How does Money Memorize Social Interactions?
Understanding time-homogeneity in Monetary Systems

Andreas Schacker, Matthias Schmitt and Dieter Braun, Systems Biophysics
Social Networks
Social Networks
Social Networks of Money are memorized by Bookkeeping.
Purpose of Monetary Systems

Persons

A  B  C  D  E

€100  €80
€40  €60  €10
€30  €70

Product A  Product B

€100  €80

Time

Memory of Transactions

Network  Money Deposits
### Aktiva:

<table>
<thead>
<tr>
<th>Vermögensgegenstände</th>
<th>Stand am 30.9.2003</th>
<th>Stand am 30.9.2002</th>
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</thead>
<tbody>
<tr>
<td><strong>A. Anlagevermögen</strong></td>
<td></td>
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</tr>
<tr>
<td>I. Immaterielle Vermögensgegenstände</td>
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<tr>
<td>1. Sachanlagen</td>
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<td>2. Finanzanlagen</td>
<td>448.339.036</td>
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<td>II. Sachanlagen</td>
<td>647.683.489</td>
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<td>III. Sachanlagen</td>
<td>1.537.974</td>
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<td><strong>A. Eigenkapital</strong></td>
<td></td>
<td></td>
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<tr>
<td>I. Grundkapital</td>
<td></td>
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</tr>
<tr>
<td>II. Kapitalrücklagen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Gebundene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Nicht gebundene</td>
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<tr>
<td><strong>A. Gewinnrücklagen</strong></td>
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<tr>
<td>Andere Rücklagen (freie Rücklagen)</td>
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</tr>
<tr>
<td><strong>B. Kapitalrücklagen</strong></td>
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<tr>
<td><strong>III. Gewinnrücklagen</strong></td>
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<tr>
<td>I. Vorräte</td>
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<td>1. Roh-, Hilfs- und Betriebsstoffe</td>
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<td>2. unbefristete Erzeugnisse</td>
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<td>3. Fertige Erzeugnisse und Waren</td>
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<td>8.624.9</td>
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<td>4. Nach nicht abrechenbare Leistungen</td>
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<td>5. Geleistete Anzahlungen</td>
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<td>6. Erhaltene Anzahlungen auf Bestellungen</td>
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<td>-83.144.7</td>
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<td><strong>B. Umlaufvermögen</strong></td>
<td>84.282.157</td>
<td>72.653.4</td>
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<td><strong>II. Forderungen und sonstige Vermögensgegenstände</strong></td>
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<td>1. Forderungen aus Lieferungen und Leistungen</td>
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<td>2. Forderungen gegenüber verbundenen Unternehmen</td>
<td>596.717.308</td>
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<td>3. Forderungen gegenüber Unternehmen mit denen ein Beteiligungsverhältnis besteht</td>
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<td>davon aktivierte latente Steuern: EUR90.470.000; Vorjahr: TEUR97.570.0</td>
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<td><strong>C. Rückstellungen</strong></td>
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<td>1. Rückstellungen für Abfindungen</td>
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<td>2. Rückstellungen für Pensionen</td>
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<td>3. Steuerrückstellungen</td>
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<td>4. Sonstige Rückstellungen</td>
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<td><strong>D. Verbindlichkeiten</strong></td>
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<td><strong>F. Verbindlichkeiten</strong></td>
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<td><strong>G. Verbindlichkeiten aus Haftungsverhältnissen</strong></td>
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Bookkeeping Networks

Clay Tablets
Bookeeping Networks

Tally Sticks
Bookeeping Networks

Tally Sticks

Asset

Liability

Network

B → A

\[ \text{A} \ni \text{B} \ni +1\$ \ni \text{A} \ni \text{B} \ni +1\$ \ni \]
Bookeeping Networks

