

St Petersburg paradox

Conclusions

Time for a change

Ole Peters



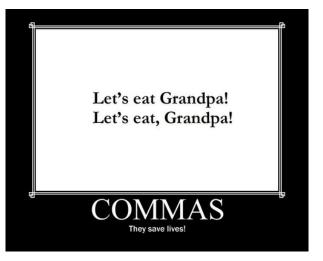
22 November 2012, Gresham College, London

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St Petersburg paradox

Conclusions





St Petersburg paradox

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Time for a change

Ole Peters



22 November 2012, Gresham College, London

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St Petersburg paradox

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Time, for a change

Ole Peters



22 November 2012, Gresham College, London

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St Petersbur, paradox

Conclusions



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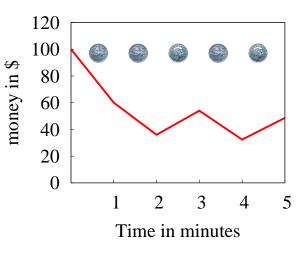
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St Petersbur; paradox

Conclusions

Toss coin once a minute



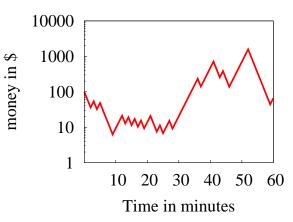
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One sequence



Conclusions



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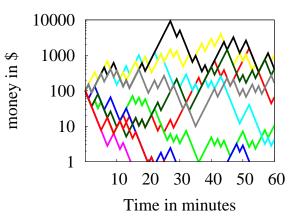


10 sequences

Leverage problem

St Petersbur; paradox

Conclusions



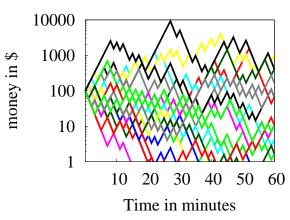


20 sequences

Leverage problem

St Petersbur; paradox

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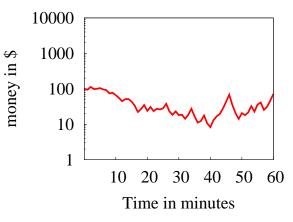
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St Petersbur_i paradox

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Average of 20 sequences



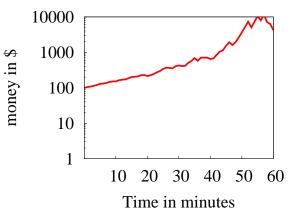
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St Petersburg paradox

Conclusions

Average of 1000 sequences



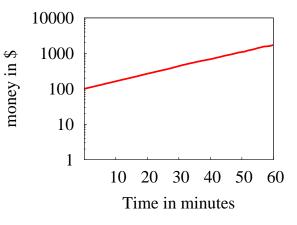
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St Petersburg paradox

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Average of 1,000,000 sequences



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St Petersburg paradox

Conclusions

Reality check

Looked at ensemble-average.

Relevant to me?

Cannot go back in time/access parallel universes.

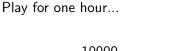
Interested in one sequence (reality).

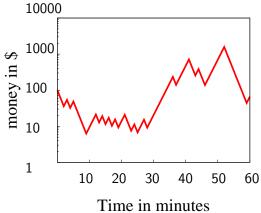
Time?



St Petersbur paradox

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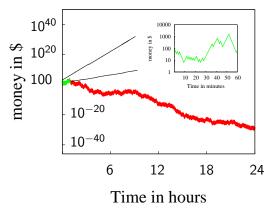
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St Petersbur, paradox

Conclusions

...continue one day (note scales)...



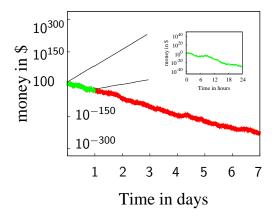
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St Petersbur, paradox

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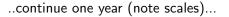
..continue one week (note scales)...

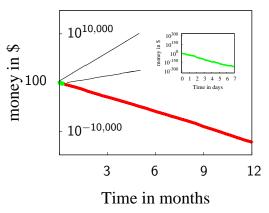




St Petersbur, paradox

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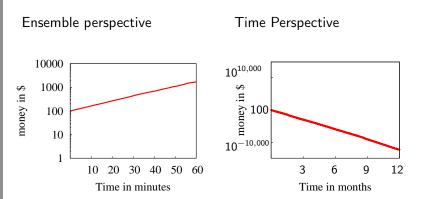






St Petersburg paradox

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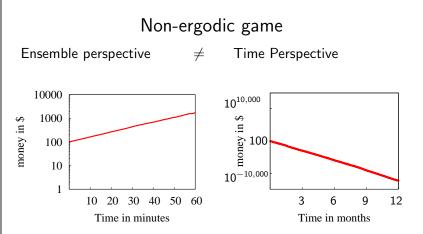


Over-emphasizes exceptional success. Relevant to the collective(?) Reflects what happens to me. Relevant to the individual.



St Petersbur; paradox

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Over-emphasizes exceptional success. Relevant to the collective(?) Reflects what happens to me. Relevant to the individual.

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St Petersburg paradox

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Physics:

a) Ensemble perspective:

Ensemble size $\rightarrow\infty$ to remove randomness.

b) Time perspective: Time $\rightarrow \infty$ to remove randomness.

Physics-ergodicity: both perspectives equivalent.

Economics:

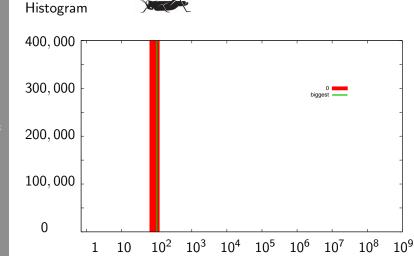
Economics-ergodicity: Laws of process don't change in time.

Logical relationship:

 $\mathsf{Physics-ergodicity} \implies \mathsf{Economics ergodicity}.$

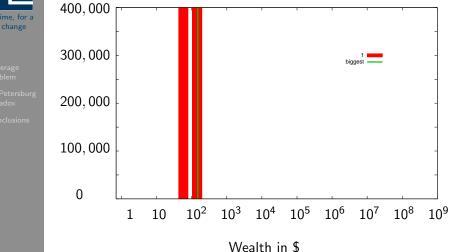
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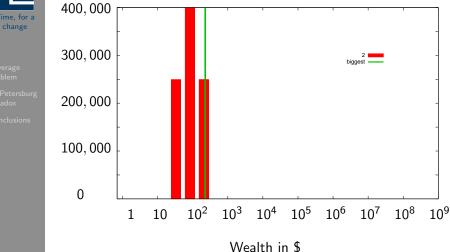
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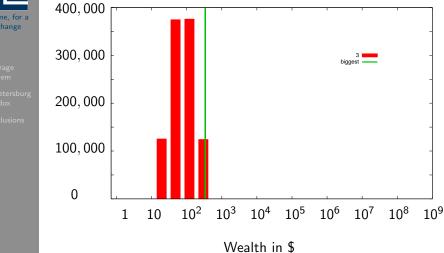
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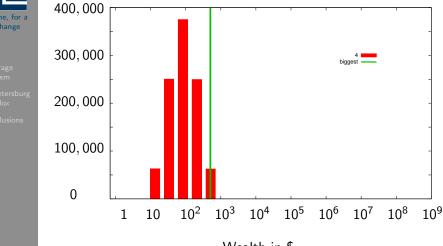
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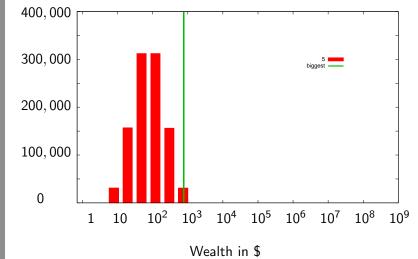
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St Petersbur paradox

