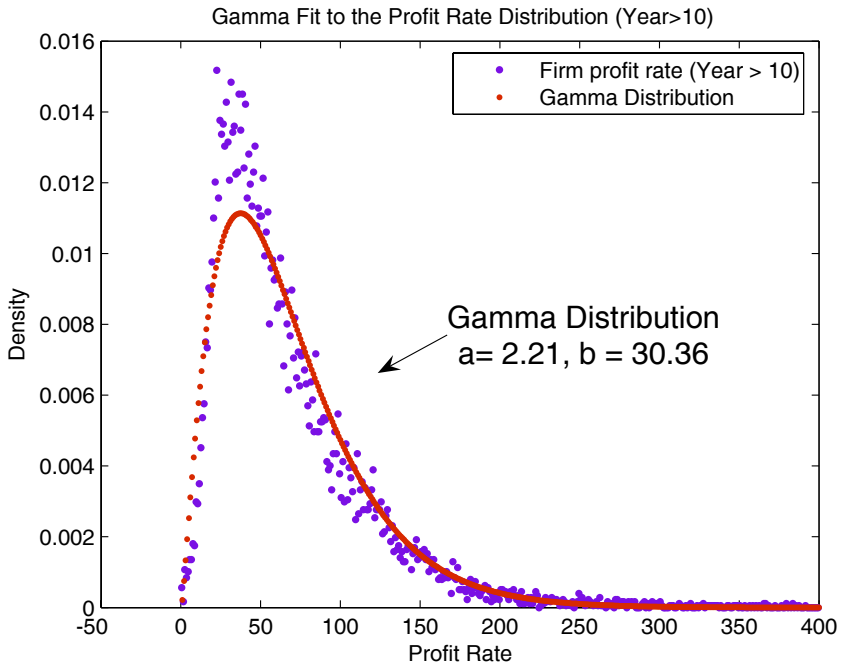


- profit share (0.3) $<$ wage share (0.7), ratios $\rightsquigarrow$ Gaussian

Simulation Results
Profit rate distribution — Gamma

- Profit rate measure: calculate firm yearly profit rate, according to the division of the firm's revenue and total wage bill