Tally Sticks

Map to Particle Excitations
Bookeeping Networks

Network

\[ B \rightarrow A \]

\[ \begin{array}{c}
\text{Creation} \\
\begin{array}{c}
A \\
+1$
\end{array}
\end{array} \quad \begin{array}{c}
\text{Annihilation} \\
\begin{array}{c}
A \\
-1$
\end{array}
\end{array} \]

\[ \begin{array}{c}
\text{Liab.} \\
\begin{array}{c}
B \\
+1$
\end{array}
\end{array} \quad \begin{array}{c}
\text{Asset} \\
\begin{array}{c}
B \\
-1$
\end{array}
\end{array} \]
Bookeeping Networks

Network

Asset Liab.

\[ \begin{array}{c}
\text{A} \\
+1$
\end{array} \]

\[ \begin{array}{c}
\text{B} \\
+1$
\end{array} \]

\[ \begin{array}{c}
\text{A} \\
-1$
\end{array} \]

\[ \begin{array}{c}
\text{B} \\
-1$
\end{array} \]

\[ \begin{array}{c}
\text{Network} \\
\text{B} \rightarrow \text{A}
\end{array} \]

\[ \begin{array}{c}
\text{Network} \\
\text{Z} \rightarrow \text{A}
\end{array} \]

\[ \begin{array}{c}
\text{Network} \\
\text{Z} \rightarrow \text{B}
\end{array} \]

\[ \begin{array}{c}
\text{Network} \\
\text{B} \rightarrow \text{Z}
\end{array} \]

\[ \begin{array}{c}
\text{Network} \\
\text{A} \rightarrow \text{B}
\end{array} \]

\[ \begin{array}{c}
\text{Accum. units} \\
\text{A} \\
p_{0}$
\end{array} \]

\[ \begin{array}{c}
\text{Com. units} \\
\text{A} \\
p_{1}$
\end{array} \]

\[ \begin{array}{c}
\text{Non-} \\
\text{banc}
\end{array} \]

\[ \begin{array}{c}
\text{B} \\
-1$
\end{array} \]

\[ \begin{array}{c}
\text{Z} \\
+1$
\end{array} \]

\[ \begin{array}{c}
\text{Bank} \\
\text{stock} \\
\text{Z}
\end{array} \]

\[ \begin{array}{c}
\text{Z} \\
+1$
\end{array} \]

\[ \begin{array}{c}
\text{Z} \\
-1$
\end{array} \]
Circular transfer

Trusted

A

B

C

D

Liab. Asset

p

t

A

B

C

D

Trusted
Circular transfer

Trusted

A

B

C

D

A

B

C

D

A

B

C

D

Liab. Asset

p

B

A

C

D

Liab. Asset

p

B

A

C

D

Liab. Asset

p

B

A

C

D

Liab. Asset

p

B

A

C

D

Liab. Asset

p
Circular transfer

Through Bank Z

Liabilities Asset

\[ E_D = E_L \]
\[ E_D \neq E_L \]
\[ \frac{E_D}{E_L} = f(t) \]
Circular transfer

Through Bank with free Rate Deposits : Credits

Deposits
Credits
Traditional Banking ... has two currencies

Credit Country

Exch. Rate

Deposit Country

Credit Creation Transfers...

Asset

Liab.

Bank

Bank

Credit Termination Transfers

Bank

A

C

E

D
Bookeeping Networks
Bookeeping Networks

Network

A exchanges currency “ ” against currency “ ” from B
Bookeeping Networks

A deposits cash “” at bank B and opens an account in bank currency “”
Bank B outsources a credit “_____” to A and opens an account for A in bank currency “_____”
Bookeeping Networks

Network

Bank A gives bank B credit line in " " and bank B gives A credit line in " "

Debt dynamics

Money

Credit

Piggy Bank
Debt dynamics

Money → Credit

A Bank → Cash

Liab. Asset

A Bank → Deposit

Time
Debt dynamics

Money ↔ Credit

A Bank

Deposit

Cash

A

Bank

Payment with Credit

Depositor

Bank

Debtor

Deposit Units

Credit Units

Piggy Bank
Debt dynamics

![Graph showing the dynamics of cash and loans over time]

