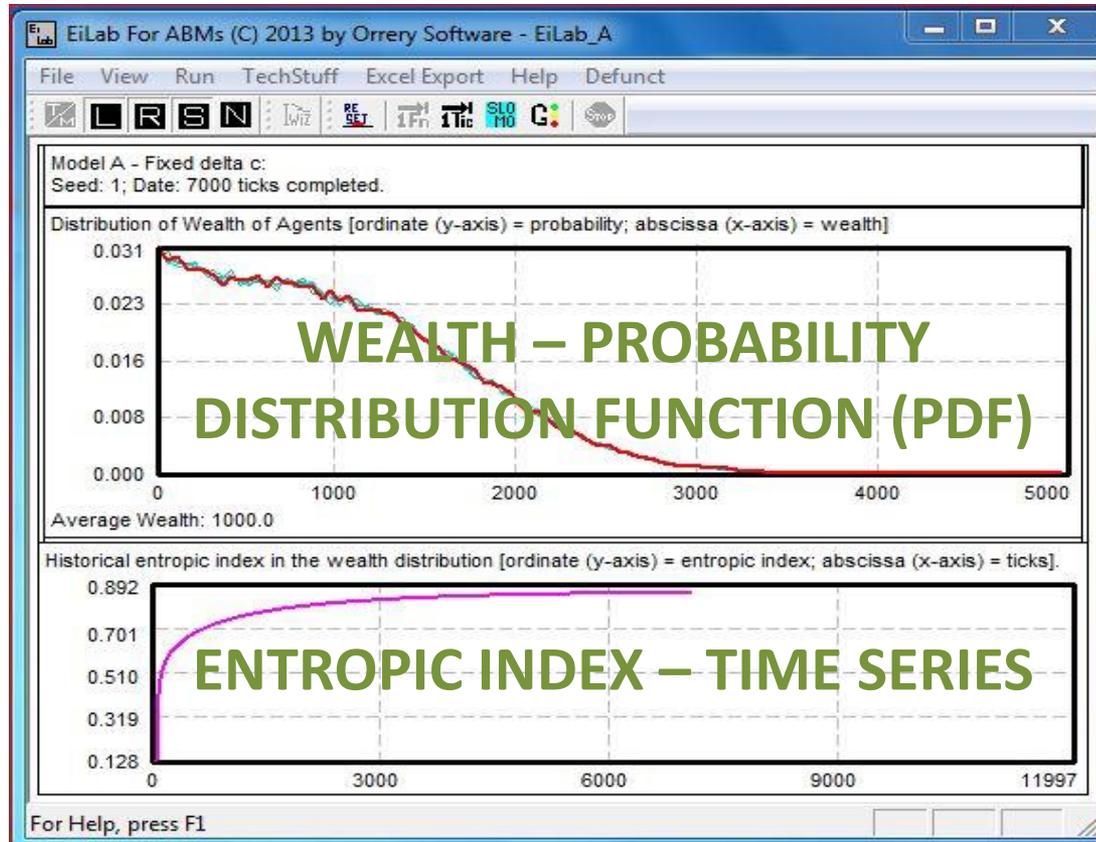


The Economics of Equity:

Insights from Econophysics and the BDY Model



By: G.H. Boyle

28TH June

ISEE 2016

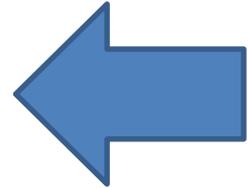
Screen shot from EiLab – at orrery-software.webs.com

Taxonomy of Concerns

1. Sustainable Society

a) Socially Just Society

i. **Distributive Social Justice**

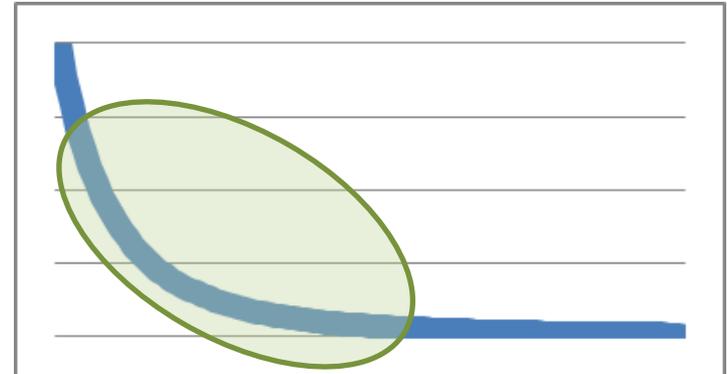


Pareto Distribution

$$P(m) = cx^{-(\alpha+1)}$$

c & α are constants > 0

- An old chestnut – by Vilfredo Pareto (1848-1923)
- Used to describe distribution of wealth in Italy
- Basis of 80%-20% rule

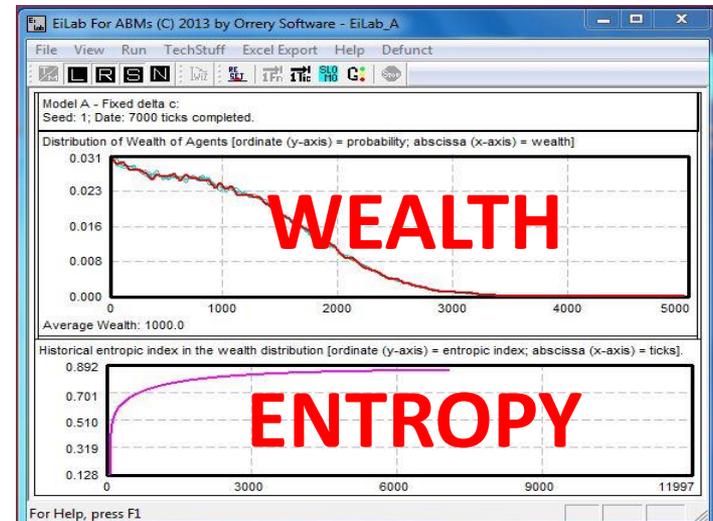


A “power law”.

BDY Model: History

- First described by Bennati in papers published in 1988 and 1993 in Italian.
- Rediscovered by Econophysicists Drăgulescu and Yakovenko in 2000.
- Analyzed mathematically by Scalas, Garibaldi and Donadio in 2006.
- Reproduced in EiLab, 2013.