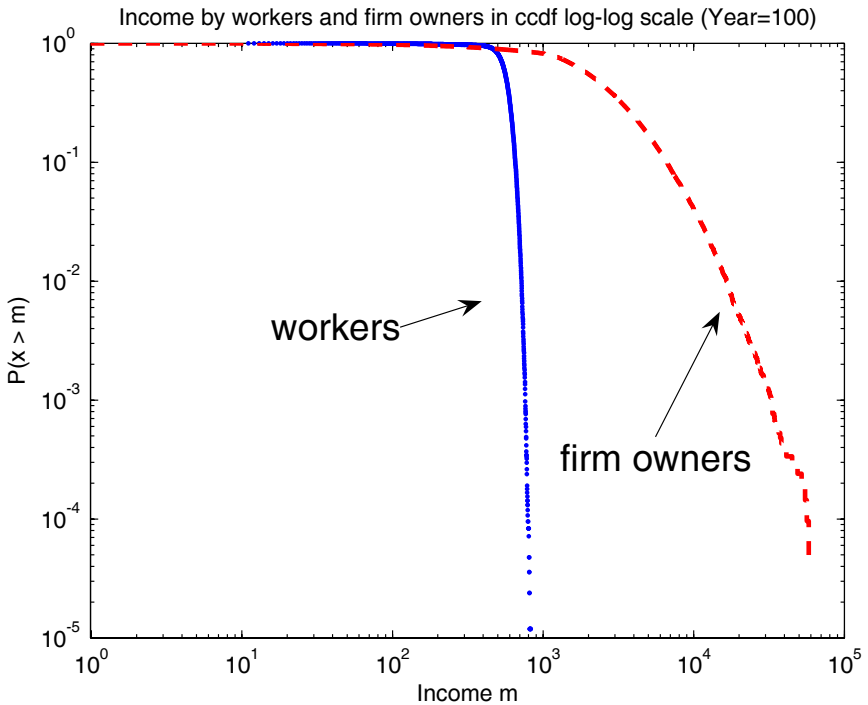


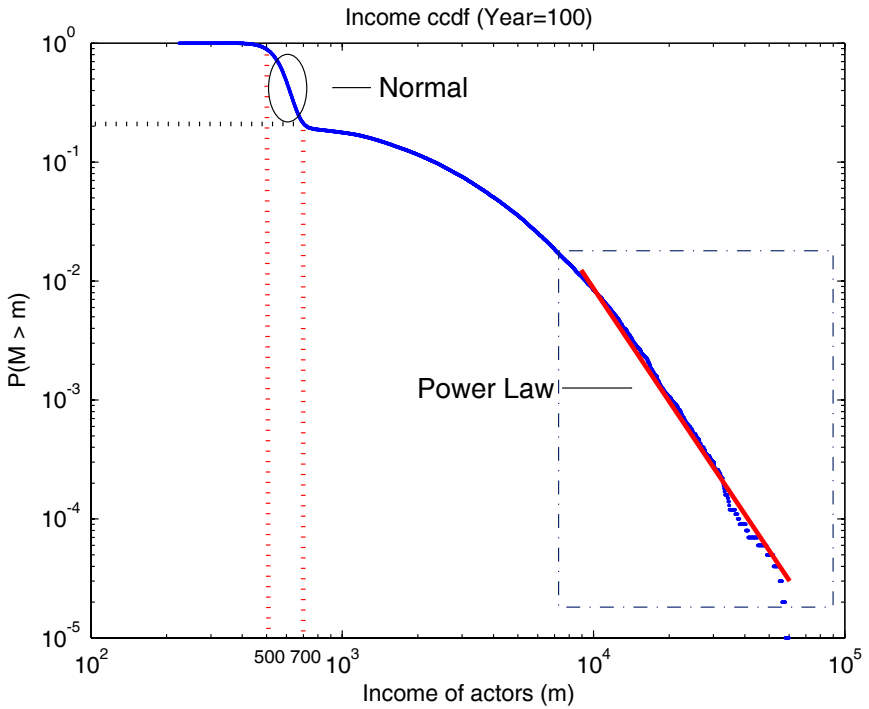
- Gamma profit rate: profit rate distribution is right-skewed, both tails can be fitted into Gamma distribution

Simulation Results

Income distribution — "knee" shape

- Income measure: record wage income by workers, and revenue income by firm owners





- Worker income cluster around mean, firm owner income has long tail; a "knee" shape with transition from exponential to power law.

Conclusion

- The model is also able to explain: Gaussian *firm-demise* distribution, Exponential *duration-of-recession* distribution. . .
- Contributions:
  - Simple game rules $\longrightarrow$ empirical distributions
  - Results not sensitive to either actor numbers or length of simulation
  - Quick convergence