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Histogram

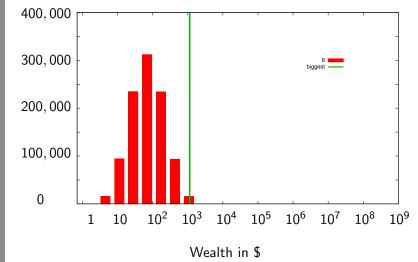




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Histogram

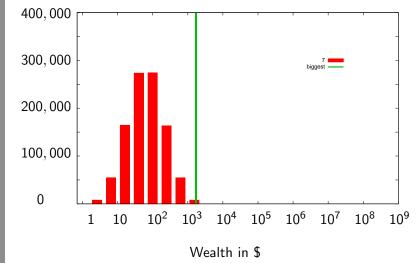




St Petersbuı paradox

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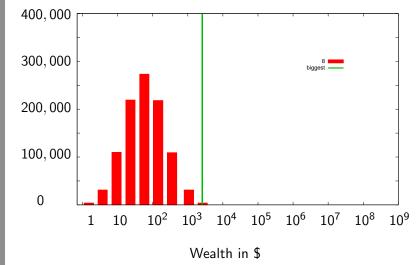




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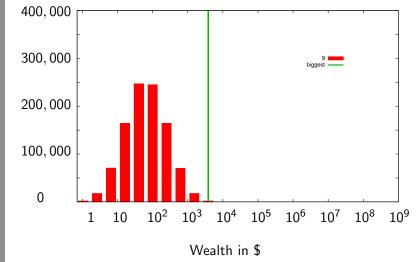




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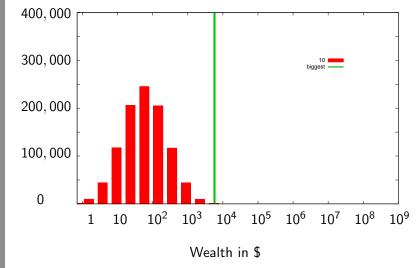




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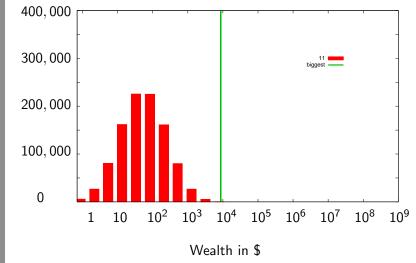




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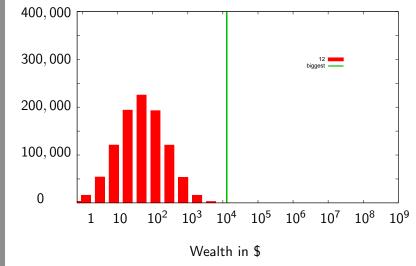




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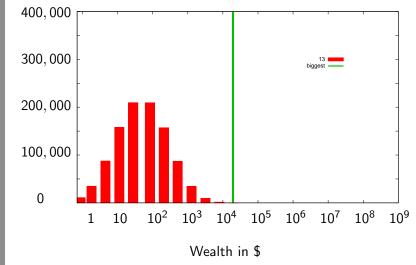




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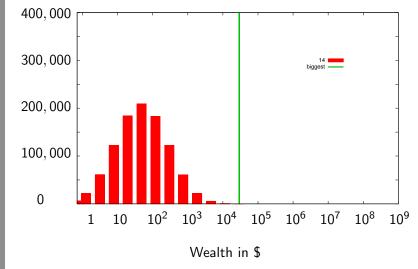
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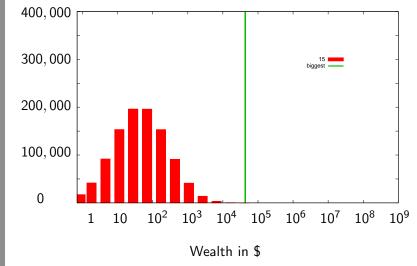




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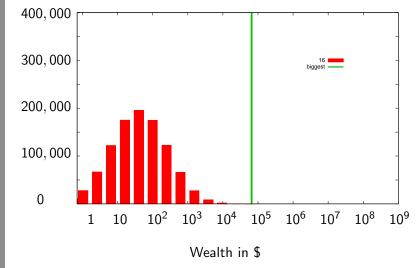




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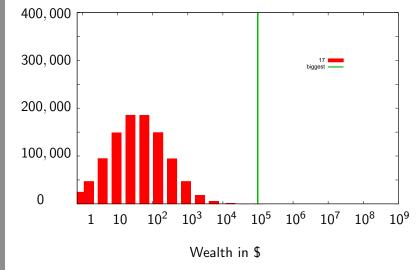




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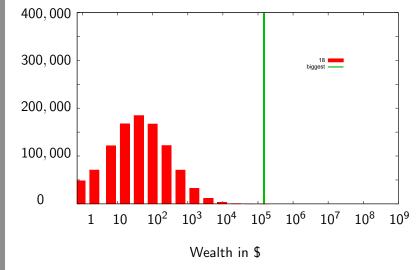




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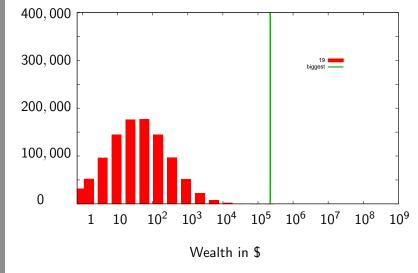
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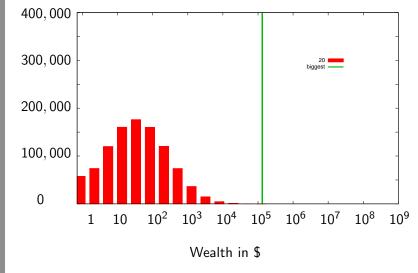




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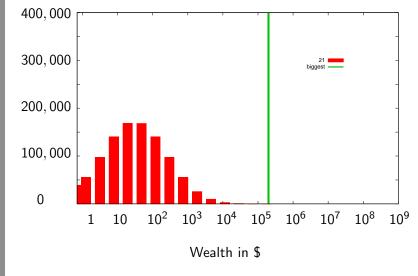




