



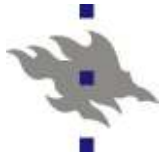
HELSINGIN YLIOPISTO  
HELSINGFORS UNIVERSITET  
UNIVERSITY OF HELSINKI

# Does money make the world go round?

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

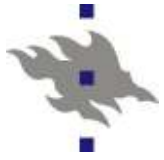
A presentation at SAT 2006,  
September 9<sup>th</sup>, 2006  
Antti Lauri

Department of Physical Sciences  
Division of Atmospheric Sciences



## History (and near future) of the Euro

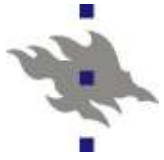
- 1957: The Treaty of Rome declared a common European market
- 1986: The Single European Act
- 1992: The Treaty of European Union introducing Economic and Monetary Union
- 1999: The exchange rates of the participating currencies were set
- 2002: Introduction of the new cash currency
- 2007→: New member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



## The Art

### **Euro coins: front sides (common design)**

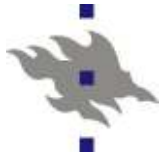




## The Art

### Euro coins: back sides (distinct design)

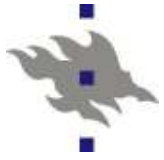




## The Art

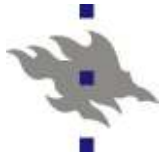
### Euro banknotes: frontsides (I)





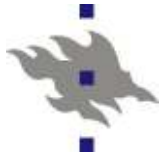
# The Art Euro banknotes: frontsides (II)





