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Does money make the world go round?

- The journey of Euro banknotes and coins as a diffusion process

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History (and near future) of the Euro

- 1957: The Treaty of Rome declared a common European market
- 1986: The Single European Act
- 1992: The Treaty of European Union introducing Economic and Monetary Union
- 1999: The exchange rates of the participating currencies were set
- 2002: Introduction of the new cash currency
- 2007→: New member countries will join the Euro

The Art

Euro coins: front sides (common design)

The Art

Euro coins: back sides (distinct design)

The Art
Euro banknotes: frontsides (I)

The Art
Euro banknotes: frontsides (II)

The Art
Euro banknotes: backsides

The European Union and the Euro zone

The Science
Diffusion

- A transport phenomenon
- Spontaneous spreading of something from higher concentration to lower one
  - Heat, particles, momentum, …
- Diffusion equilibrium is reached when concentrations of a diffusing substance are homogeneous throughout the system

The EuroBillTracker (EBT) community

- An international non-profit volunteer team dedicated to tracking Euro notes around the world
- Each user enters the printer code, serial number and location of the place the note was got from of the notes they get
- Currently (September 7th, 2006)
  - 90 991 users
  - 20 419 964 notes
  - 71 120 notes entered more than once (0.35%)
- http://www.eurobilltracker.com