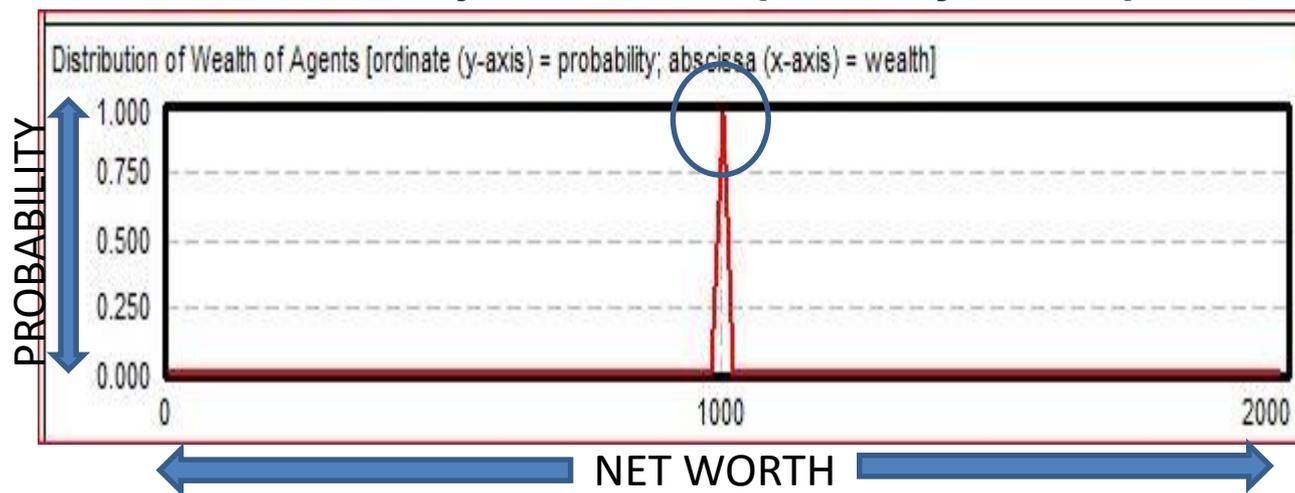
- BENNATI, E. (1988). Un metodo de simulazione statistica per l'analisi della distribuzione del reddito. Rivista Internazionale di Scienze Economiche e Commerciali 35, 735-756, (1988).
- BENNATI, E. (1993). Il metodo di Montecarlo nell'analisi economica. Rassegna di Lavori dell'ISCO, Anno X, n. 4, 31-79.
- DRĂGULESCU, A., & YAKOVENKO, V. M. (2000). Statistical mechanics of money. Eur. Phys. J. B., (17), 723-729.
- SCALAS, E., GARIBALDI, U., and DONADIO, S. (2006). Statistical Equilibrium in simple exchange games I: Methods of solution and application to the Bennati-Drăgulescu-Yakovenko (BDY) game. Eur. Phys. J. B: Condensed Matter and Complex Systems, 53 (2). pp. 267-272. ISSN 1434-6028.



BDY Model: Construction

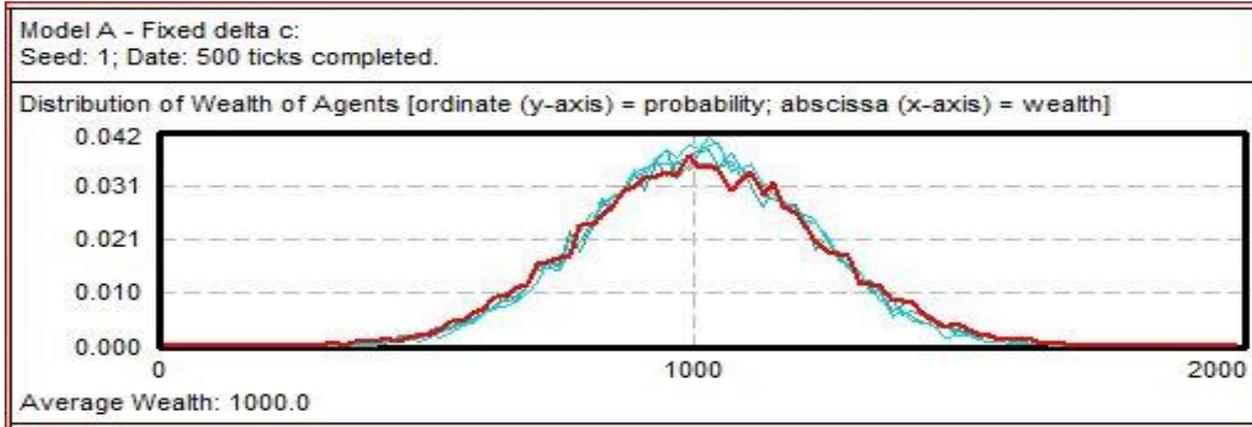
A "GAS MODEL" OF BINARY CAPITAL EXCHANGE

- We start with 10,000 identical agents, each given ~\$1,000, for a total of \$10M in this economy.
- Time progresses in discrete "ticks".
- During one tick:
 - Agents are selected randomly to form 5,000 pairs;
 - In each pair, a loser is randomly selected;
 - If the loser has \$10, he/she pays it to the winner.
- Run until equilibrium (steady state) is reached.



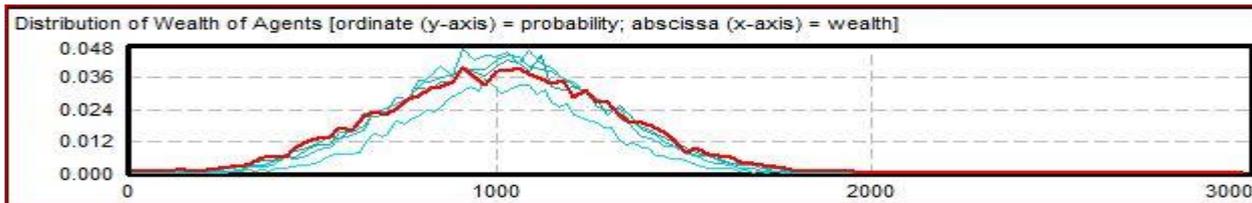
At 0 ticks –
**FINANCIAL
EQUALITY.**

BDY Model: Behaviour

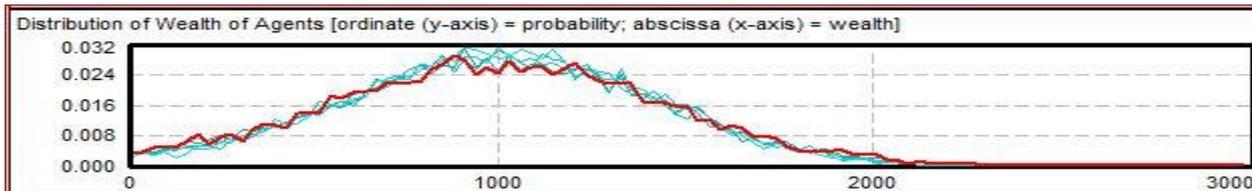


By 500 ticks a nice Gaussian distribution forms, i.e. a bell curve.