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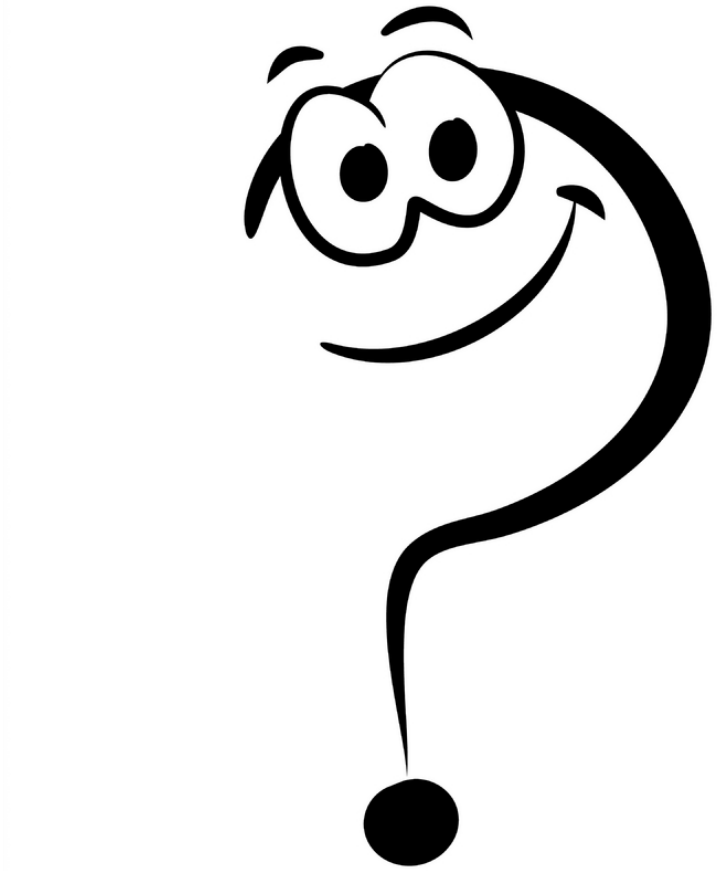
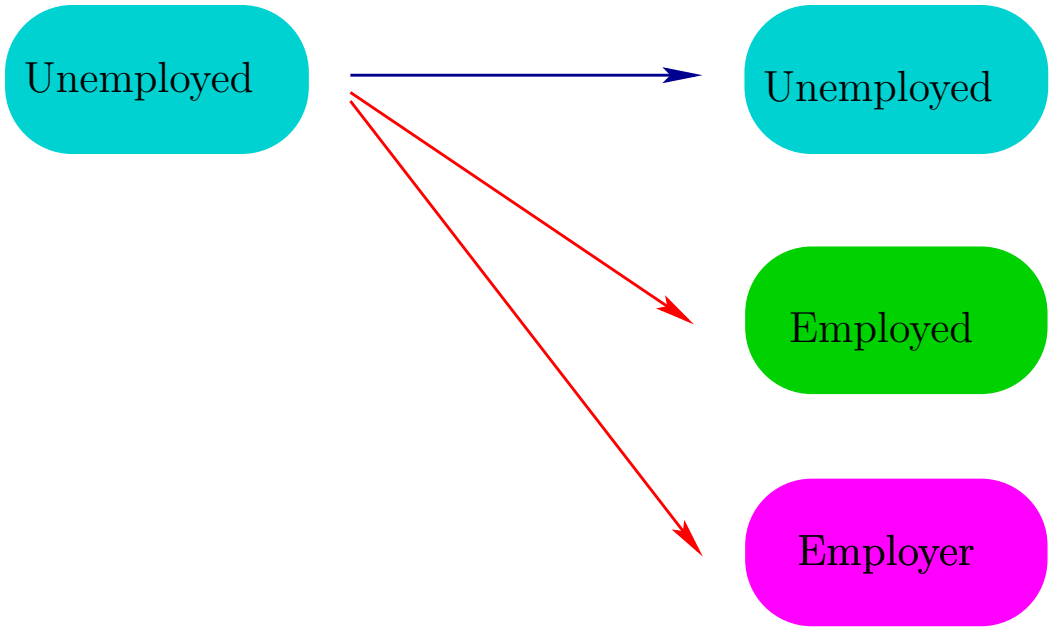
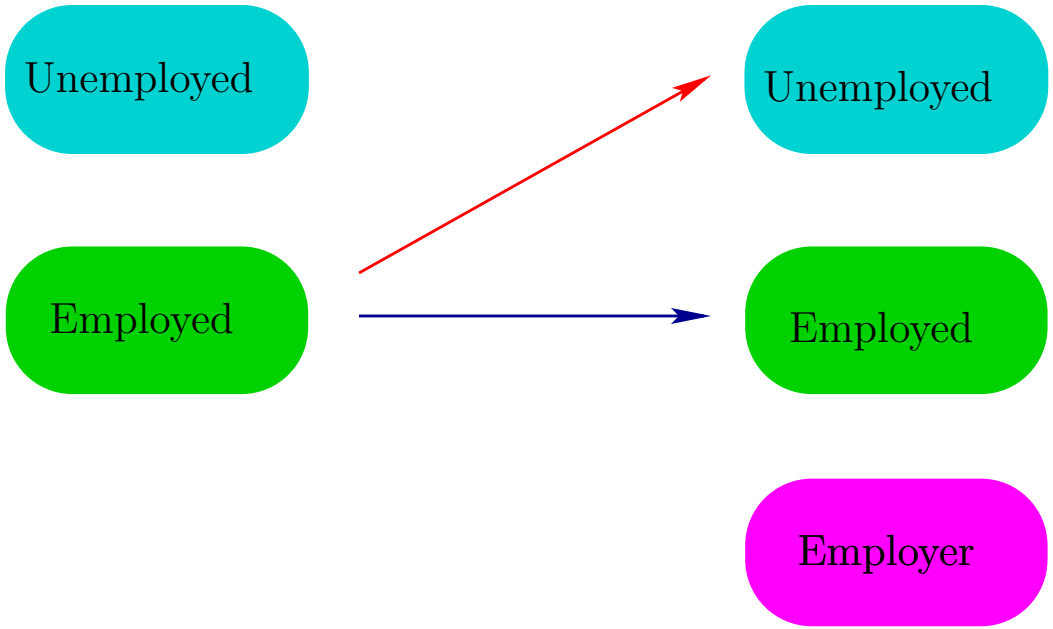
- Contributions:
  - Simple game rules $\longrightarrow$ empirical distributions
  - Results not sensitive to either actor numbers or length of simulation
  - Quick convergence
- Future Work:
  - Keep the model simple, explore more applicability
  - Add more ingredients to the model, e.g., bank
  - Can it explain some phenomena in labor market or financial market?