The Science
Possible ways to model the Euro diffusion

- Diffusion equation

$$\frac{\partial u}{\partial t} = c\nabla^2 u$$

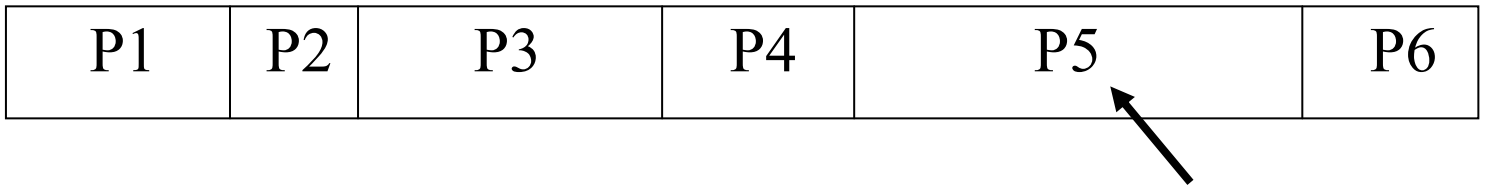
- Markov chains

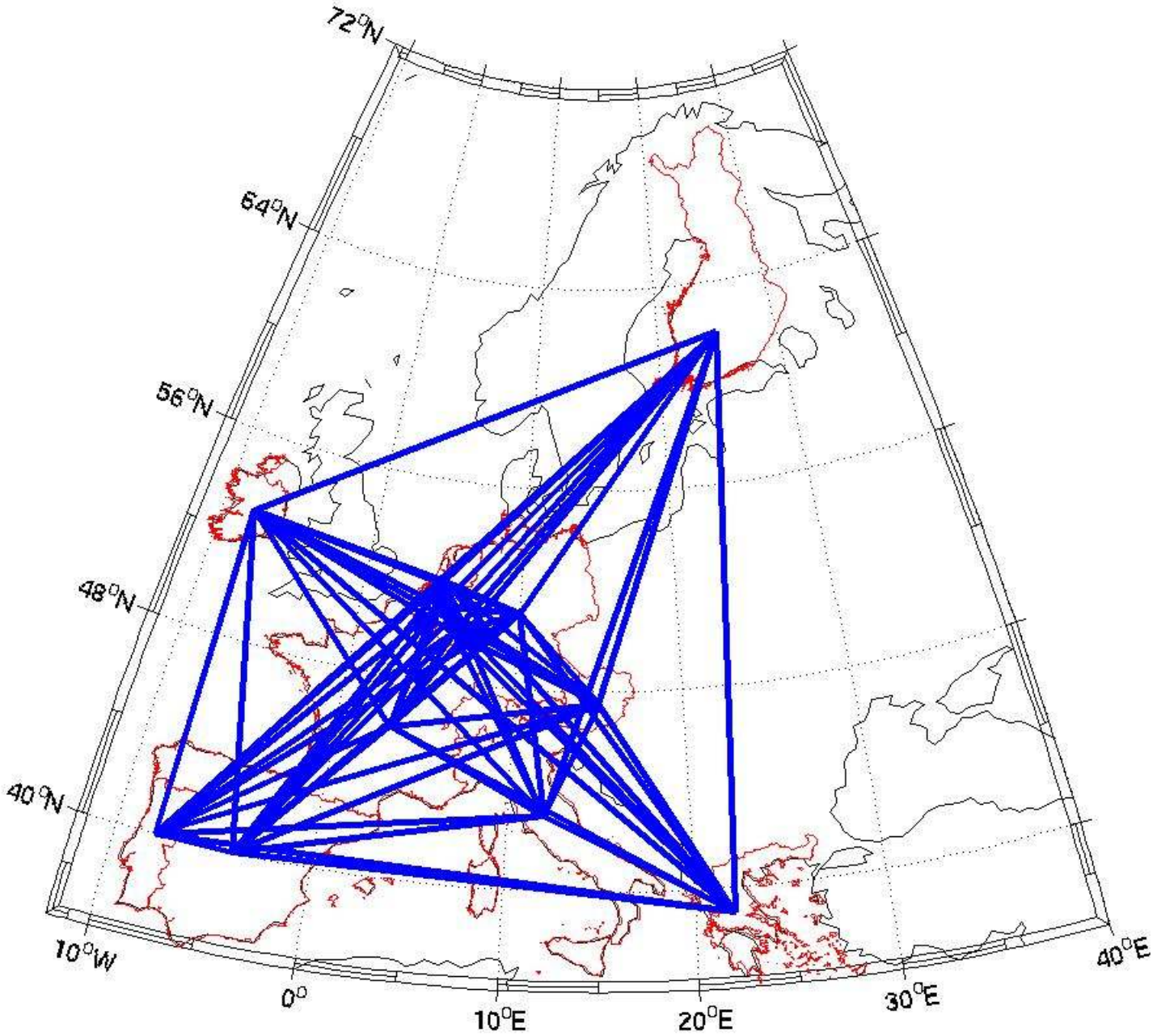
- Monte Carlo simulations
  - If there are nonlinear phenomena

The Technology
The Monte Carlo simulation method

- Basic idea: coins and banknotes move from one country to another with travellers.

- Residence time algorithm was used.
  - Also known as BKL (Bortz, Kalos, Lebowitz), kinetic Monte Carlo.
  - Transitions selected randomly according to probabilities in a cumulative function
  - Total number of probabilities in the cumulative function is 12 x 12 - 12 = 132