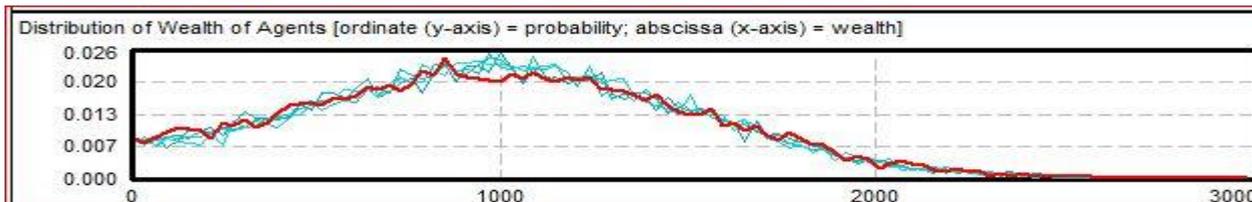
This is the sum of many random walks.



At 1,000 ticks.

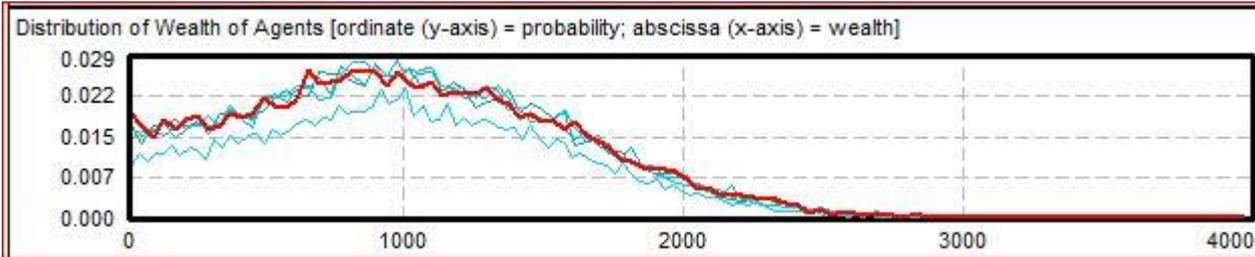


At 2,000 ticks.

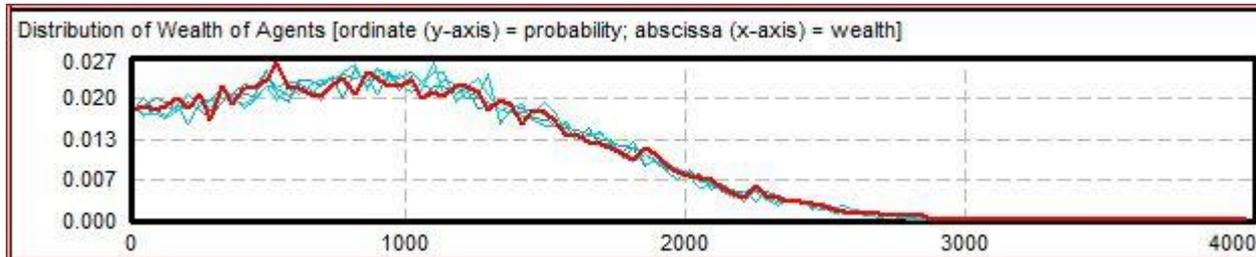


At 3,000 ticks.

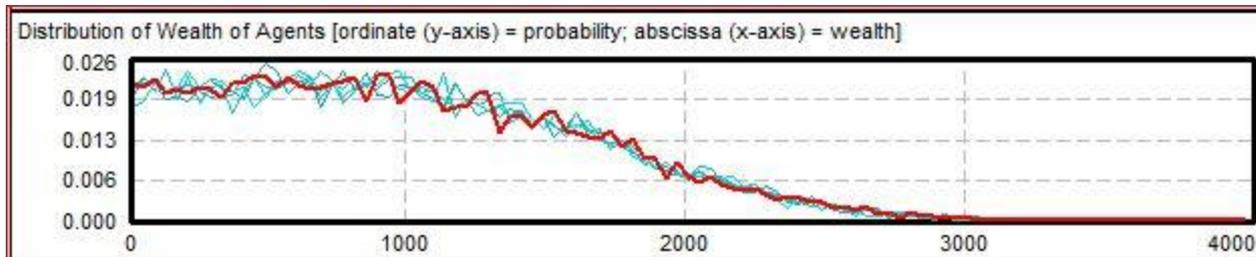
BDY Model: Behaviour



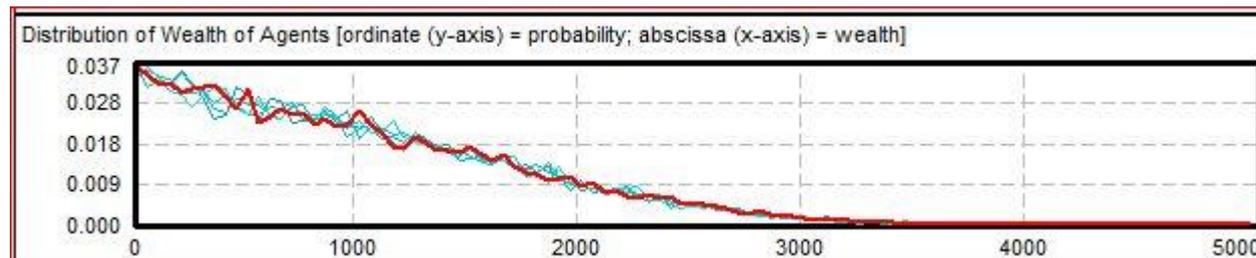
At 4,000 ticks.



At 5,000 ticks.