- **Graph Title**: Debt dynamics
- **Axes**: Time [Year] on the x-axis, Cash, Loans [T€] on the y-axis
- **Lines**: Dotted line for Monetary financial institutions, solid line for Cash Euro in Circulation
- **Legend**:
  - **Dotted line**: Monetary financial institutions
  - **Solid line**: Cash Euro in Circulation

**Diagram Notes**:
- **Nodes**: A, Bank, Cash, Deposit, Bank, Depositor, Debtor, Payment with Credit, Deposit Units, Credit Units
- **Arrows**:
  - **A to Bank**: Cash
  - **Deposit to Bank**: Deposit
  - **Bank to Depositor**: Bank
  - **Bank to Debtor**: Bank
  - **Red arrows**: Payment with Credit
- **Time**: Time [Year]
Debt dynamics

Payment with Credit

Bank
Depositor
Debtor
Bank

Monetary financial institutions
Cash Euro in Circulation
Other Financial Institutions
Government


density of monetary financial institutions
Cash Euro in Circulation
Other Financial Institutions
Government

Time [Year]

0.1 2000 2004 2008 2012
Nonlocal Effects of Credit Creation
Cantillon Effect: Nonlocal Wealth Change

Assets

Liabilities

Direct Transfer

Credit Creation
Cantillon Effect: Nonlocal Wealth Change

Assets

Liabilities

Direct Transfer

Credit Creation
Circular transfer with interest

Through Bank with interest

Network

Through Bank with interest
**Traditional Banking ... ‘renormalized’**

Money Quantity $M \propto$ Number of Persons

...Exit of Persons
Traditional Banking ... ‘renormalized’

Entry of Persons...

Asset ↑

Liab. ↓

Bank

...Transfers...

A D Bank

...Exit of Persons

D Bank

Bank

D

t
Traditional Banking ... ‘renormalized’

Entry of Persons...

Asset | Liab.
--- | ---
A | A

Bank

...Transfers...

A | D | Bank | A

Bank

...Exit of Persons

D | Bank | E

Bank

Exchange Rate between Debts and Deposits

Judgement in real-time by all market participants

No Nonlocal Cantillon Effect

Debts for the Future

Julian Stein

\( \lambda \in \mathbb{D} \)

\( \lambda \in \mathbb{L} \)

.entry of persons...

asset | liab.
--- | ---
A | A

bank

...transfers...

A | D | bank | A

bank

...exit of persons

D | bank | E

bank

exchange rate between debts and deposits

judgement in real-time by all market participants

no nonlocal cantillon effect
Under a Random Economy

Quantity per Person

\[ T_i = \frac{M_i}{N} \]

\[ P(\omega) = \frac{p_a p_l}{T_l p_a + T_a p_l} \cdot \exp \left( -\frac{\omega p_a}{T_a} \right) \]
Instead of Credit Creation: Liquidity transfer from A to C

Quantity per Person

$$T_i = \frac{M_i}{N}$$

$$P(\omega) = \frac{p_a p_i}{T_i p_a + T_a p_i} \cdot \exp \left( -\frac{\omega p_a}{T_a} \right)$$
Stability of Monetary Systems

Traditional Banking

Credit Default

Network

‘Renormalized’ Banking

Money Deposits only local transfers!

...Exit of Persons

D

Bank

D

Bank
Traditional Banking ... diverges under Random Transfers

A first stress test for monetary systems?
Random Graph

\[ D = \frac{\Delta p^2}{\Delta t} \]
Random Economy

Random Graph

\[ D = \frac{\Delta p^2}{\Delta t} \]

\[ n(p, t) \propto \exp\left(-\frac{p^2}{4Dt}\right) \]

Random Economy

Random Graph

\[ D = \frac{\Delta p^2}{\Delta t} \]

Inflational Information Overflow

(like wavepacket in QM)

\[ n(p, t) \propto \exp\left(-\frac{p^2}{4Dt}\right) \]

\[ M(t) = 4N \sqrt{\frac{Dt}{\pi}} \]