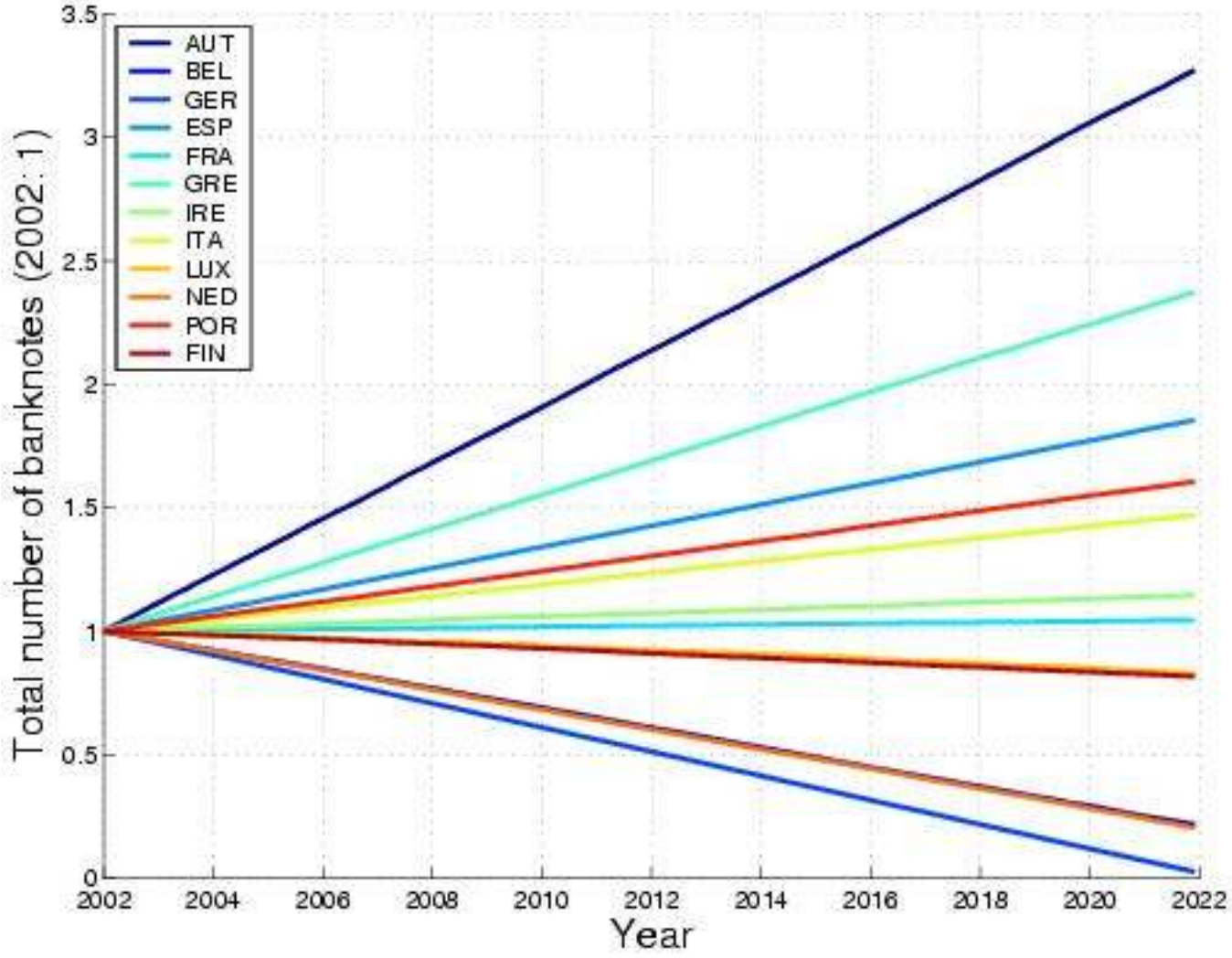



72°N
64°N
56°N
48°N
40°N
10°W
0°
10°E
20°E
30°E
40°E

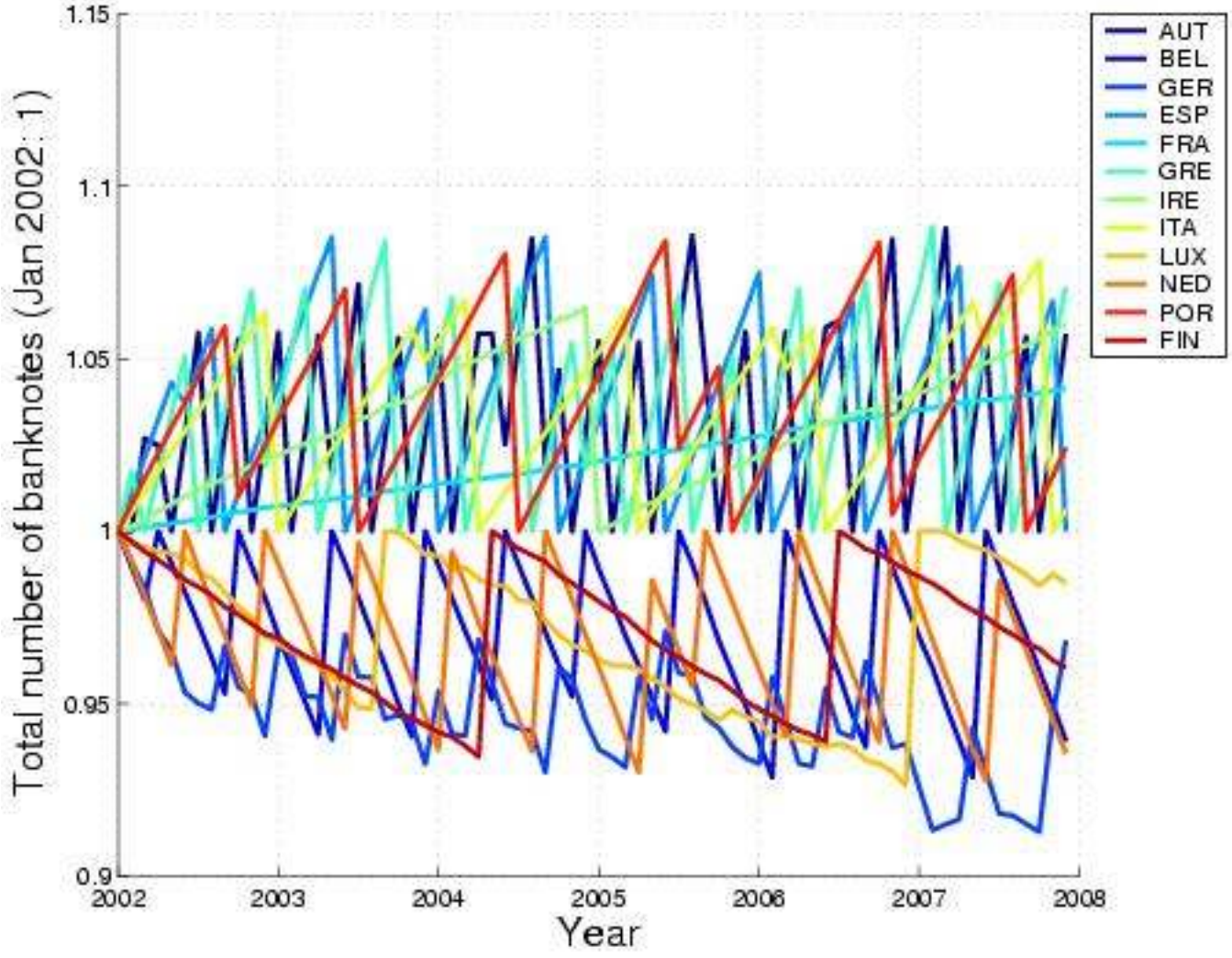
Main assumptions

- The diffusion rate: related to the number of travellers between Euro countries and the number of coins/notes they carry with them
- The replenishment rate: an average lifetime of 2.5 years for banknotes, much longer for coins (~25 years)
- The transportation of coins and banknotes from ”overpopulated” to ”underpopulated” areas