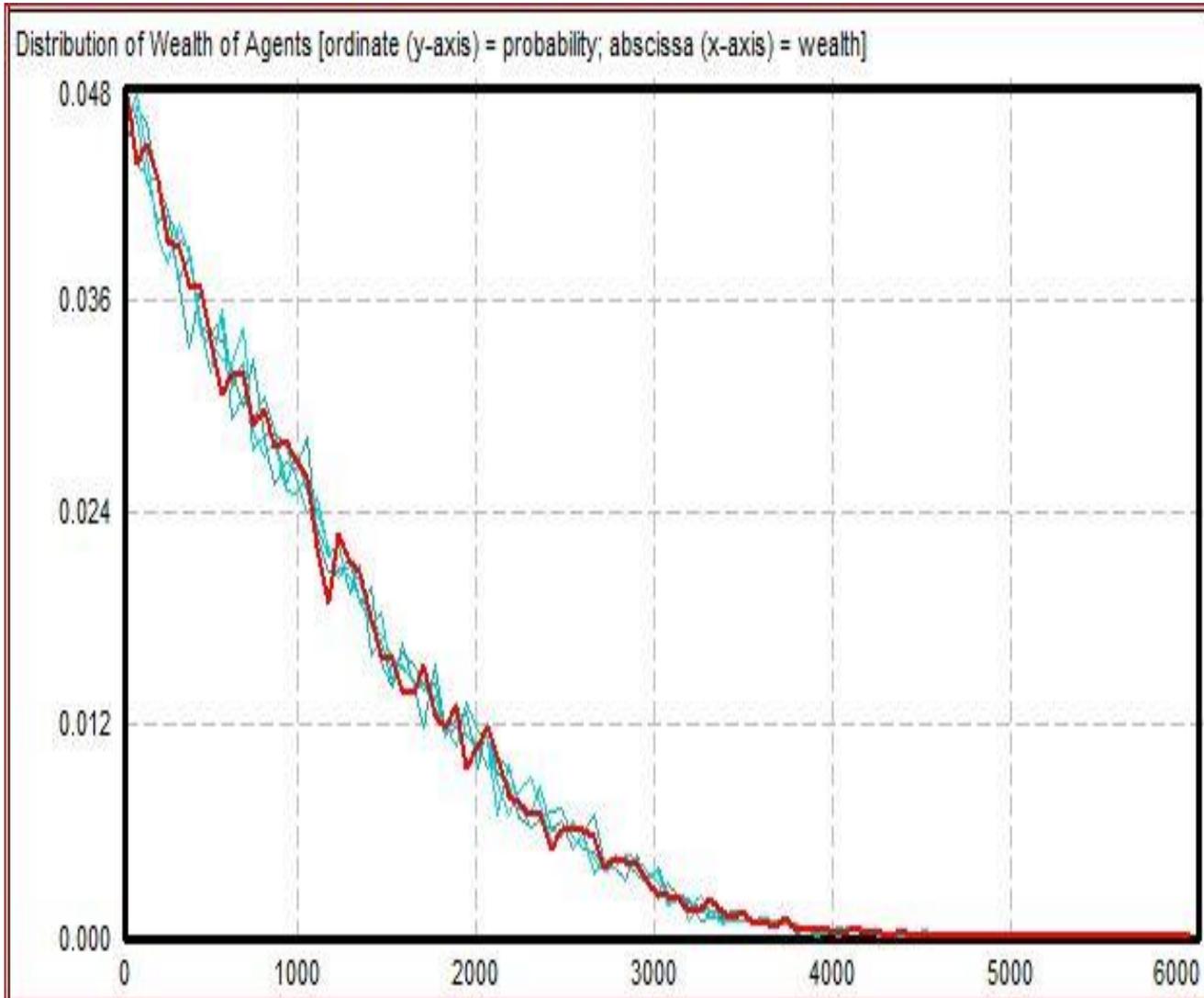
At 6,000 ticks.



At 10,000 ticks.

**Almost
Equilibrium!!**

BDY Model: Behaviour

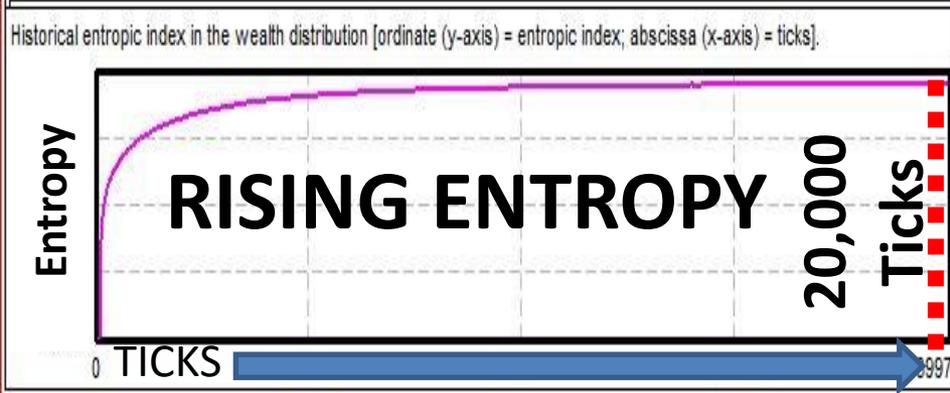
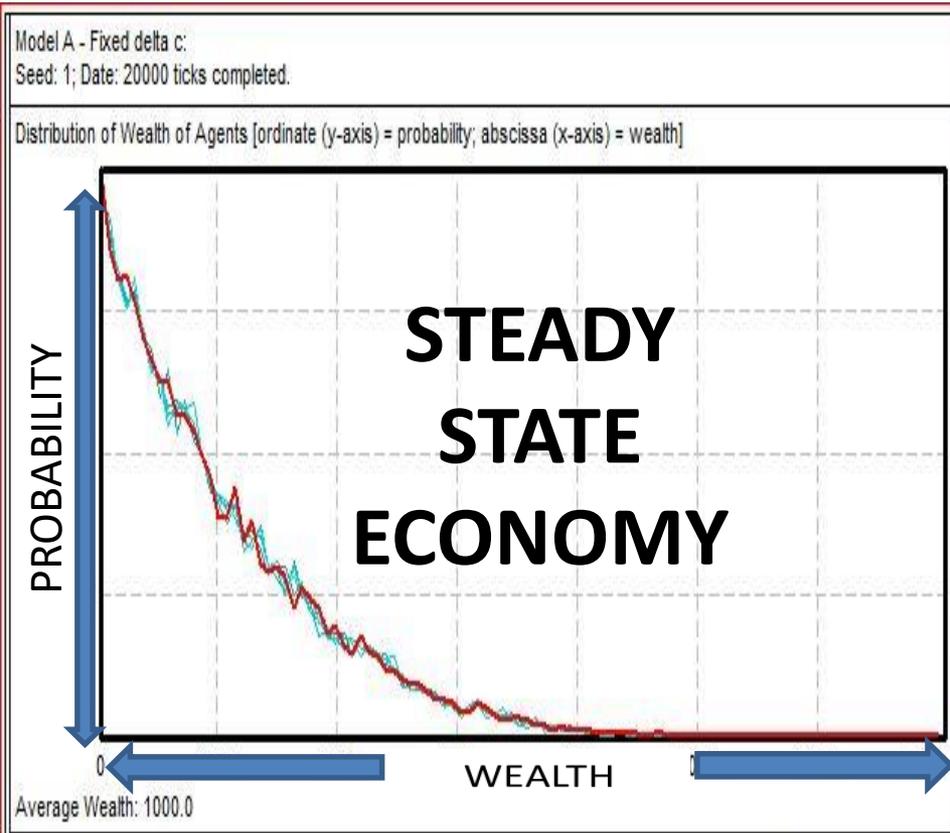


At 15,000 ticks.

Equilibrium!!

**No further
change to
shape of
distribution
of wealth.**

Role of Economic Entropy

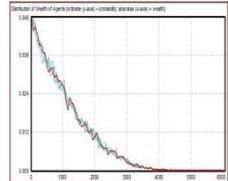


By 20,000 ticks the **entropic index for wealth** has virtually maximized, and this economy can be considered to be in steady state.

“Steady State” means the inherent **drive for change** has been neutralized.

Dependence upon Structure of Capital Exchange?