# The Art Euro banknotes: backsides





# The European Union and the Euro zone

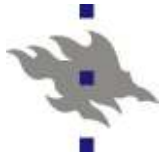






## The Science Diffusion

- 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




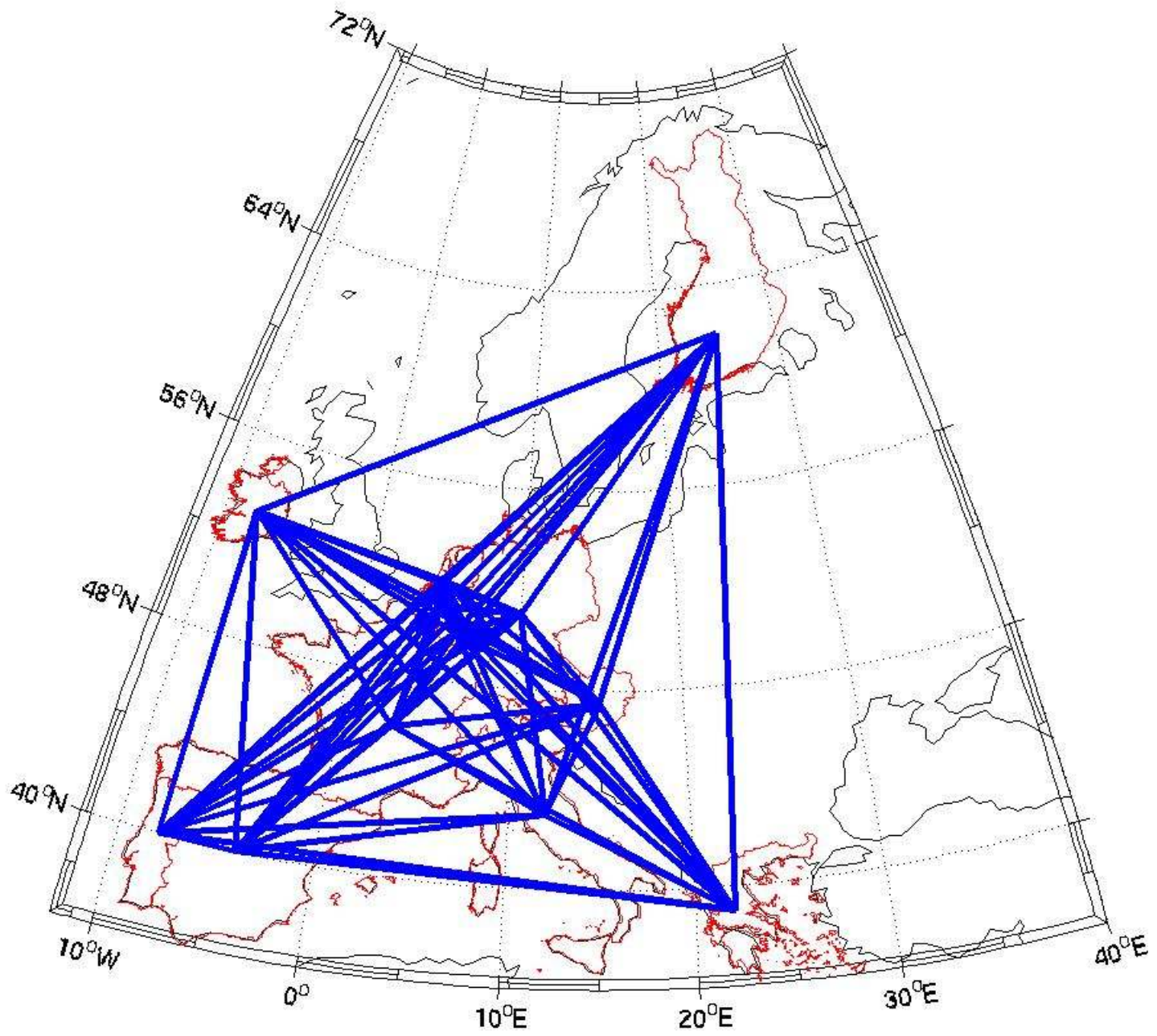