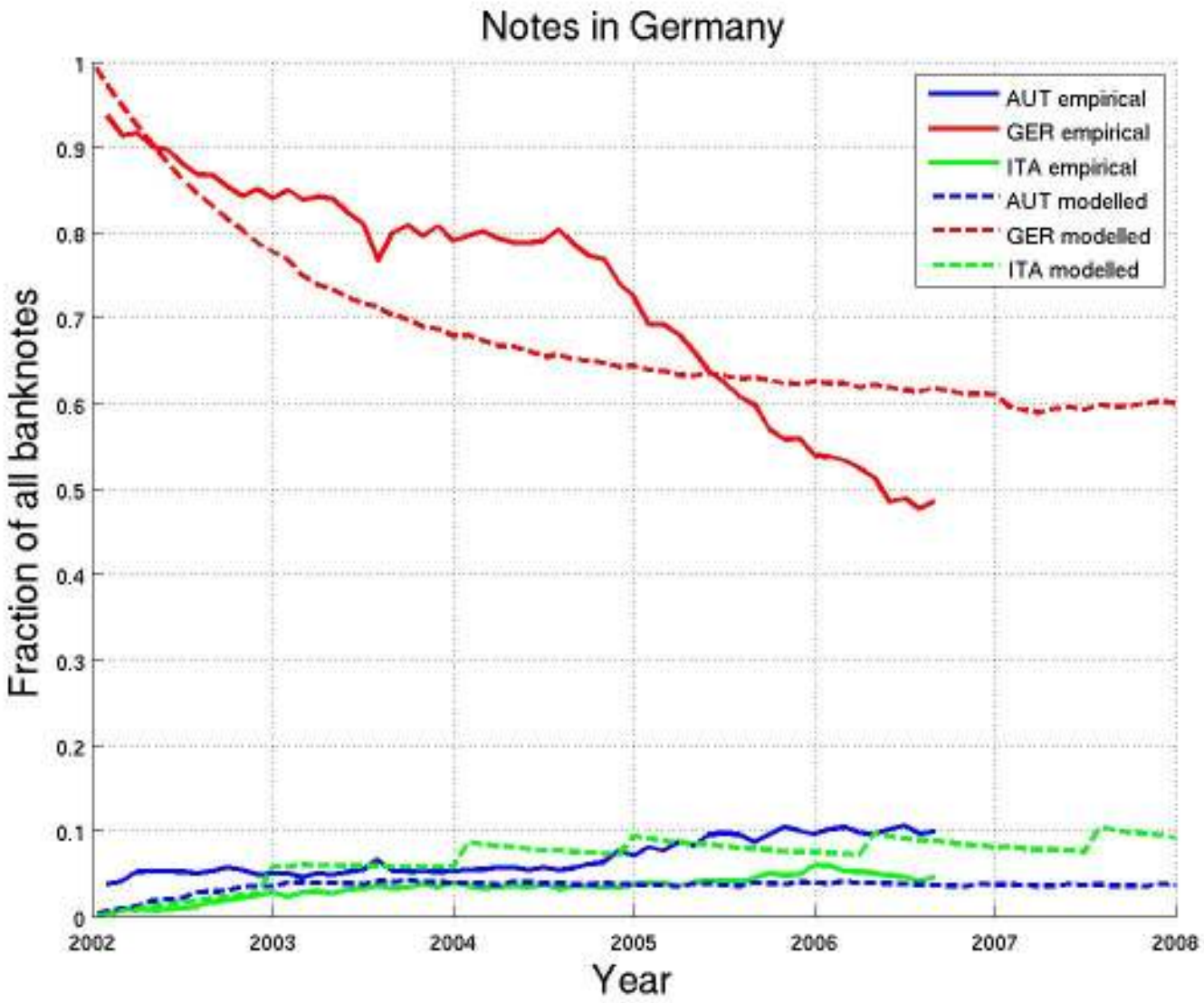
Results: notes / no transportation



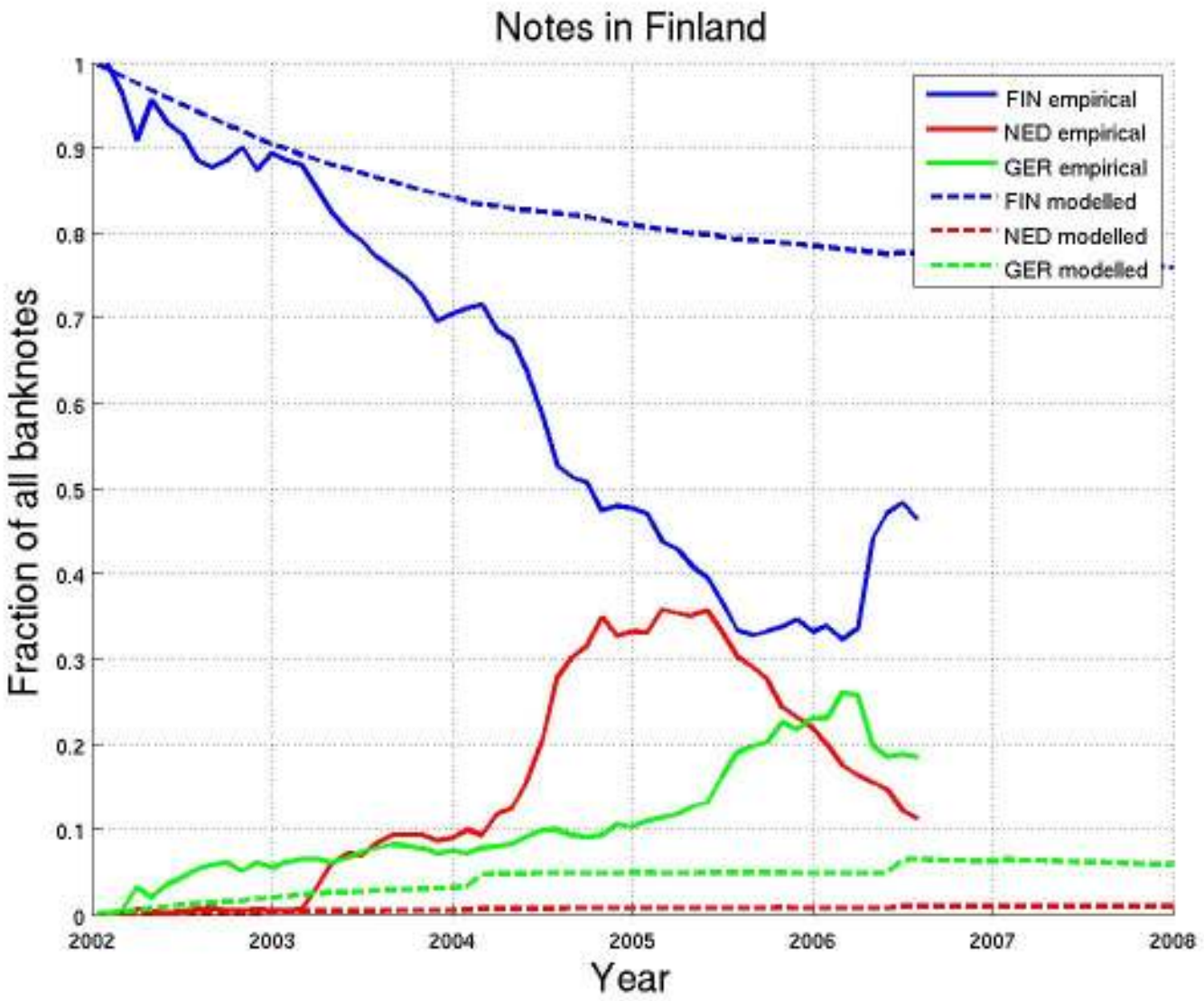
Results: notes / transportation monthly from the most overpopulated to the most underpopulated country