- Drăgulescu and Yakovenko tried many variations in the structure of the simple binary capital exchanges:
 - Debt allowed, or not (say minimum holding is $X_m \leq 0$);
 - With fixed or random amounts exchanged;
 - Pro-rata amounts exchanged, based on % wealth;
 - Unilaterally or co-determined amounts exchanged;
- They also tried two variations with complex transactions:
 - A “Cobb-Douglas Production/Profit” model in which entrepreneurs hired random agents to build products, and sold the products to other random agents; and
 - A “Banking” model, with investments made, bonds sold, and interest paid, the details of which were not published.

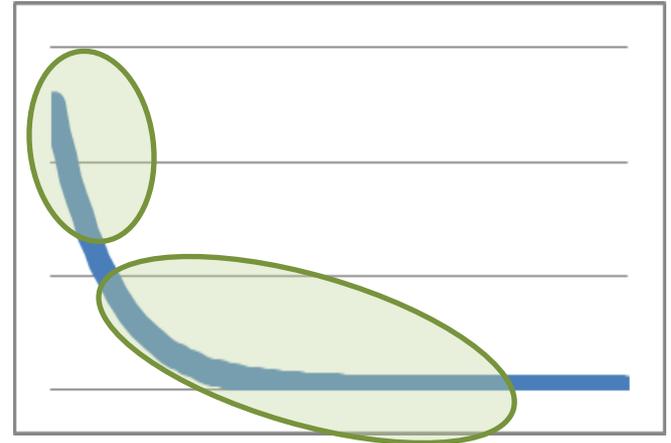


Exponential Distribution

$$P(m) = ce^{-(m/T_m)}$$

m is money; c is scaling constant; e is Euler's constant, T_m is the average wealth.

An
"exponential".

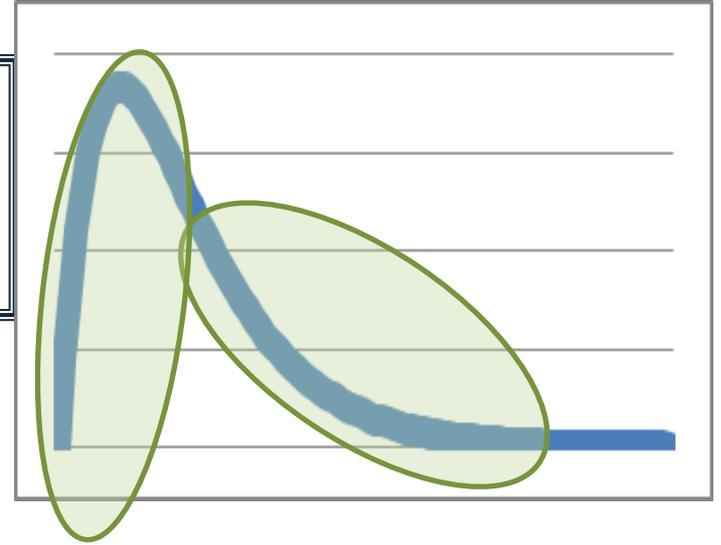


- As long as the capital exchange is **time-symmetric**, the final shape of the equilibrium distribution is always the same, regardless of the structure of the exchange, or the initial distribution of money.

A Hybrid Distribution

$$P(m) = \underline{cme}^{-(m/T_m)}$$

m is money; c is scaling constant; e is Euler's constant, T_m is the average wealth.



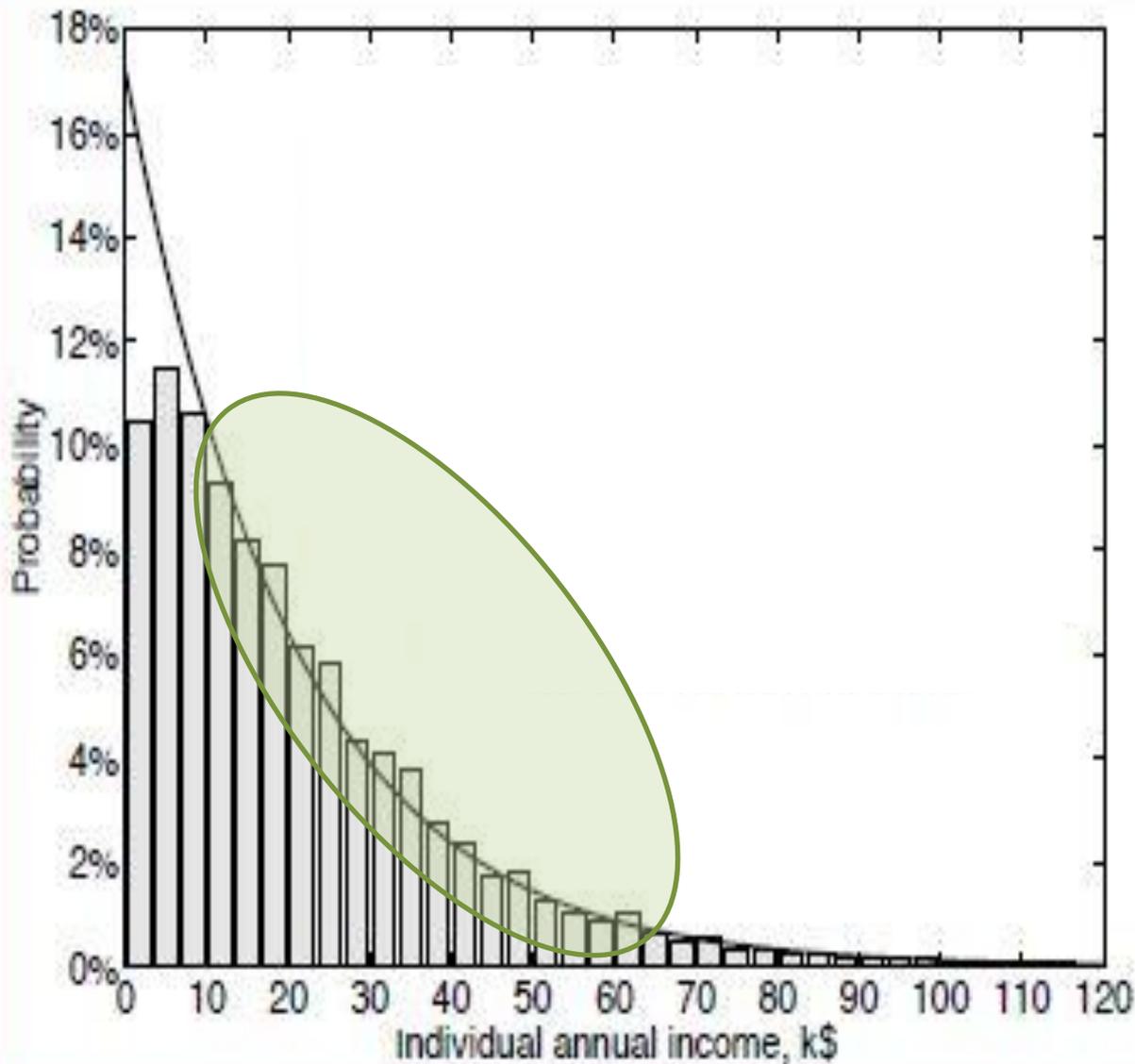
But, when the capital exchange is **time-asymmetric**, the shape of the equilibrium distribution is a little different, but with an exponential-like body.

