The evolution of wealth transmission in human populations

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SEH 2009 - Montpellier
Wealth and fitness in humans

In most non-industrial societies, some aspects of reproductive success increase with wealth...


An example from the Krummhörn population (Germany, 18th and 19th Centuries) adapted from Voland 1990, *Behavioral Ecology and Sociobiology*. 26:65-72
The familial transmission of wealth

The future social status of a child depends on his parents wealth.

Wealth is transmitted from parents to children.

An example from the Krummhörn population (Germany, 18th and 19th Centuries) adapted from Voland 1990, *Behavioral Ecology and Sociobiology*. 26:65-72
The rules of wealth transmission vary a lot:
- among populations (e.g. among French regions)

The rules of wealth transmission vary a lot:
- among populations (e.g. among French regions)
- over time (e.g. between first and third generation settlers in Massachusetts)

A mathematical modeling approach

The optimal transmission rule might vary from one parent to another because not all parents have the same wealth to transmit!

The way wealth transmission rules evolve depends on how wealth is distributed in the population.
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1. an economical model that predicts how wealth is distributed in the population,
A mathematical modeling approach

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1. an **economical model** that predicts how wealth is distributed in the population,
2. a **reproduction model** that predicts how many children a parent has depending on his wealth,
A mathematical modeling approach

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1. an **economical model** that predicts how wealth is distributed in the population,

2. a **reproduction model** that predicts how many children a parent has depending on his wealth,

3. a **devolution model** that predicts how a parent transmits his wealth to his children,
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1. an **economical model** that predicts how wealth is distributed is the population,
2. a **reproduction model** that predicts how many children a parent has depending on his wealth,
3. a **devolution model** that predicts how a parent transmits his wealth to his children,
4. a **mutation model** that creates variation in transmission rules.
A mathematical modeling approach

**Question**

What is the impact of economical inequalities on the way wealth transmission rules evolve?
A model for land trade

Each individual owns some land,
Individuals produce crops.
A model for land trade

By chance, some individuals produce more than others:

- those that produce the least have to sell part of their land,
- those that produce the most can buy some extra land.
A model for land trade

buy / sell

× 25

harvest
Random events combined to economical transactions will create inequalities in the population.

**Question**

How should we quantify inequalities?
Measuring inequalities: the Gini index

The graph illustrates the relationship between rank and cumulated wealth. The table below shows the data used to construct the graph:

<table>
<thead>
<tr>
<th>rank</th>
<th>wealth</th>
<th>cumulated wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: The data in the table is fictional for the purpose of illustration.
Measuring inequalities: the Gini index

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<tr>
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<tbody>
<tr>
<td>1</td>
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<td>0</td>
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<td>3</td>
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<td>0</td>
</tr>
<tr>
<td>5</td>
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</table>
The Gini index is proportional to the area between the curve of perfect equity and the actual curve.
Measuring inequalities: the Gini index

- A Gini index close to zero means that all individuals have the same wealth,
- A Gini index close to one means that all wealth goes to a single individual.
A model for land trade

The key parameters

- \( \sigma^2 \) the (environmental) variance of crop production per unit of land,
- \( \alpha \) the fraction of the production that is taxed and redistributed evenly over the whole population.
The economical model: environmental variance creates inequalities

Inequalities increase when
- taxes \((\alpha)\) decrease,
- environmental variance \((\sigma^2)\) increases.
The reproduction cycle

Wealth determines the probability to reproduce

Reproduction

Ferdy et al. (EDB)  Evolution of devolution  SEH 2009 - Montpellier
The reproduction cycle

- Reproduction
- Wealth
- Buy / sell
- Harvest
- Reproduction

× 25

Reproduction

P

wealth
The reproduction cycle

Reproduction
Wealth determines the probability to reproduce

Reproduction
The number of children is drawn from a Poisson distribution with mean $f$
The reproduction cycle

- **Devolution**: Father dies and transmits his land to his children.
- **Reproduction**: The number of children is drawn from a Poisson distribution with mean $f$.
- **Reproduction**: Wealth determines the probability to reproduce.

The cycle includes:
- Buy/sell
- Harvest
- Reproduction
Land is transmitted from parent to offspring

The parameter $\rho$ is the fraction of father’s land given to the firstborn (preferred) child.

- $\rho = 1$ the firstborn child gets all the father’s land,
- $\rho = 0$ all children receive the same fraction of the father’s land.
Land is transmitted from parent to offspring

\[ \rho w \]  
\[ \rho (1 - \rho) w \]  
\[ \rho (1 - \rho)^2 w \]  

- On average children transmit their wealth just as their father did,
- But mutation creates random changes between father’s and children’s \( \rho \).

\( \rho \) is heritable, variable and determines in part the average reproductive success of children... it must evolve!
Two regimes of selection...

- when environmental variance is weak the fraction given to the firstborn child increases,
- when environmental variance is high the fraction given to the firstborn child decreases.
Poor people should favor one of their children

A situation where a father has two sons and give 3/4 of his land to the firstborn...

When the father is poor to moderately rich, the probability that one of the children reproduces would be lower if they had been transmitted equal wealth.
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Rich people should transmit evenly their wealth

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If the father is very rich, the probability that one of the children reproduces would be greater if they had been transmitted equal wealth.
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Economical systems that decrease inequalities promote primogeniture
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When environmental variance is high, the Gini index is high and selection can play on very rich people...
Conclusion

If selection plays mostly on poor people
- selection favors unigeniture

If selection can play on very rich people
- selection favors egalitarian transmission
Conclusion

If land trade does not create a lot of inequalities
- selection favors unigeniture

If land trade does create a lot of inequalities
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If land trade does create a lot of inequalities
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The evolution of an egalitarian transmission rule is explained by a saturating relationship between wealth and fitness...

This is not really new!
- etc.
What is new...

The idea that economical systems that create inequalities favor egalitarian transmission rule is counter-intuitive.

Future work

- What would happen if individuals could decide their transmission rule is response to their wealth?
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Future work

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- How would the decision rule evolve?
Conclusion

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Future work

- What would happen if individuals could decide their transmission rule is response to their wealth?
- How would the decision rule evolve?
- What would happen if individuals could change their fecundity, instead of modifying their transmission rule?
An optimality approach of this latter point shows that, under some conditions, rich people should have fewer children than poor people...