## The Technology

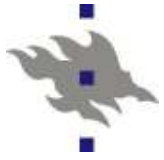
### The Monte Carlo simulation method

- 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  $12 \times 12 - 12 = 132$

P1	P2	P3	P4	P5		P6
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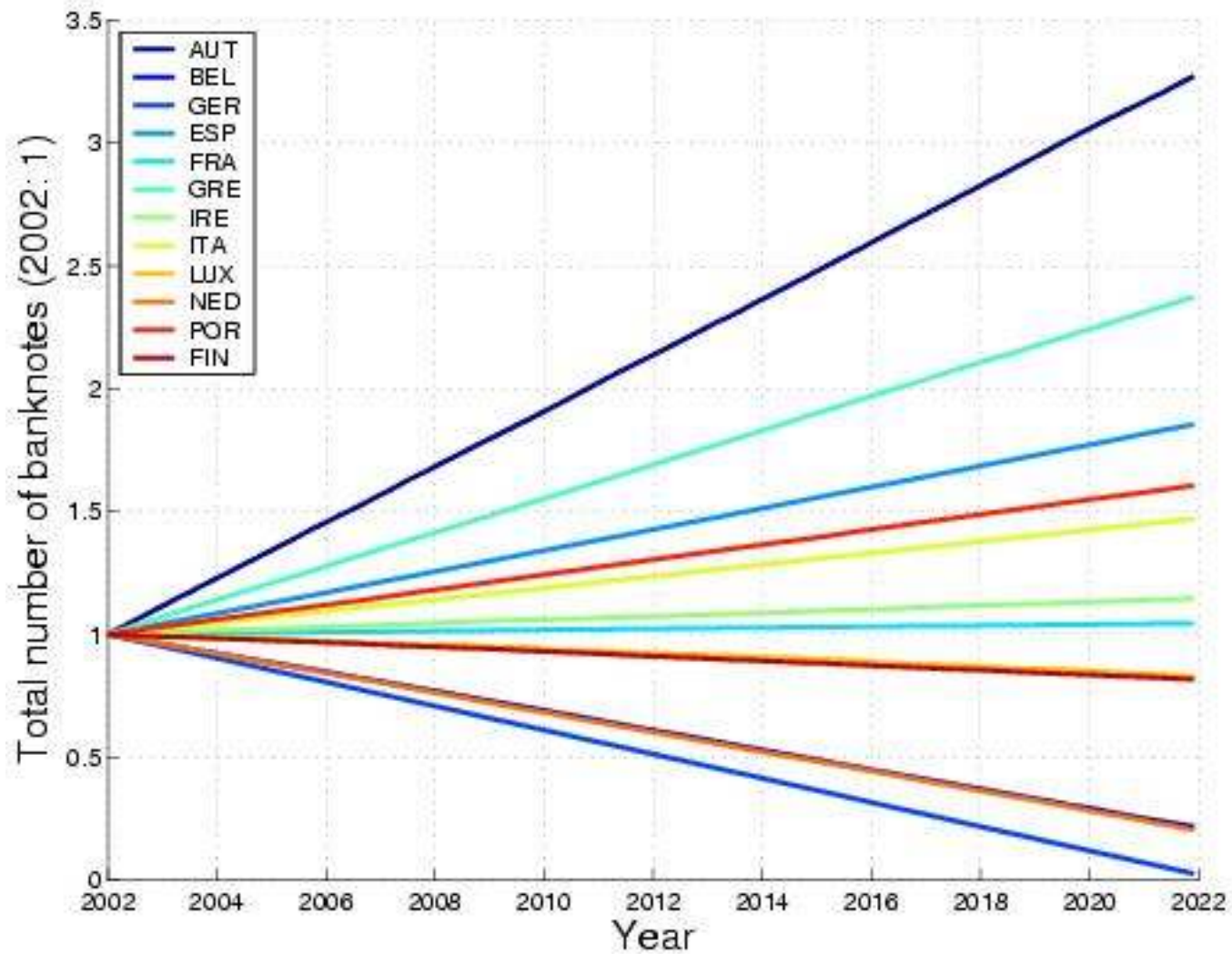