What Leads to Success?

- In the BDY model all agents are identical to one another:
 - **Skill** or **education** does not distinguish any agent;
 - **Talent** does not distinguish any agent; and
 - **Greed** does not distinguish any agent.
- The shape of the central part of the distribution is:
 - independent of agent characteristics, and
 - independent of the structure of capital exchanges.
- Success of any agent is entirely a matter of random processes.
 - Always, some few agents will benefit from many wins.
 - Always, most agents will suffer many losses.

**But, that's a silly primitive model.
Of what use is it, really?**

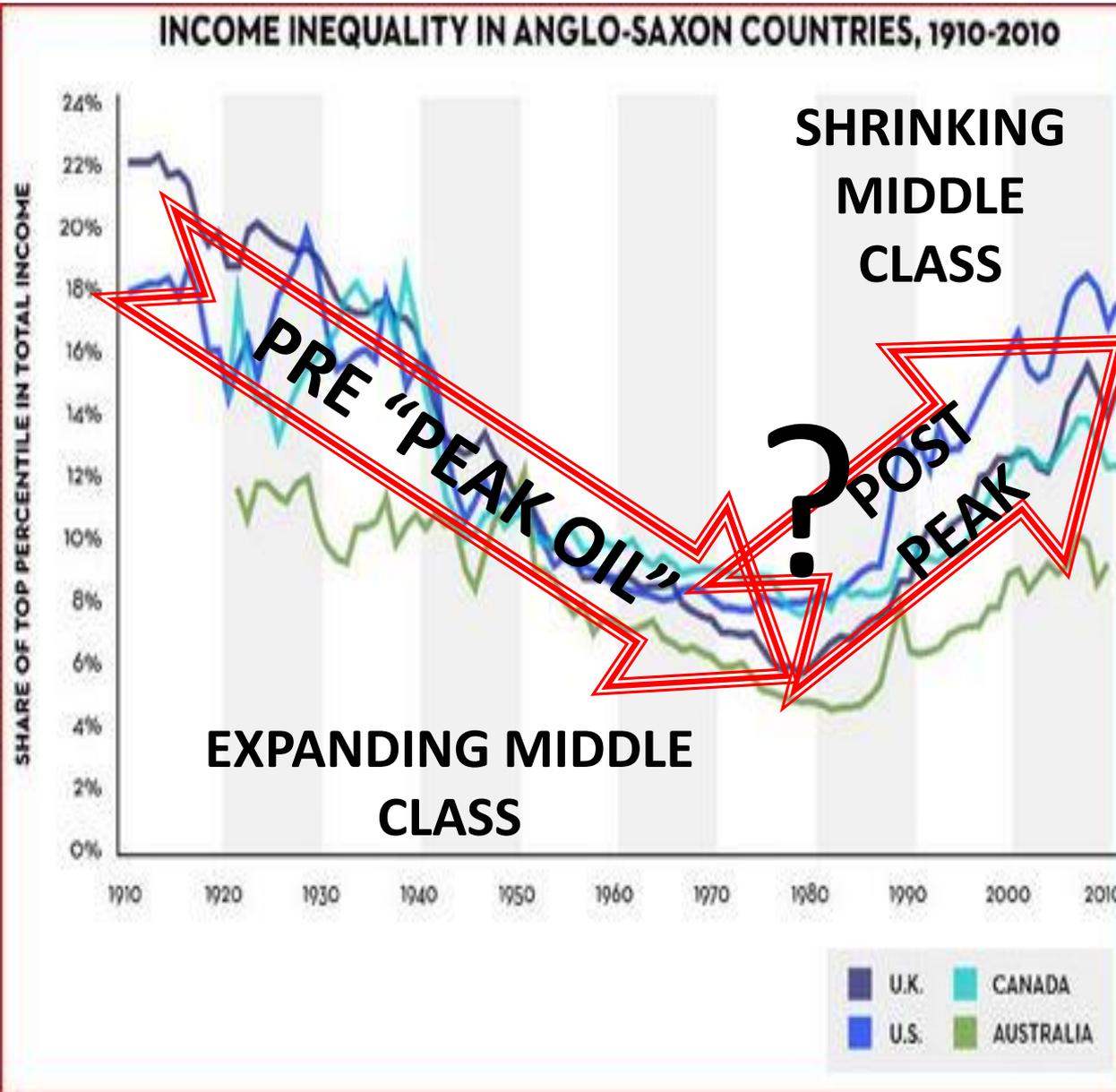
Empirical Studies



**US Individual
Income Tax
data, for
1996,
compared to
exponential
curve.**

SOURCE:
Drăgulescu and Yakovenko
(2001) Evidence for the
exponential distribution of
income in the USA“, The
European Physical Journal B, 20:
585-589.