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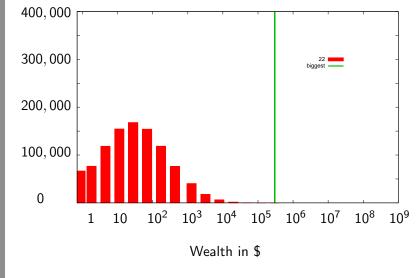




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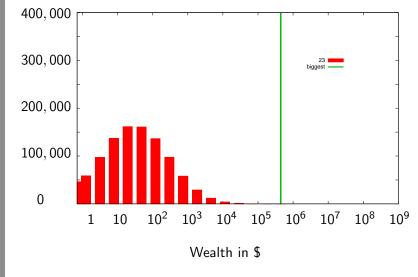




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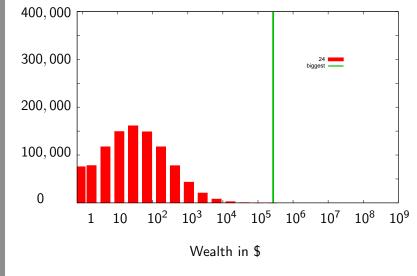
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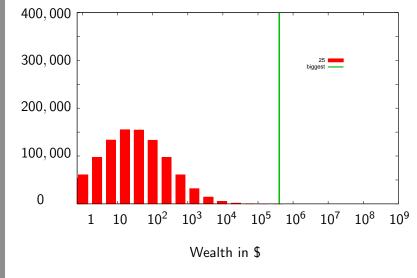
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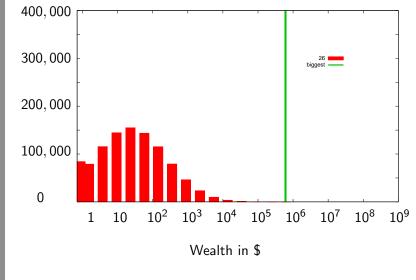




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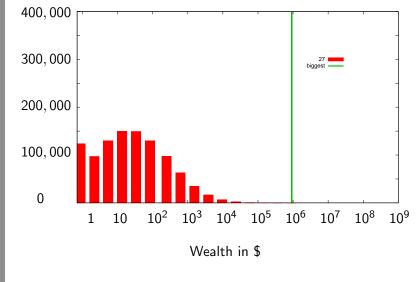




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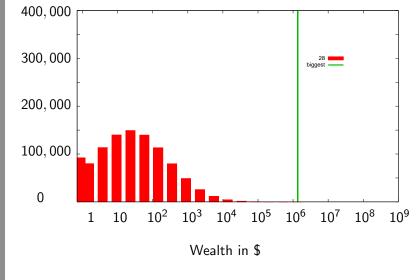
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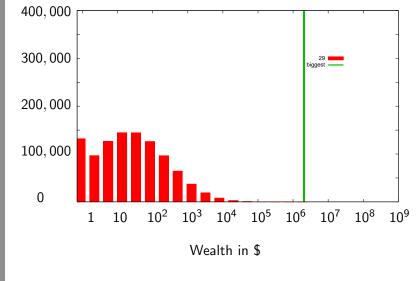
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St Petersbur paradox

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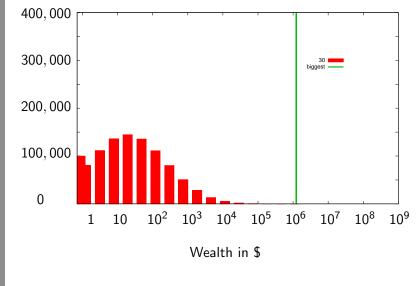




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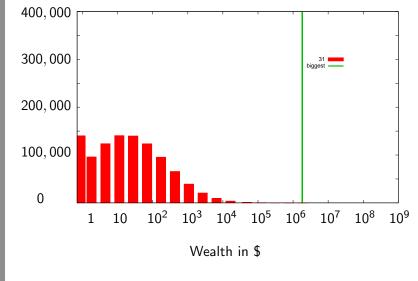




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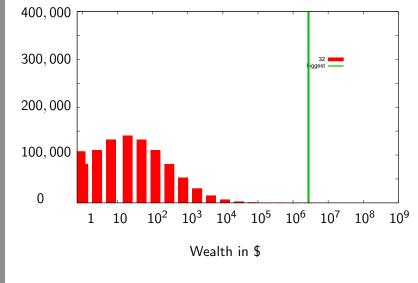




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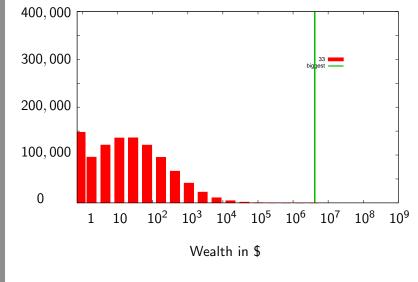
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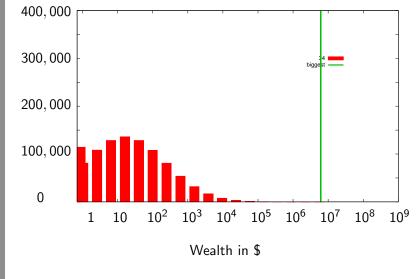




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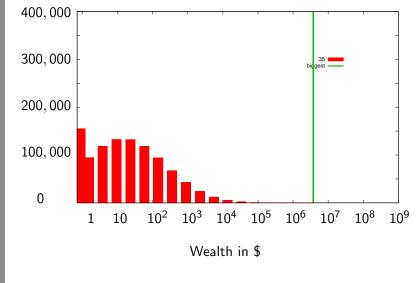




St Petersbur paradox

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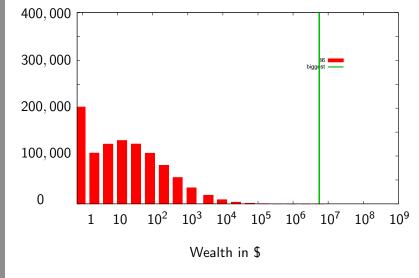




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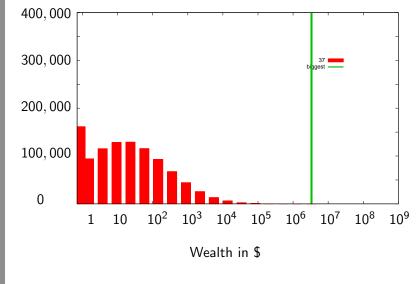
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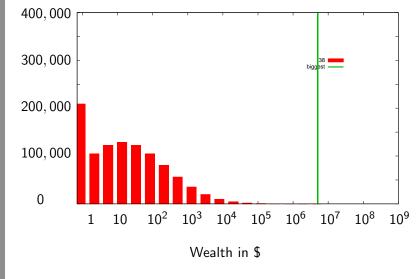
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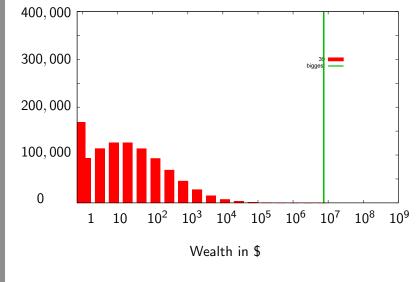