Thank you for your attention!




Unemployed
Unemployed
Employed
Employer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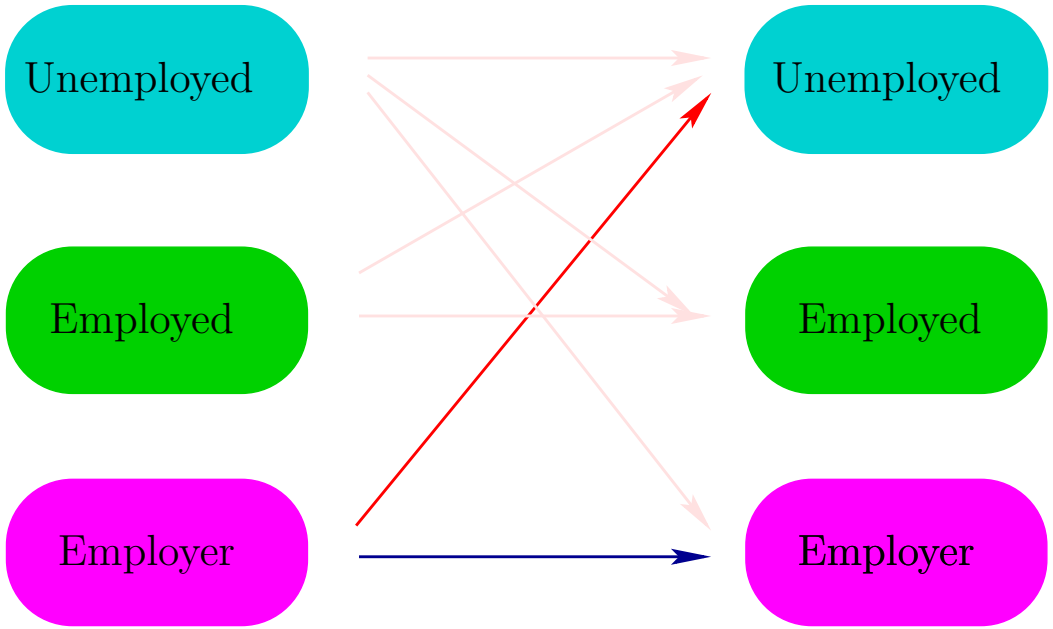
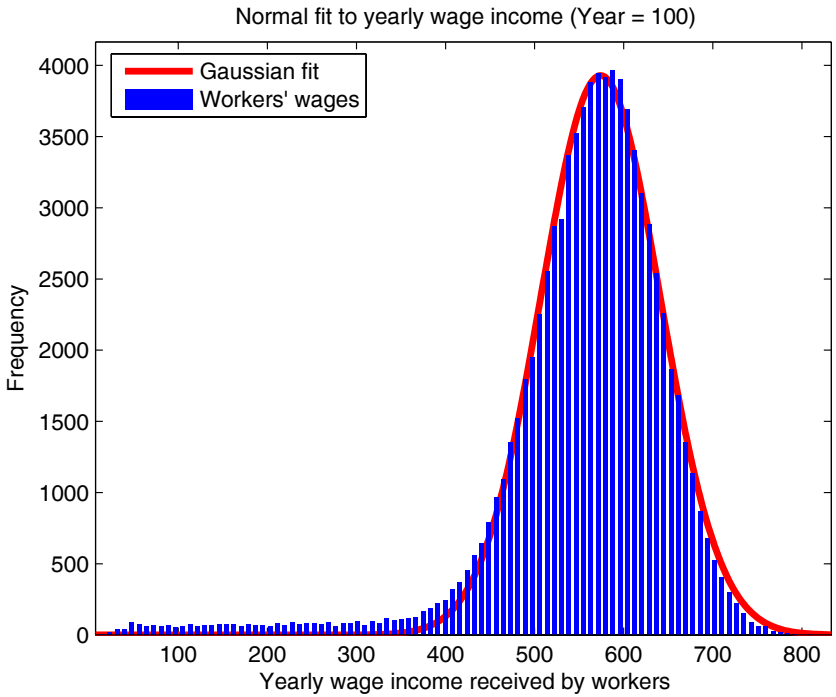
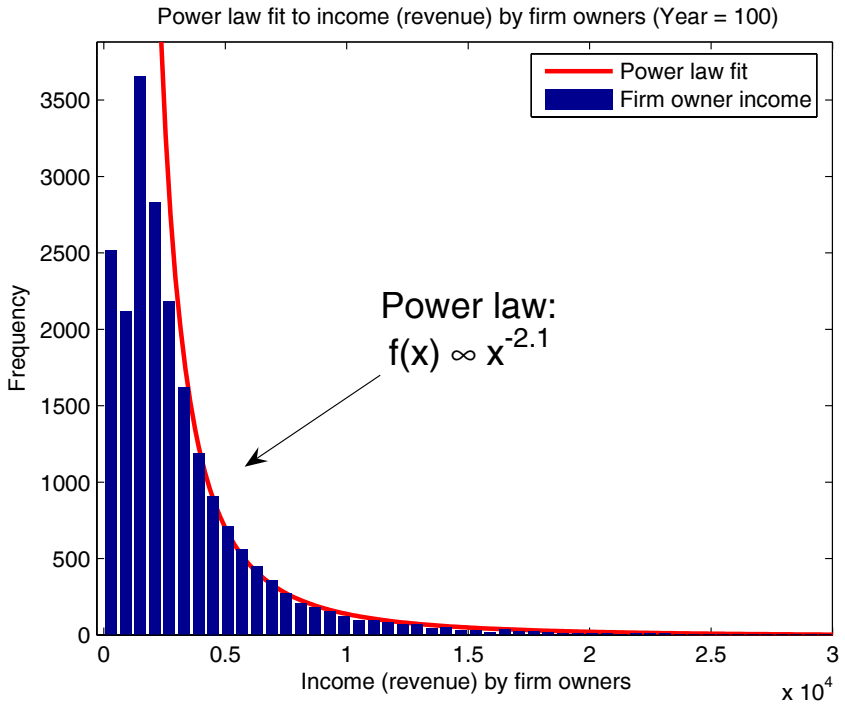