Random Economy

Random Graph

\[ D = \frac{\Delta p^2}{\Delta t} \]

Quantity limit
No transactions which exceed the quantity of money limit \( M \).

\[ n = \frac{N^2}{2M} \exp\left(-\frac{N|p|}{M}\right) \]

Random Graph

\[ D = \frac{\Delta p^2}{\Delta t} \]

Liability limit
Debts are limited to L.

\[ n = \frac{\Delta p N}{L} \exp\left(-\frac{p}{L}\right) \]

Random Economy

Random Graph

\[ D = \frac{\Delta p^2}{\Delta t} \]

Energy limit
No transactions which exceed a quadratic Energy measure of money.

\[ n = N \sqrt{\frac{N}{2\pi E}} \exp \left( -\frac{Np^2}{2E} \right) \]

Random Economy under Central Limit

Quantity limit
No transactions which exceed the quantity of money limit $M$.

\[ n = \frac{N^2}{2M} \exp\left(-\frac{|p|}{M}\right) \]

Liability limit
Debts are limited to $L$.

\[ n = \frac{\Delta p N}{L} \exp\left(-\frac{p + L}{L}\right) \]

Energy limit
No transactions which exceed a quadratic Energy measure of money.

\[ n = N \sqrt{\frac{N}{2\pi E}} \exp\left(-\frac{Np^2}{2E}\right) \]

Random Economy under Central Limit

Quantity limit
No transactions which exceed the quantity of money limit $M$.

\[ n = \frac{N^2}{2M} \exp \left( \frac{-|p|}{M} \right) \]

Liability limit
Debts are limited to $L$.

\[ n = \frac{\Delta p N}{L} \exp \left( \frac{p + L}{L} \right) \]

Energy limit
No transactions which exceed a quadratic Energy measure of money.

\[ n = N \sqrt{\frac{N}{2\pi E}} \exp \left( -\frac{Np^2}{2E} \right) \]

Wealth Distribution by “Economic Boltzmann”  
\[ n(p) \propto \exp\left(-\frac{\text{Limit}(p)}{D}\right) \]

Random Economy + Transfer Potential

Quantity limit
No transactions which exceed the quantity of money limit M.

Liability limit
Debts are limited to L.

Energy limit
No transactions which exceed a quadratic Energy measure of money.

Wealth Distribution by “Economic Boltzmann”
\[ n(p) \propto \exp \left( -\frac{U(p)}{D} \right) \]

Interpret Limit as Transfer Potential \( U \)
\[ \frac{\Delta p}{\Delta t} = -\nabla \text{Limit}(p) \]

Random Economy + Transfer Potential

Quantity limit
No transactions which exceed the quantity of money limit $M$.

Liability limit
Debts are limited to $L$.

Energy limit
No transactions which exceed a quadratic Energy measure of money.

Symmetric Head Tax
State imposes a head tax which it distributes to liability holders.

Cropped Head Tax
Head tax together with highly non-linear social security benefits for liability holders.

Negative interest
Negative interest rate imposed as money tax. Results in transfer from rich to poor.

Wealth Distribution by “Economic Boltzmann”

$$n(p) \propto \exp\left(-\frac{U(p)}{D}\right)$$

Random Economy + positive Interest
Random Economy + positive Interest
Random Economy + positive Interest

Work

more

less

Work

less

more

Agents n [%/€]  Potential U [€]

Agents n [%/€]  Potential U [€]

Agents n [%/€]  Potential U [€]

Agents n [%/€]  Potential U [€]

Wealth p [€]

Wealth p [€]

Wealth p [€]

Wealth p [€]
Random Economy + positive Interest

Work
more
less

Work
less
more

Agents n [%/€]
Potential U [€²]

Agents n [%/€]
Potential U [€²]

Agents n [%/€]
Potential U [€²]

Cumulative Wealth [%]

Wealth of Richest 1% [%]

Wealth & Debt of Top 1% [%]

Interest r
- 50%
- 20%
- 15%
- 10%
- 8%
- 6%
- 4%
- 2%