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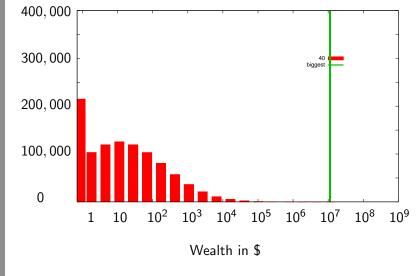
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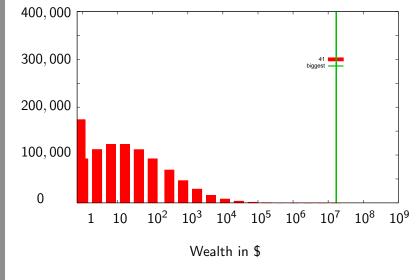




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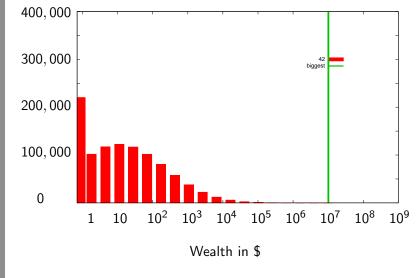




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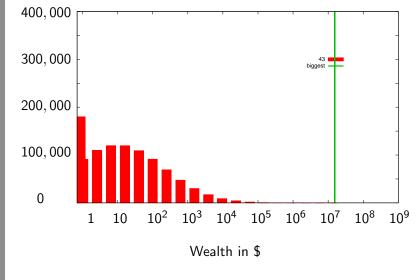




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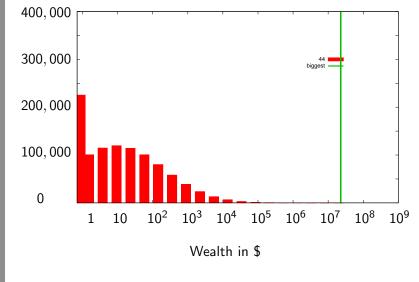




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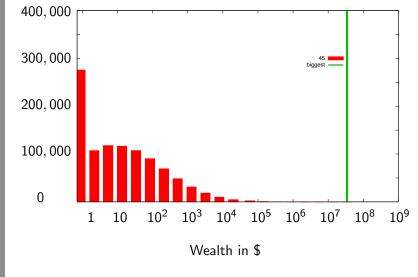




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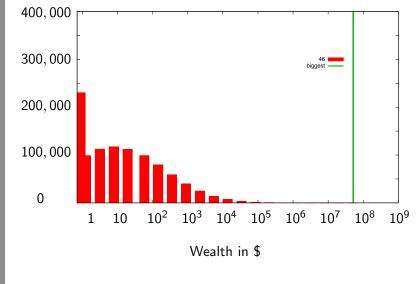




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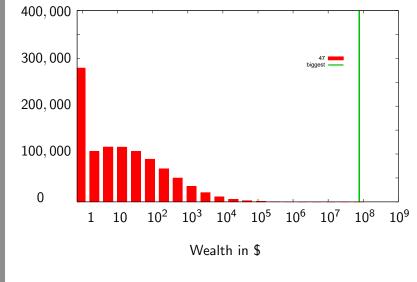




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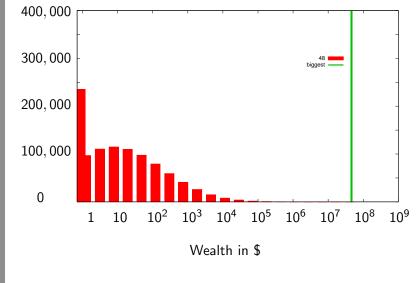




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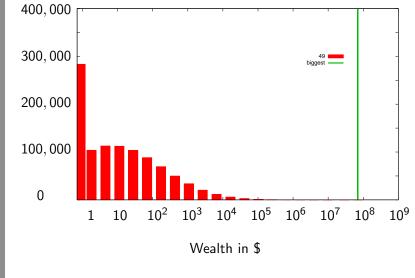
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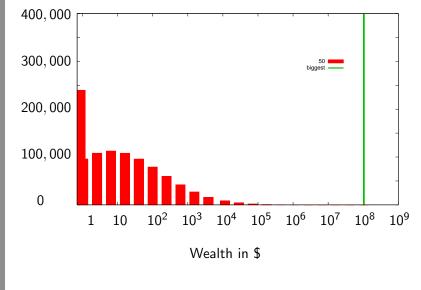
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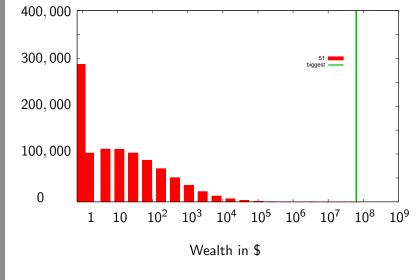




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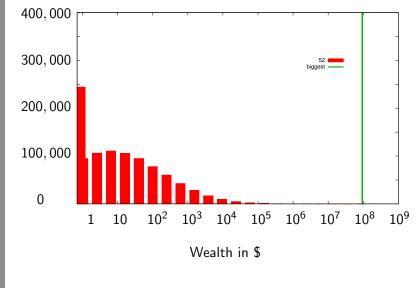




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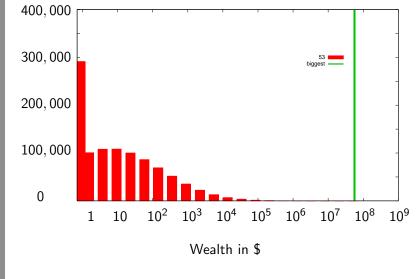
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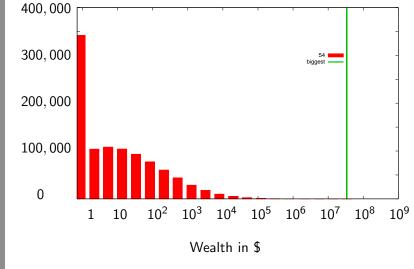




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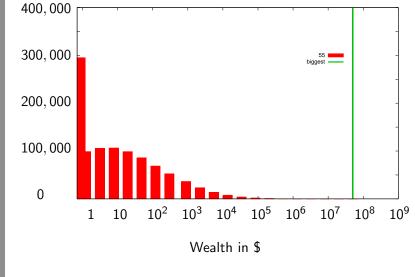