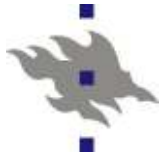
## Main assumptions

- 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

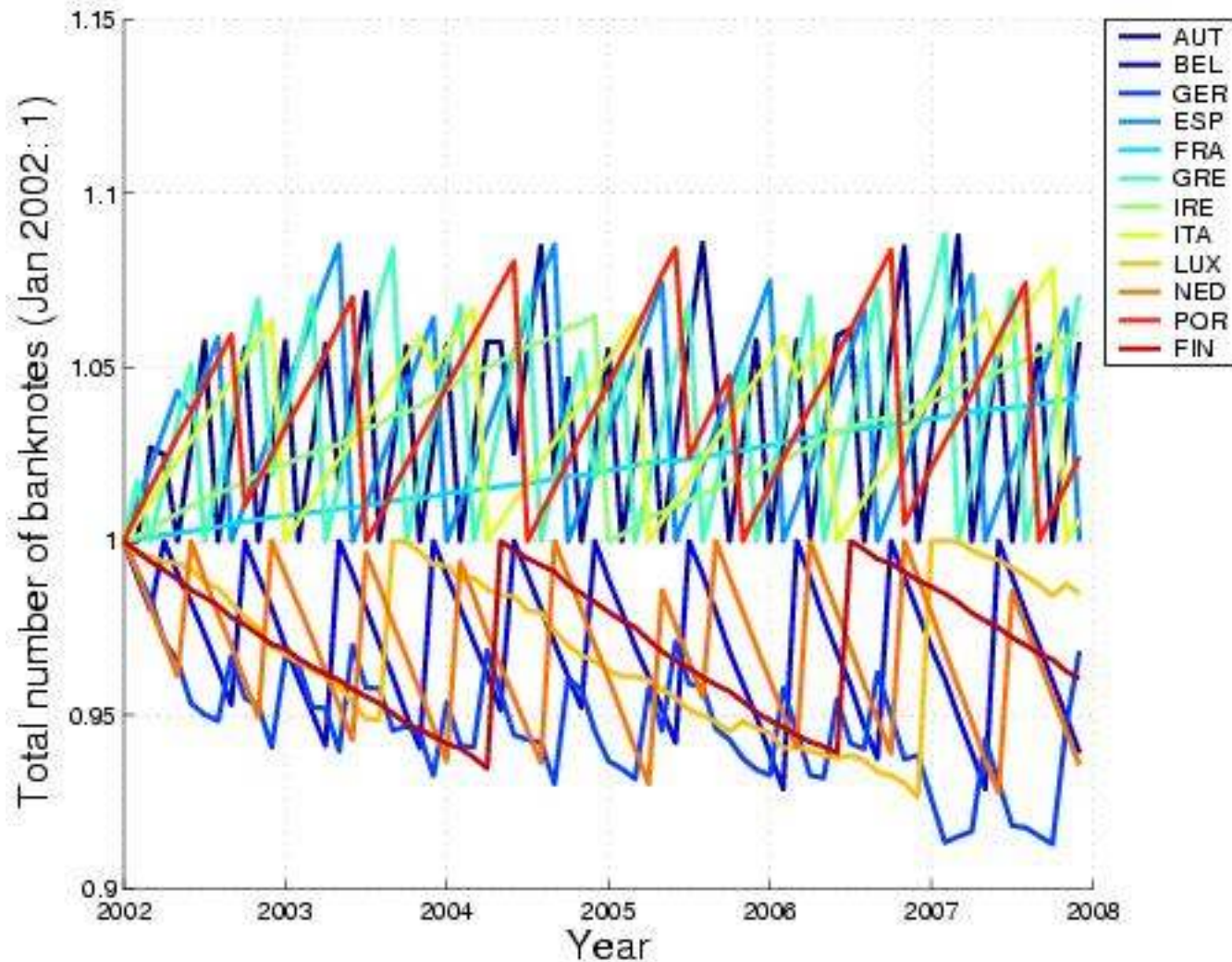