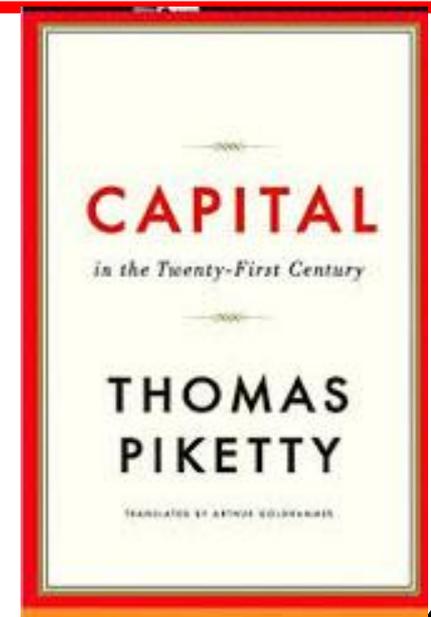
Empirical Studies



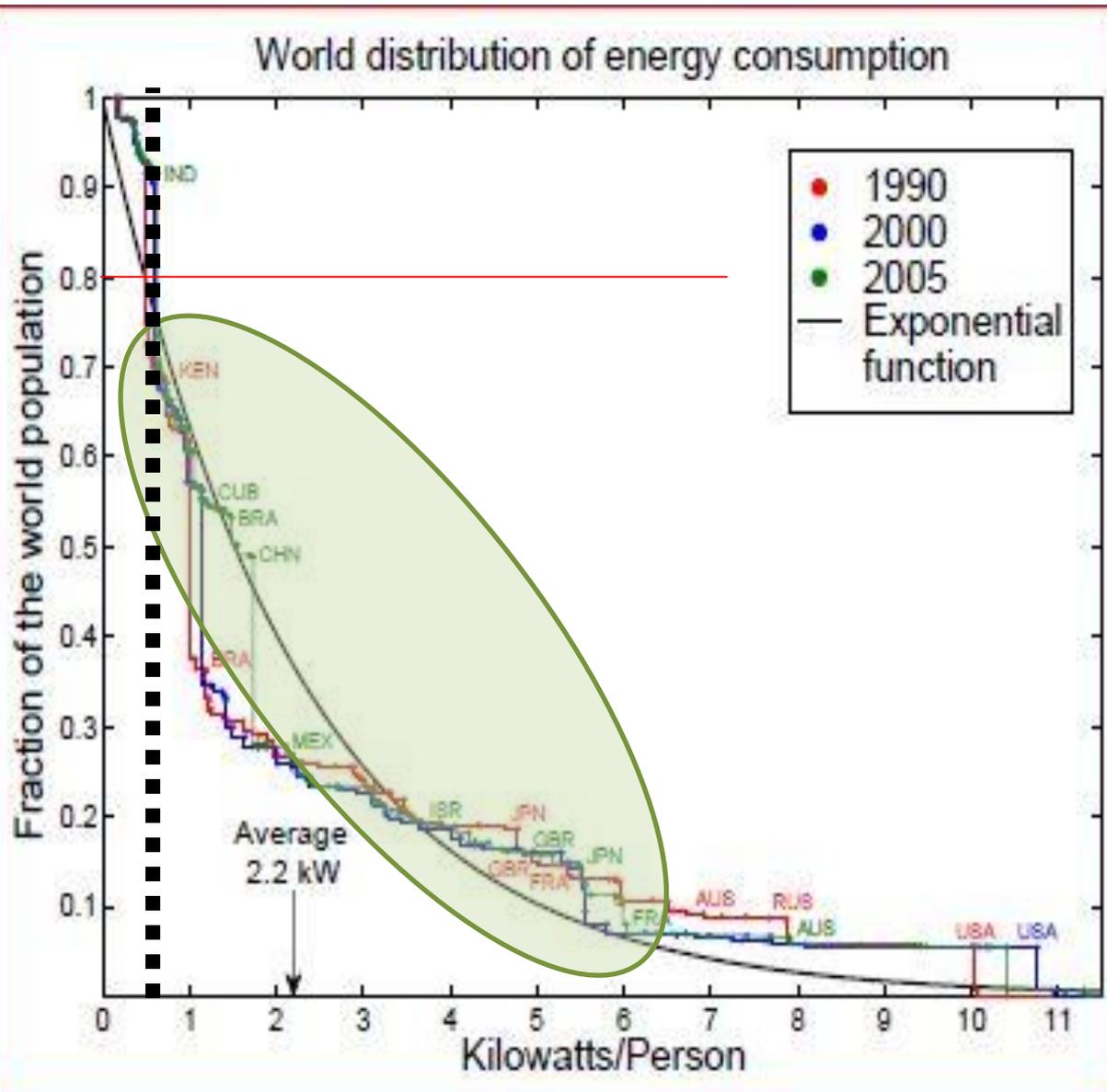
Recent History of Income Inequality

SOURCE:

Piketty, (2014) "Capital in the Twenty First Century", President and Fellows of Harvard College.



Empirical Studies



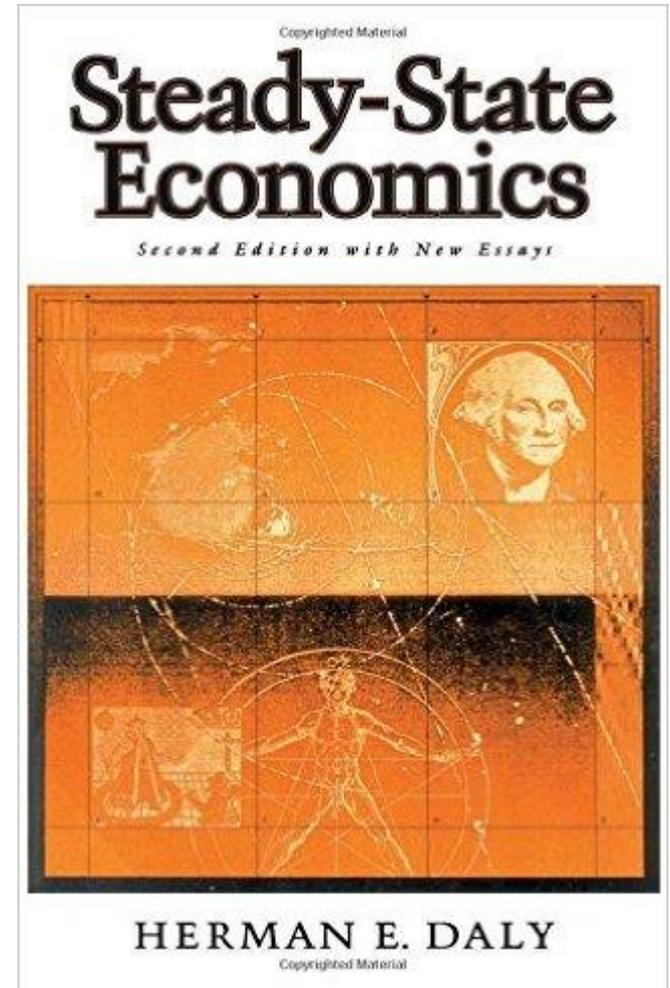
CDFs of per capita energy consumption, by country.

SOURCE:

Yakovenko (2010) Statistical Mechanics of money, debt and energy consumption.

Connection to Ecological Economics

- Herman Daly's vision of a "steady state" economy leads us directly to this phenomenon of a wealth distribution characterized by maximum wealth entropy.
- To be truly science-based, Ecological Economics must encompass this phenomenon.



ECONOMIC ENTROPY RISES AS WE APPROACH STEADY STATE

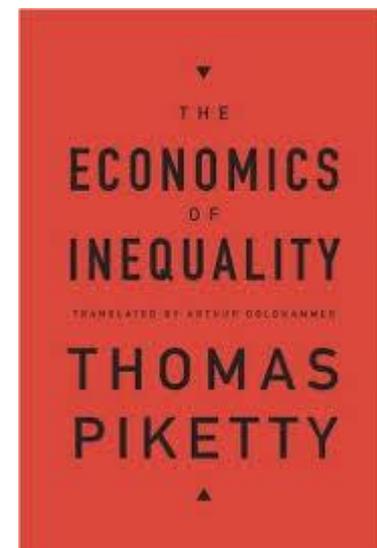
Insights from BDY Capital Exchange Models

- **STEADY STATE \Rightarrow MAXIMUM WEALTH ENTROPY**
 - **MAXIMUM WEALTH ENTROPY \Rightarrow EXTREME INEQUITY IN WEALTH DISTRIBUTION**
- **EXTREME INEQUITY OF WEALTH HAS LITTLE OR NOTHING TO DO WITH GREED, TALENT, SKILL OR EDUCATION**
 - **IT IS A NATURAL CHARACTERISTIC OF ALL ECONOMIES**
- **THE DRIVE TOWARDS MAXIMUM WEALTH ENTROPY IS BOTH NATURAL AND RELENTLESS**

THOMAS PIKETTY ARGUES:

“The political implications of these theories is important. If a significant part of inequality is in fact due to **perverse mechanisms** of the sort described [previously, in his book, such as **bad luck**, prejudice, birth circumstances], then **new redistributive mechanisms** are needed.”