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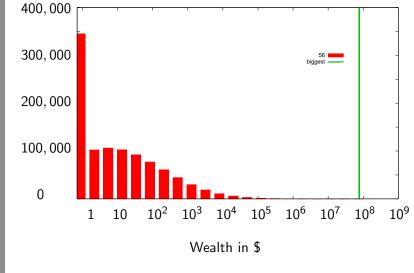
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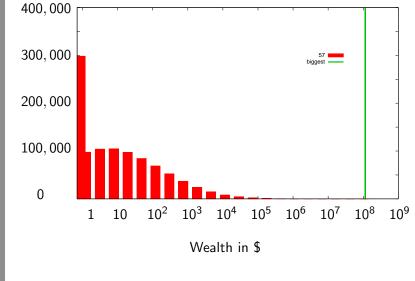




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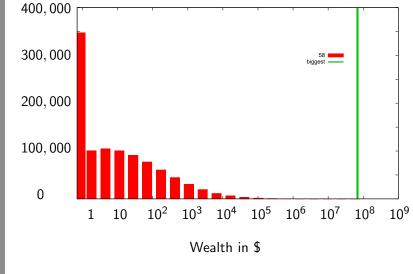
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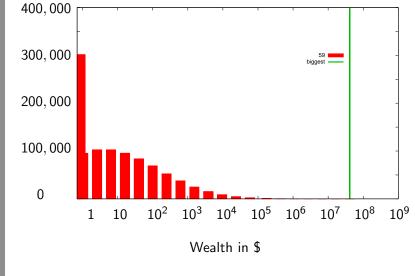




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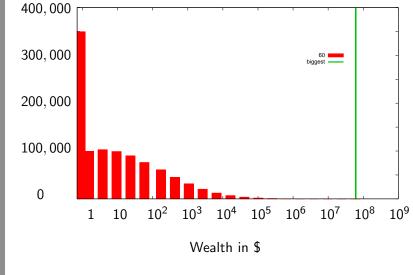




St Petersbur paradox

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St Petersburg paradox

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1 Leverage problem

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Outline

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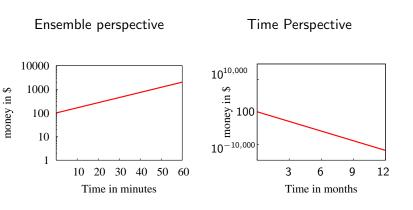
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3 Conclusions



St Petersburg paradox

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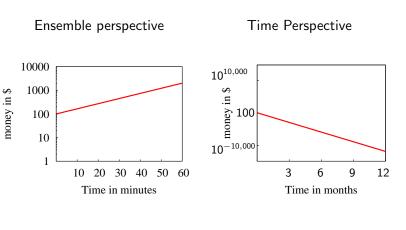
Inaccessible

Too risky



St Petersburg paradox

onclusions



Inaccessible

Too risky

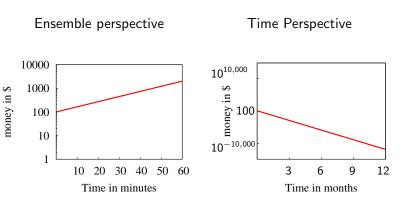
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 \rightarrow Keep some money safe (reduce leverage)!



St Petersburg paradox

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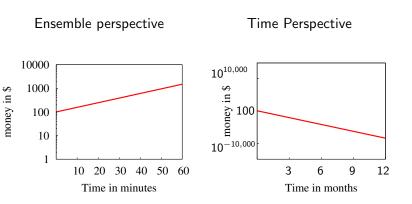


 $\mathsf{Leverage} = 100\%$



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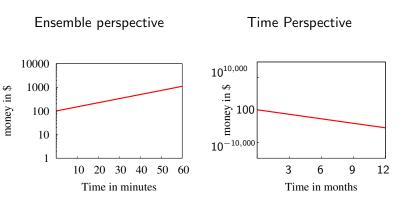


Leverage = 90%



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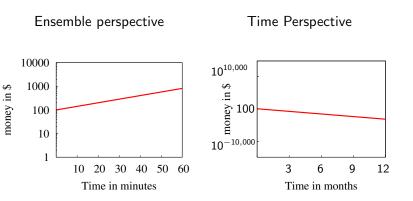


Leverage = 80%



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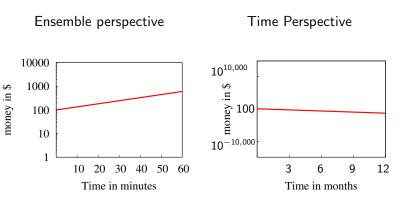


Leverage = 70%



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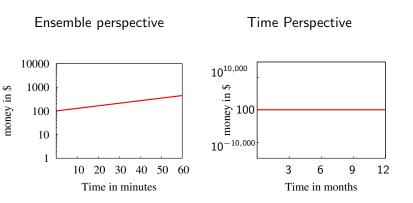


Leverage = 60%



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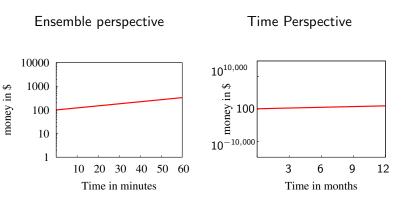


Leverage = 50%



St Petersbur; paradox

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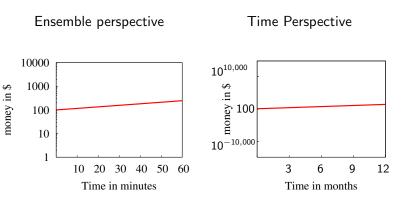


Leverage = 40%



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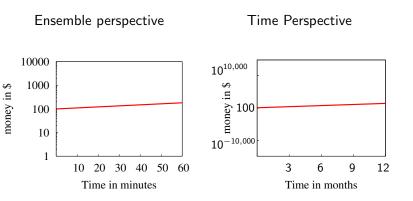


Leverage = 30%



St Petersburg paradox

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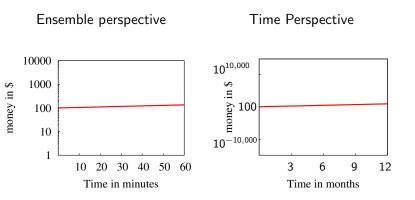


 $\mathsf{Leverage}=20\%$



St Petersburg paradox

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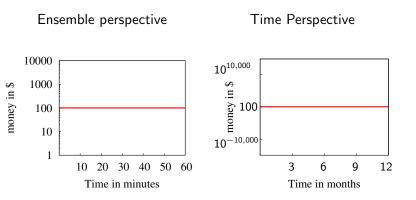


Leverage = 10%



St Petersburg paradox

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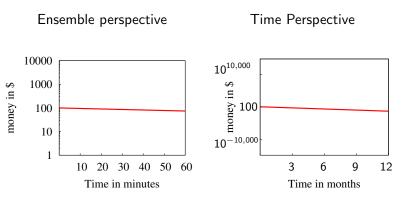