## Results: notes / no transportation





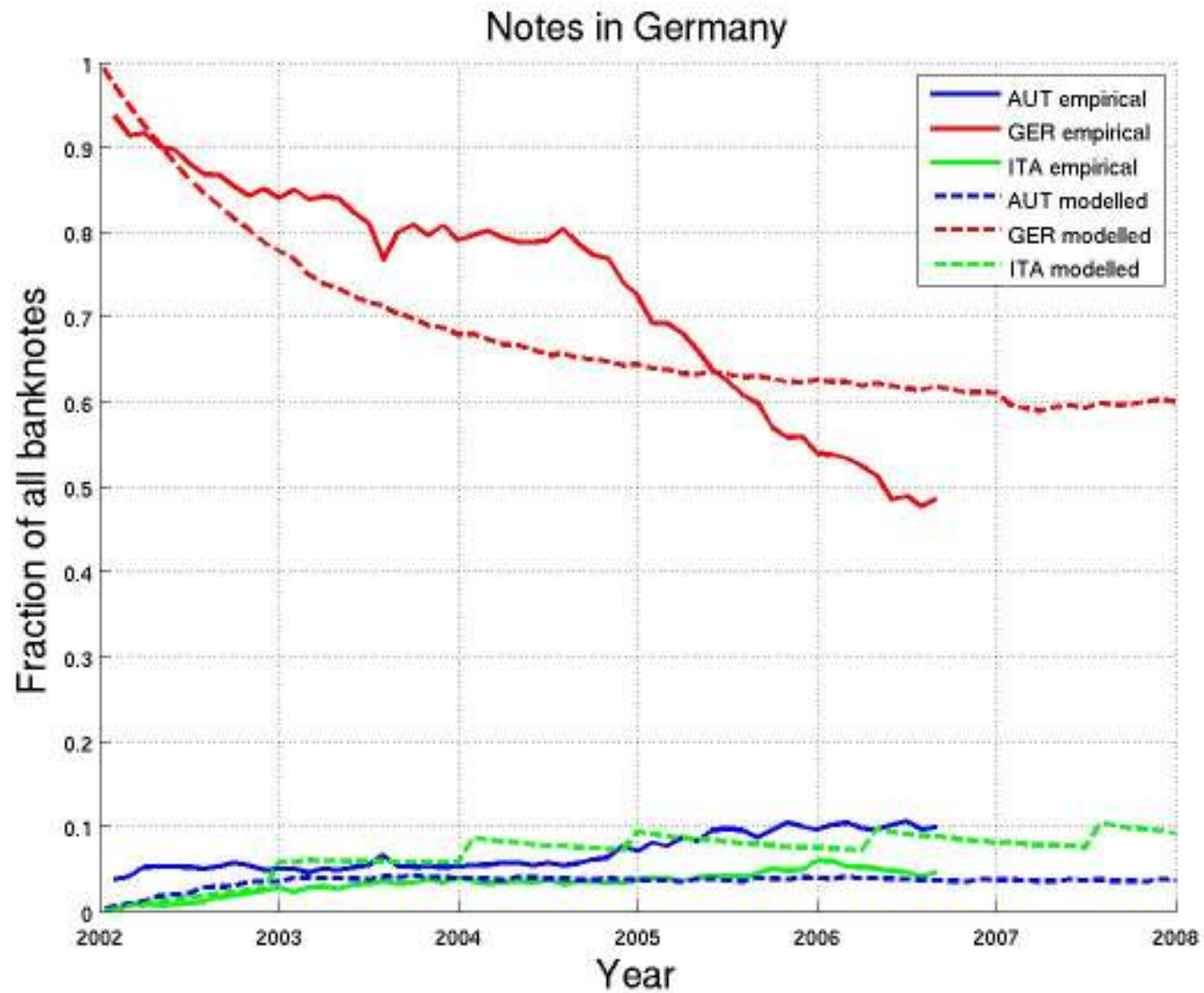
## Results: notes / transportation monthly from the most overpopulated to the most underpopulated country