- All rules are executed N times to allow each of the N actor an equal possibility to realize all the possible rules
- A year counter records every 12 applications of the monthly rule (Year=100)

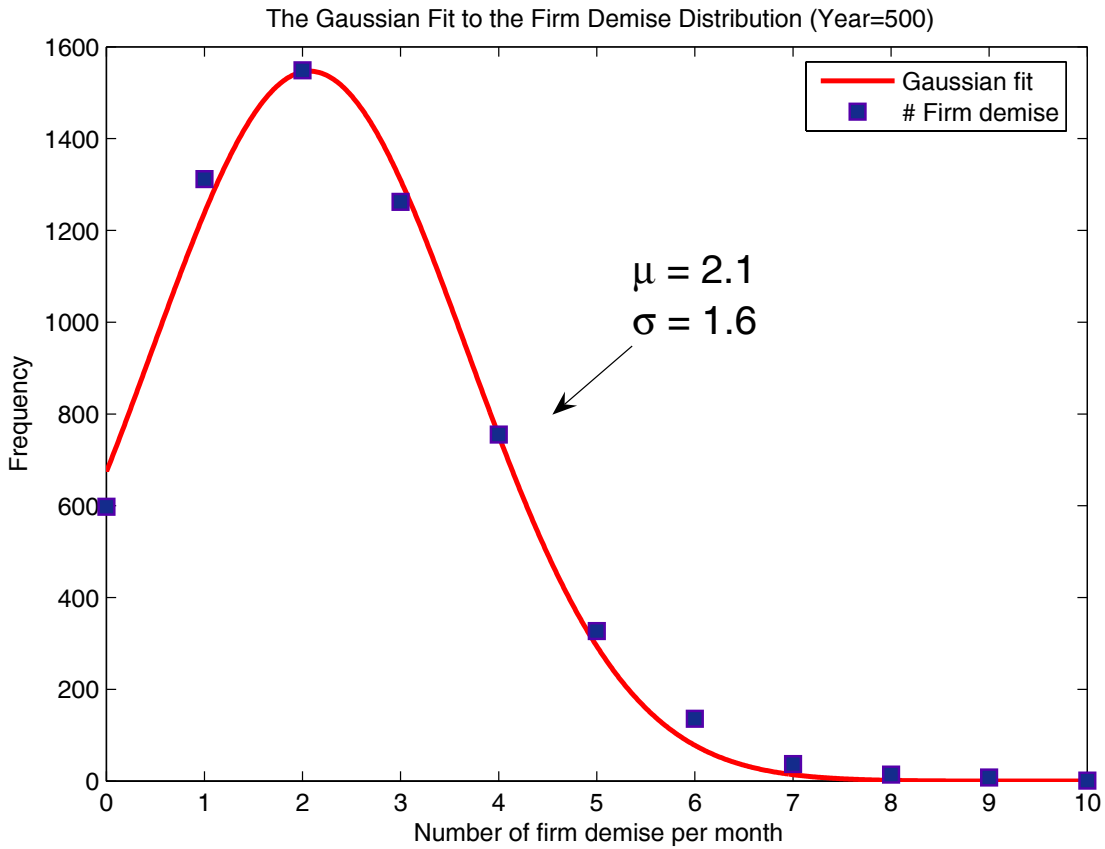
- Income measure: record wage income by workers, and revenue income by firm owners