 $\mathsf{Leverage} = 0\%$



St Petersbur; paradox

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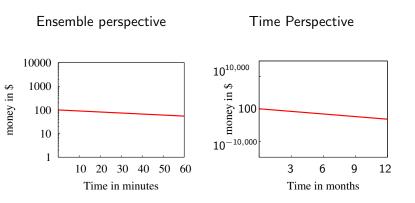


Leverage = -10%



St Petersburg paradox

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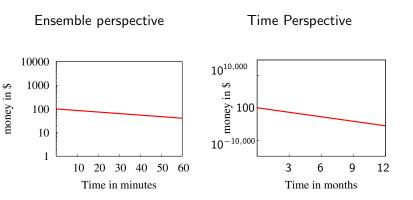


 $\mathsf{Leverage} = -20\%$



St Petersbur; paradox

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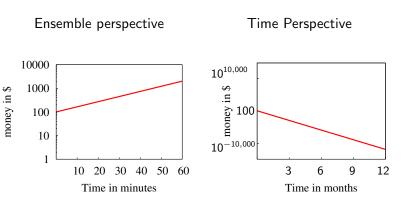


 $\mathsf{Leverage} = -30\%$



St Petersburg paradox

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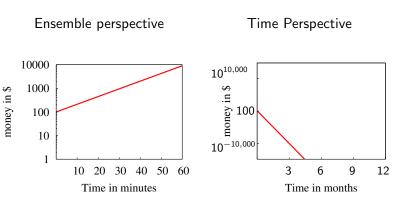


Leverage = 100%



St Petersburg paradox

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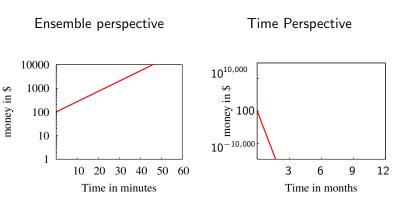


Leverage = 150%



St Petersburg paradox

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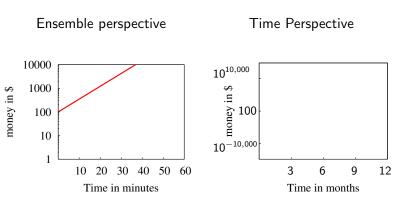


Leverage = 200%



St Petersburg paradox

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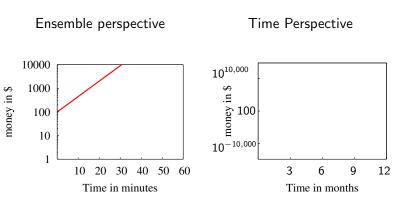


Leverage = 250%



St Petersburg paradox

onclusions



 $\mathsf{Leverage}=300\%$



St Petersburg paradox

Conclusions

Ensemble perspective: leverage as much as you can!

Time perspective:

optimal leverage exists – more is bad (here: $l_{opt} = 0.25$).

- Gambling "Kelly criterion" (information theory).
- Here: time irreversibility.
- Same techniques: *l*_{opt} for geometric Brownian motion, any other process.

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O.P. "Optimal leverage from non-ergodicity" Quant. Fin. 11, 11, 1593-1602 (2011).



Optimal leverage from non-creodicity

OLD PATERNING

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St Petersburg paradox

Conclusions

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St Petersburg paradox

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1 Leverage problem

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3 Conclusions



St Petersburg paradox

Conclusions

St Petersburg paradox:

Players won't pay much for lottery ticket with infinite expected payout.

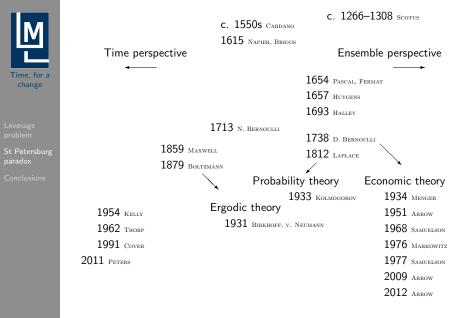
Resolution (same techniques):

Expectation value irrelevant to player. Time average growth rate under multiplicative dynamics compatible with human behavior.

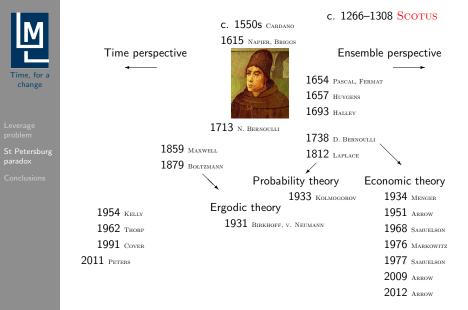


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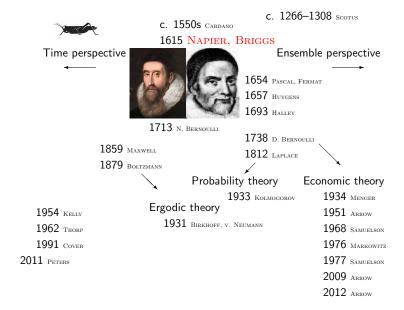
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St Petersburg paradox

Conclusions



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Time perspective

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2011 PETERS

1859 MAXWELL

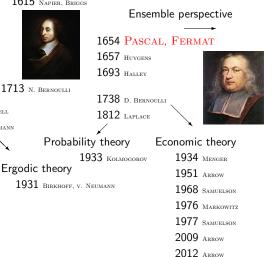
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Leverage problem