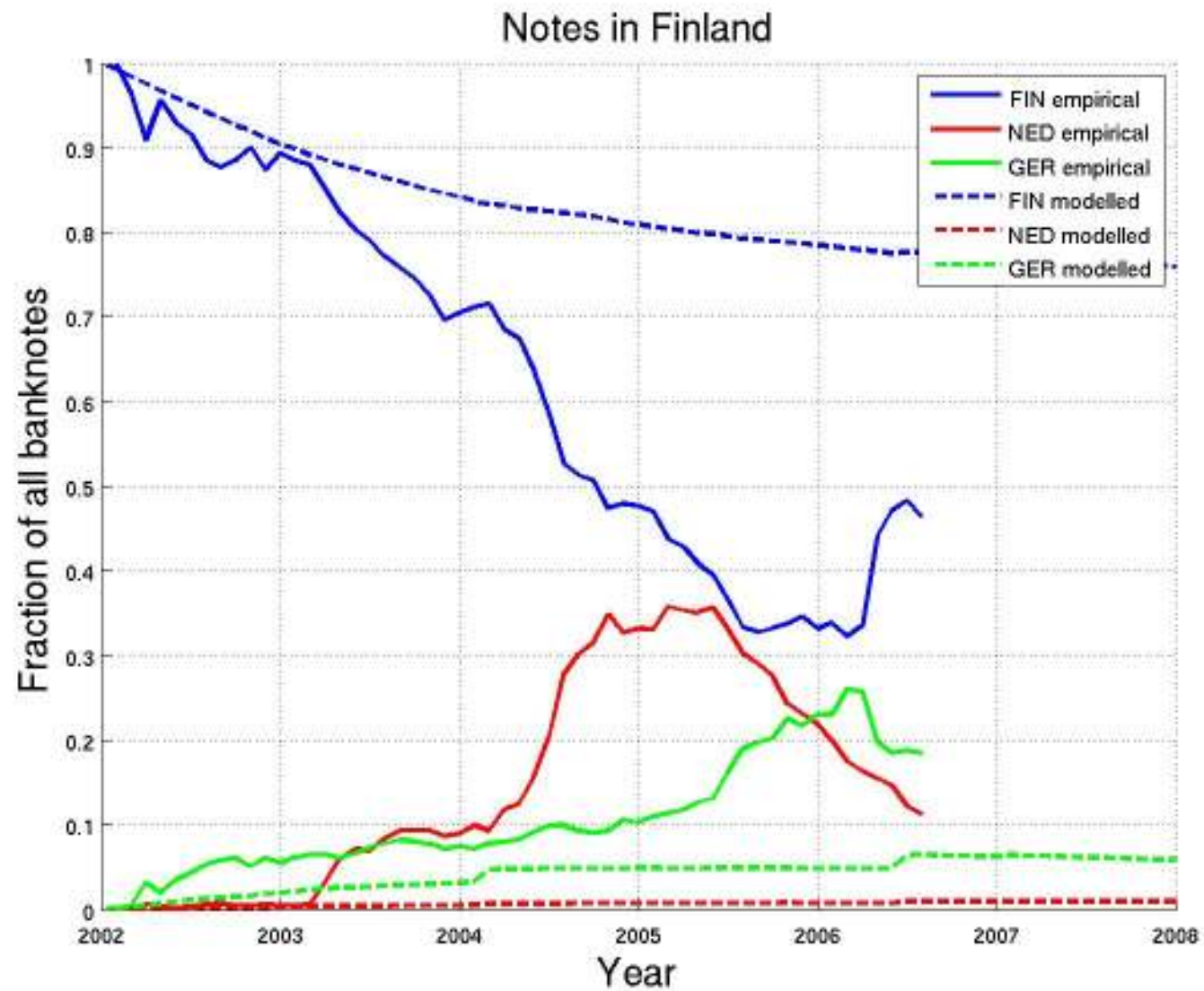


## Results: banknotes in Germany



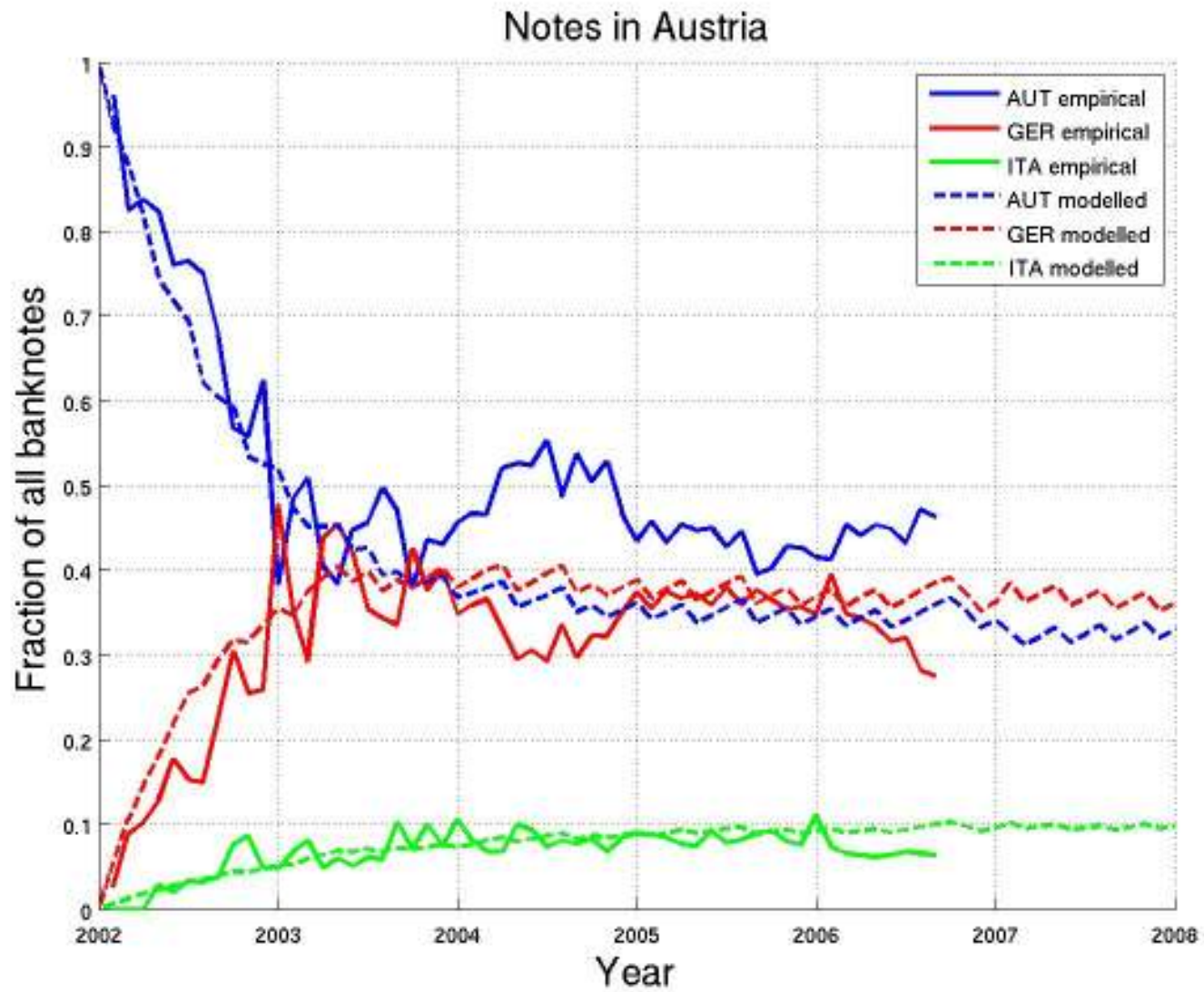


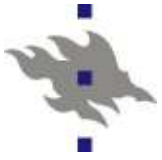
## Results: banknotes in Finland



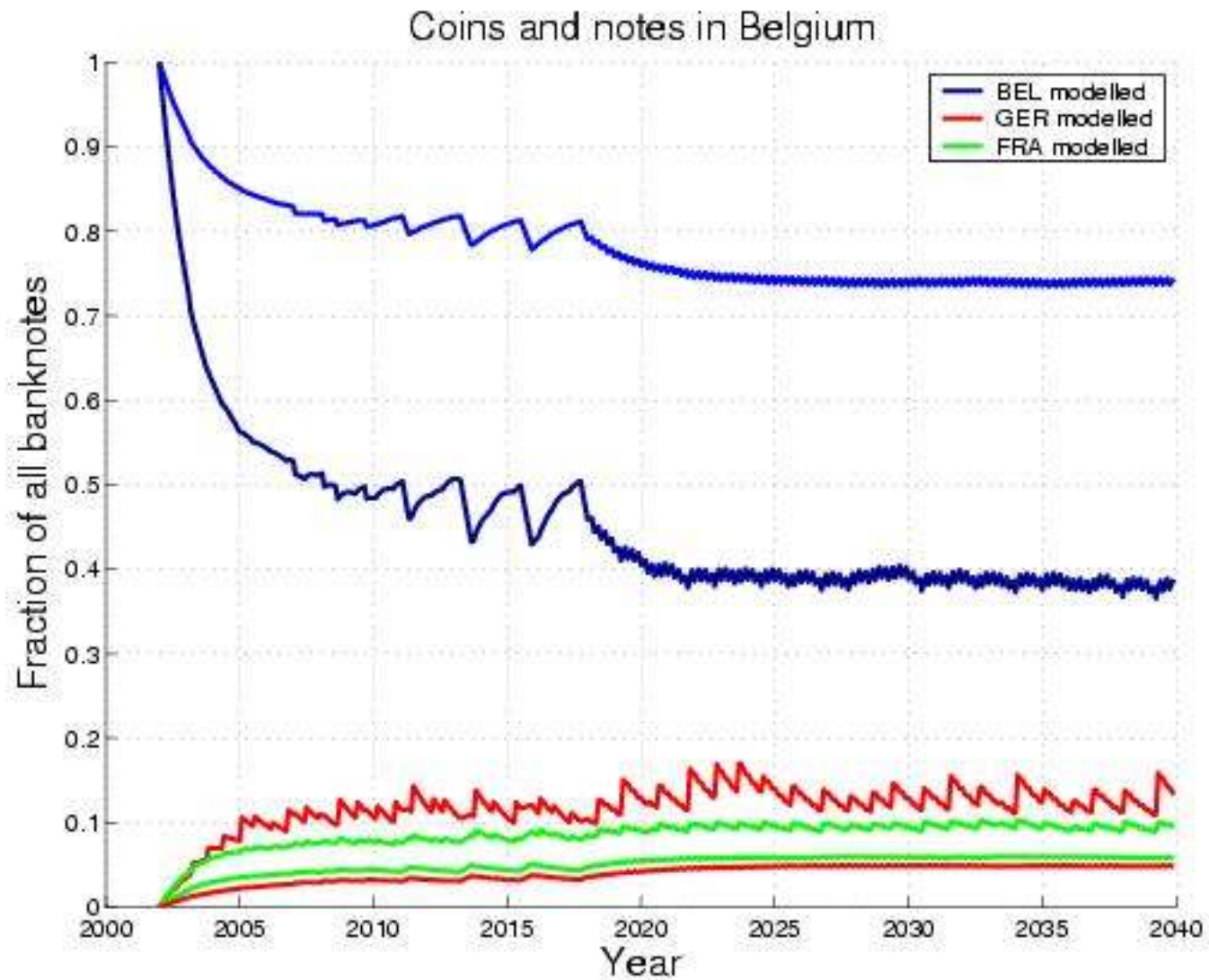


## Results: banknotes in Austria





## 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
- Mr. Tommi Bergman, Ms. Anna Ruhala and Mr. Walter Rydman for co-operation with the first version of the coin diffusion model in 2002