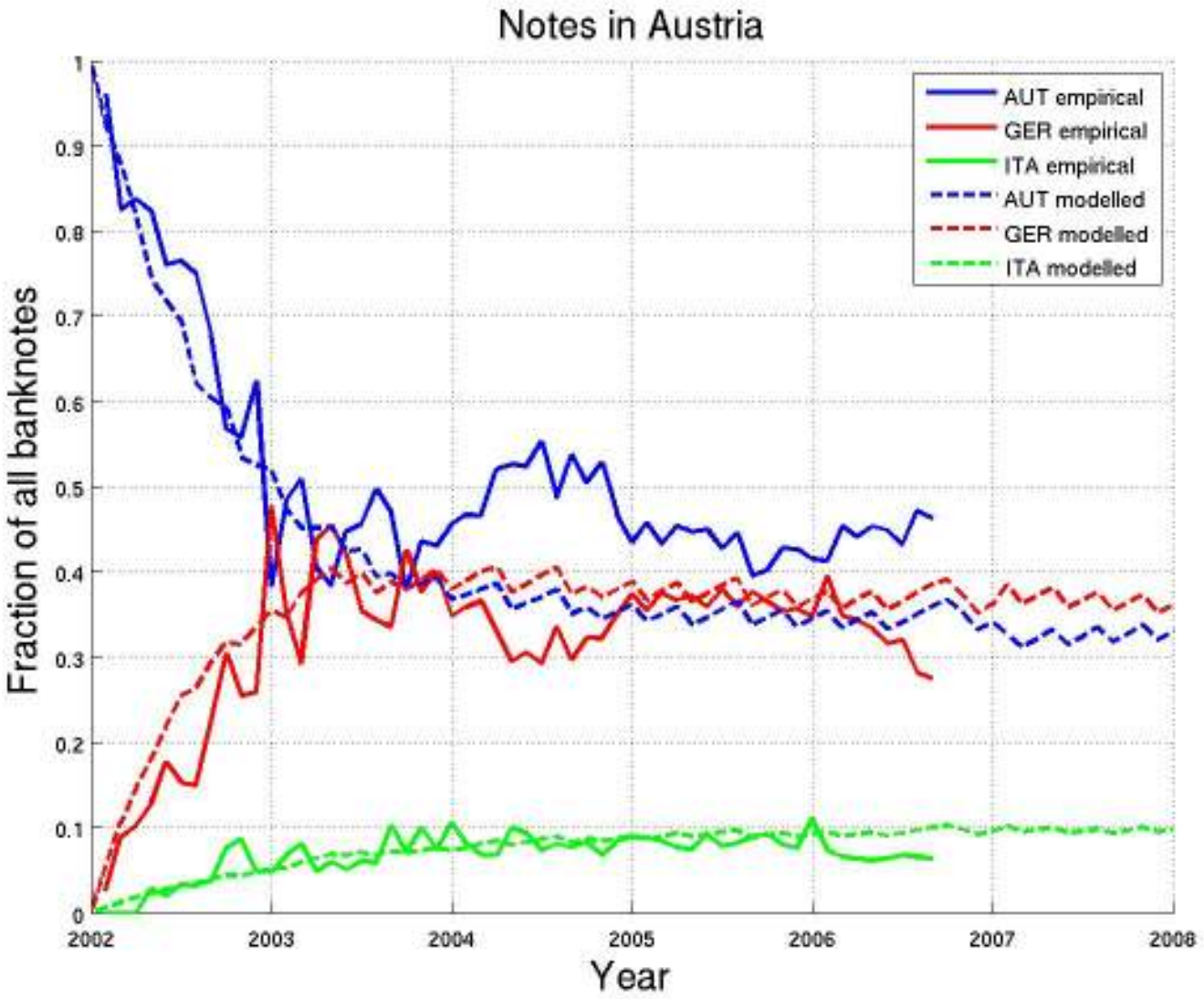
Results: banknotes in Germany



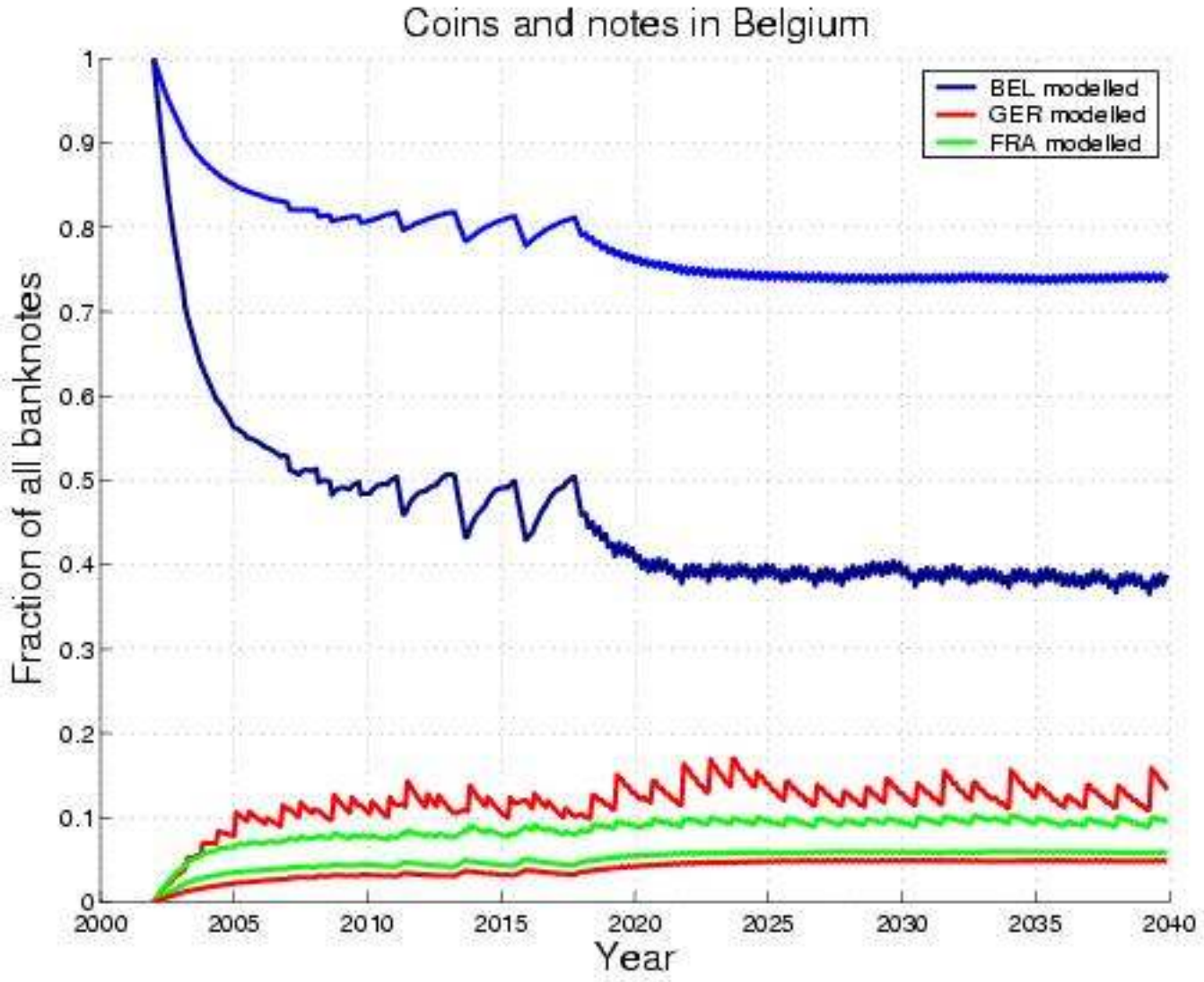
Results: banknotes in Finland



Results: banknotes in Austria



Results: coins and banknotes in Belgium



Conclusions

- The predicted diffusion of Euro banknotes compares surprisingly well with the empirical data just using a few simple assumptions
- Diffusion equilibrium is never reached
- The local equilibrium in each country is different for coins and notes because of the differences in number, lifetimes and transportation statistics
- The time needed to reach the local equilibrium seems to be approx. 20 years with the parameters used

Thanks

- Prof. Kai Nordlund for the idea

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