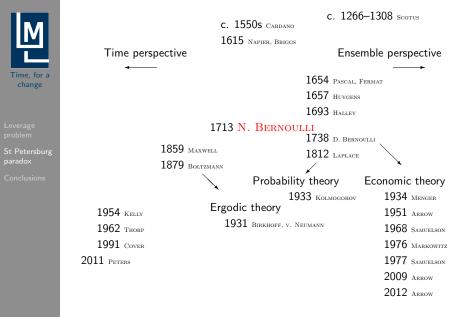
St Petersburg paradox

Conclusions

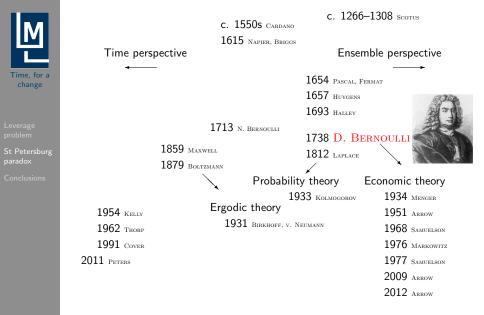
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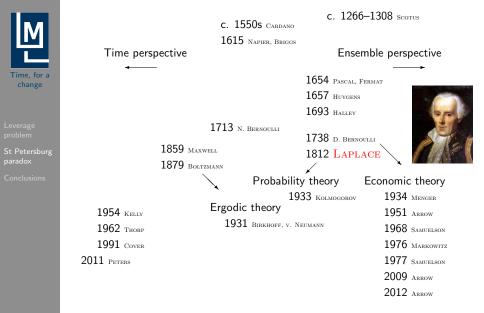
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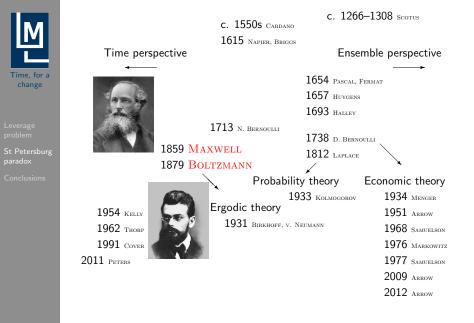
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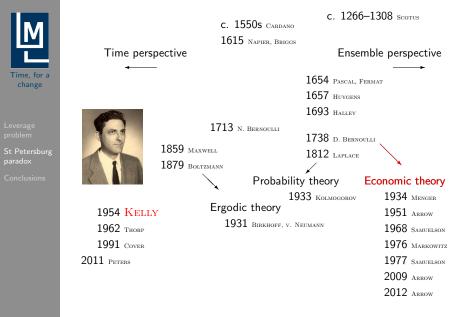
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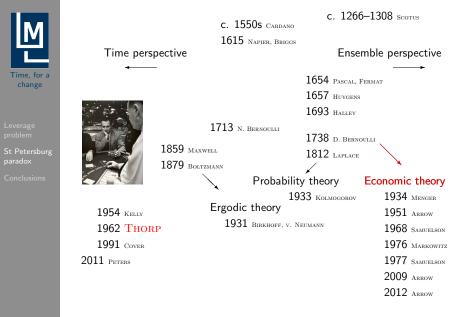


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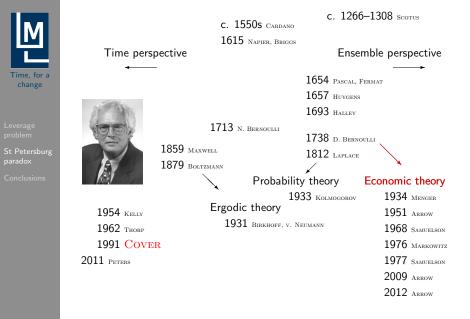


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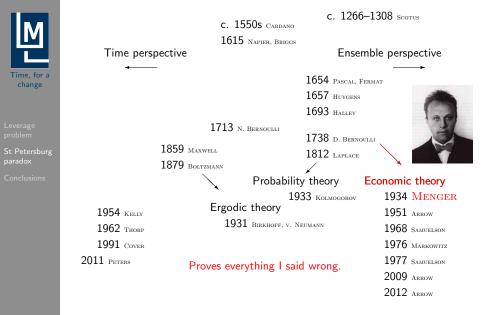
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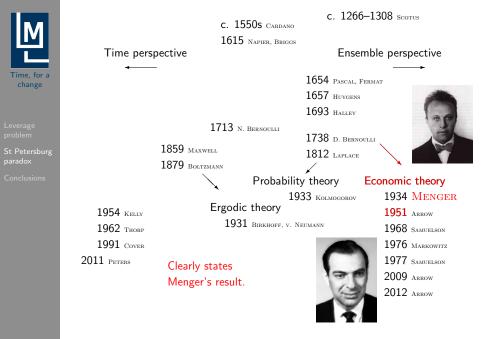


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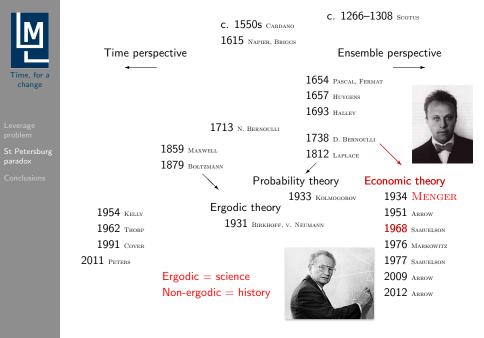


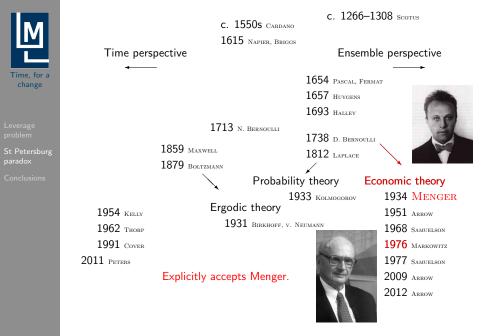
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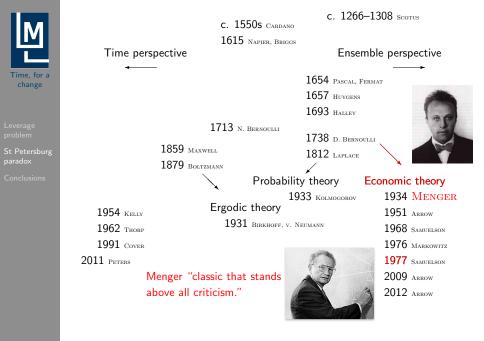




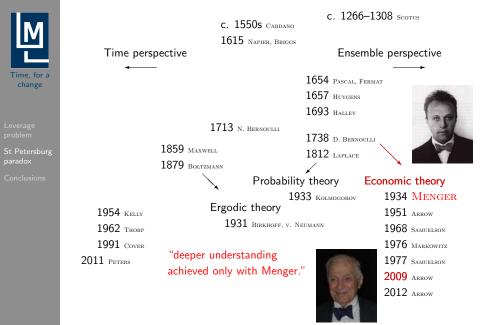
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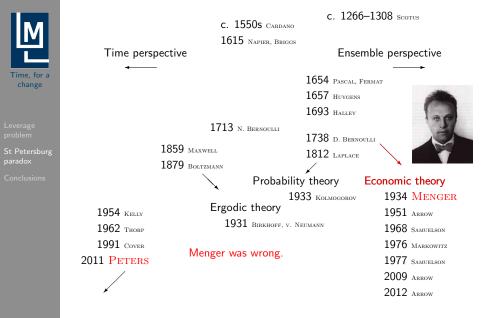




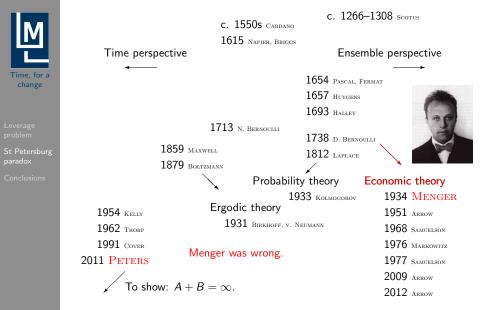
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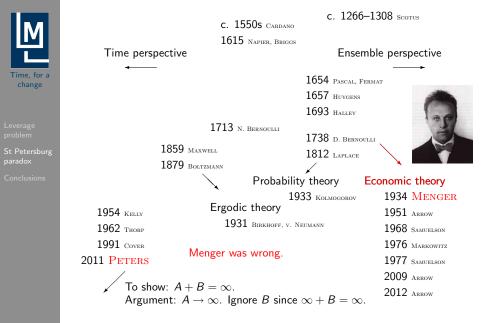
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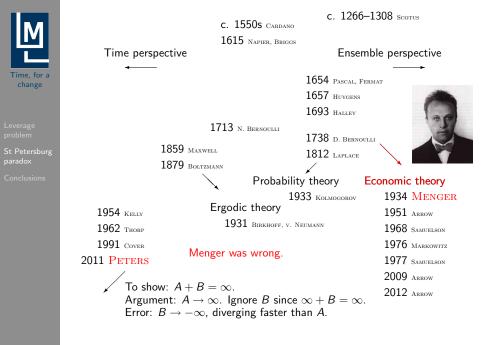