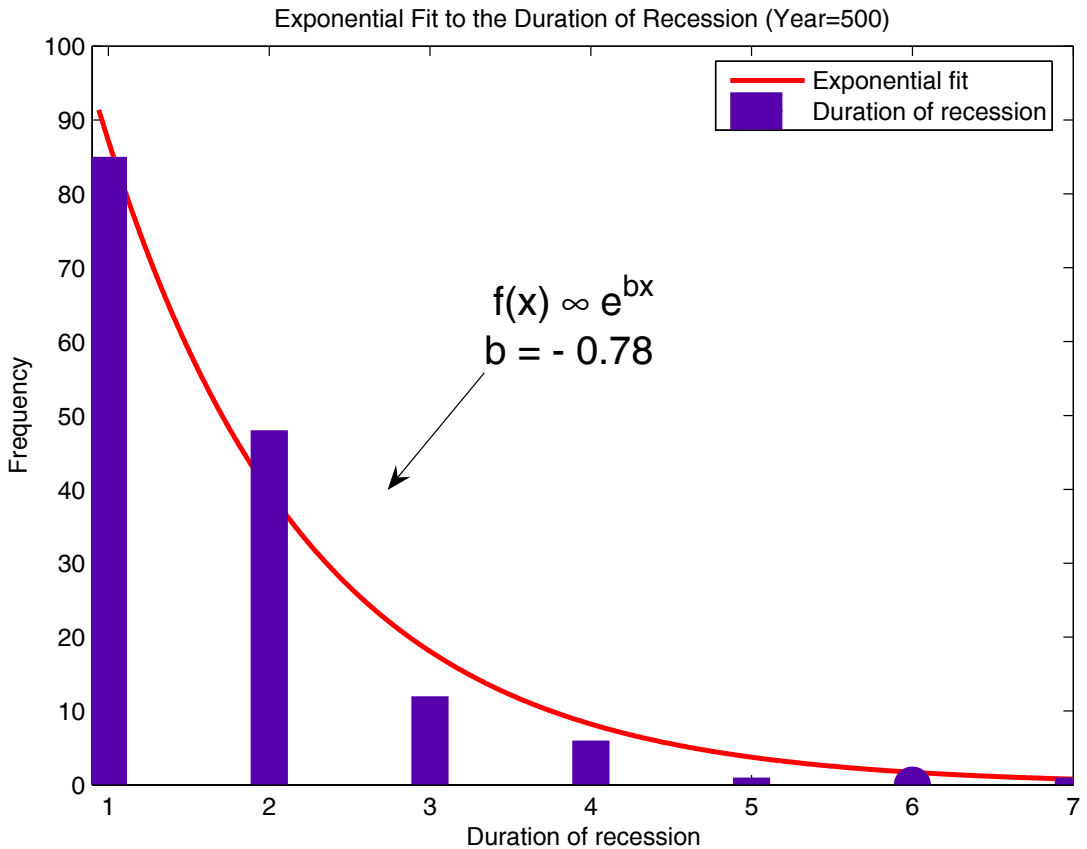
- Wages as income paid to workers — Gaussian, higher tail of income by firm owners — Power law

- Firm demise measure: A firm demise occurs when a firm fires all its employees, count monthly firm demise number



- Gaussian firm demise: 10% yearly firm demise rate

- Recession duration measure: A recession begins when the GDP declines, and ends when the GDP recovers



- Exponential recession duration: average 1.7 years, max 7 years