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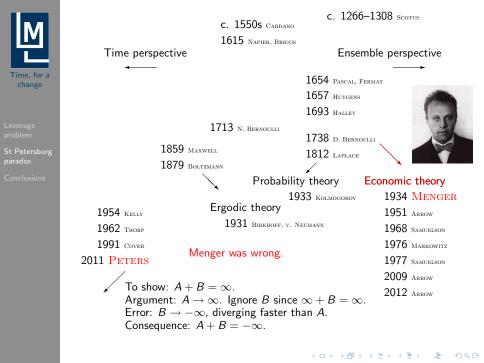


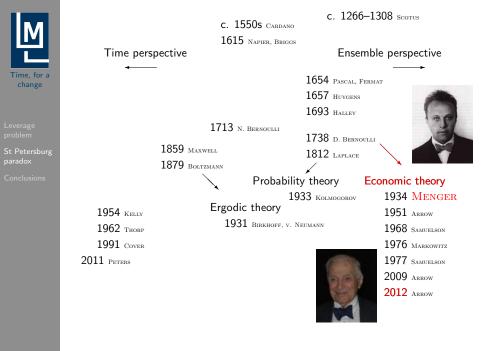
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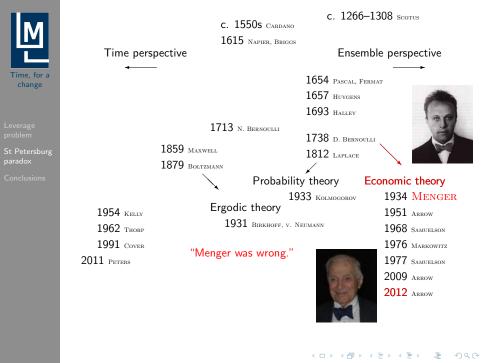


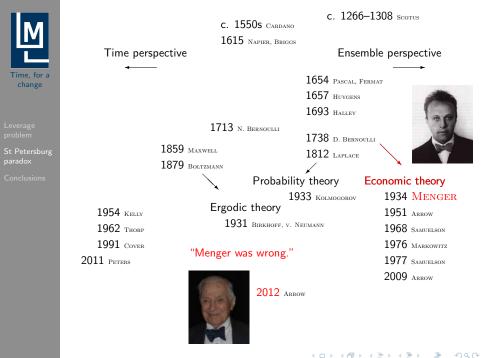
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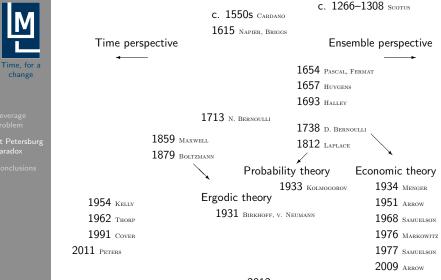




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St Petersburg paradox

Conclusions

Summary

Risk management conceptually re-framed.

- Key concept: time.
- Extends probability spaces to dynamical systems.
- No utility functions.
- 77 year-old error endorsed by several Nobel laureates.
- Slight "error" in D. Bernoulli's work.
- Kelly: identical for multiplicative dynamics; time-averages more general.

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St Petersburg paradox

Conclusions

<u>What next</u>

Solved classic problems as proof of principle.

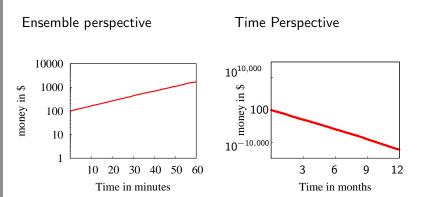
New concepts \rightarrow new possible questions

- Time vs. parallel worlds in daily life.
- Market stability (SME).
- Inequality and welfare economics.



St Petersburg paradox

Conclusions



Over-emphasizes exceptional success. Relevant to the collective(?) Reflects what happens to me. Relevant to the individual.

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1 Leverage problem

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St Petersburg paradox

Conclusions

Need to re-think communication in economics.

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St Petersburg paradox

Conclusions

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Dear Dr. Peters,

our Referee's comments on your work have now been received. You will see that the Referee does not think that your criticism of Merger's piece is economically relevant. In accordance with

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Conclusions

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Ocuber 2, 2009 Professor Ole Paras Department of Meldernetics Imported College London TBI Quenci Kater London 5997 ZAZ

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JOURNAL OF FINANCIAL ECONOMICS

G. WILLIAM SCHWERT Managing Editor Interacting for the second second pulposition and Interpret statistications and Witten E, Simon Erselasta-School of Subman Administration University of Fochader Placinitier, R11 MICT

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Professor Olio Patens Department of Mathematics and Gramham Institute Inspersite College London 190 Quanti Gate London RWT 202 UK optimit (impetial Jac uk

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Ocaber 2, 2009 Professor Ole Paten Department of Mellemation Imperial College London 188 Quanty Gate London 5997 2AZ Darr Ole.

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St Petersburg paradox

Conclusions

Need to re-think communication in economics.

- * No economics journal has published this.
- * No economics conference has let us speak.



St Petersburg paradox

Conclusions

Need to re-think communication in economics.

- * No economics journal has published this.
- * No economics conference has let us speak.
- * Publications by Royal Society, Santa Fe Institute, TEDx, Quantitative Finance, blogs, financial firms.





ED Ideas worth

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- Leverage problem
- St Petersburg paradox
- Conclusions

We've given up too easily

Cannot predict economic system because of reflexivity: prediction \rightarrow response \rightarrow invalidates prediction.

 \rightarrow Can't use scientific method because it relies on prediction.

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Wrong because

- a) Not all predictions elicit responses.
- b) Other predictions valid if recursive.
- \rightarrow hints at utilitarian understanding of science.



Mathematics is richer:

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Leverage problem

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St Petersburg paradox

Conclusions

Mathematics is richer:

• more subtle.



St Petersburg paradox

Conclusions

Mathematics is richer:

- more subtle.
- more vague.



St Petersburg paradox

Conclusions

Mathematics is richer:

- more subtle.
- more vague.
- more concept-dependent.



St Petersburg paradox

Conclusions

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• more advanced.



St Petersburg paradox

Conclusions

Mathematics is richer:

- more subtle.
- more vague.
- more concept-dependent.

- more advanced.
- more correct.



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Conclusions

Thank you!