The BDY model shows us that the effects of “bad luck” are **immense, endemic, and ubiquitous** in all economies.



SOURCE: Thomas Piketty (2015) The Economics of Inequality: Translated by Arthur Goldhammer, Belknap Press of Harvard University Press. Page 86.

Policy Issues for Ecological Economics Theorists

LOCAL – Within Nations

- The relentless tendency for economic entropy to rise will **continuously redistribute wealth and income** away from the poor people into the hands of the wealthy people.
- There is a **hidden cost** to distributive equity which must be paid in energy, in dollars, and in lost business opportunity.
- Distributive equity requires a **policy of continuous counter-active redistribution** from the hands of the wealthy to the poor.
- A science-based theory of ecological economics **must recognize and account for such costs**, or distributive equity within a nation will remain an unachievable utopian dream.

Policy Issues for Ecological Economics Theorists

GLOBAL – Between Nations

- The relentless tendency for economic entropy to rise will continuously redistribute wealth and income **away from the poor nations into the hands of the wealthy nations**.
- The source of wealth for nations will be, as it has always been, **anchored in pragmatic access to energy**.
- Distributive equity requires a **policy of continuous counter-active redistribution** from the hands of the wealthy nations to the poor nations.
- A science-based theory of ecological economics **must recognize and account for the role of energy**, or economic theory will remain impotent in global affairs.

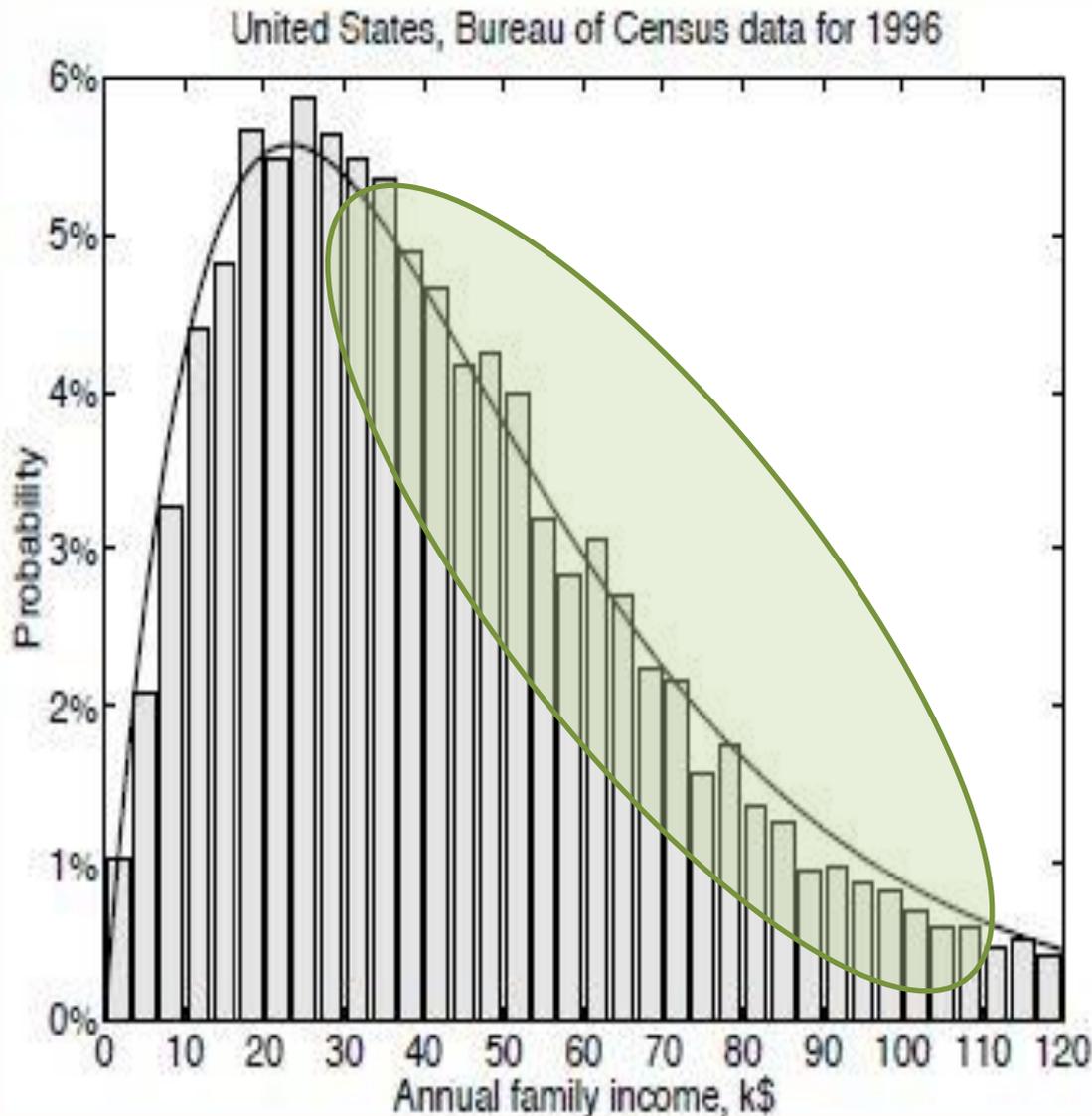
QUESTIONS?

Hip Pocket Slides

Empirical Studies

- A. DRĂGULESCU, V.M. YAKOVENKO (2001a) “Evidence for the exponential distribution of income in the USA”, *Eur. Phys. J. B* 20, 585–589
- A. DRĂGULESCU, V.M. YAKOVENKO (2001b) “Exponential and power-law probability distributions of wealth and income in the United Kingdom and the United States” *Physica A* 299, 213–221
- YAKOVENKO, V. M. (2010a). Statistical mechanics of money, debt, and energy consumption. *Science and Culture*, 76(9-10), 430-436. doi: arXiv:1008.2179
- YAKOVENKO, V. M. (2010b). Statistical mechanics approach to the probability distribution of money. Informally published manuscript, Available from arXiv. (1007-5074v1).
- YAKOVENKO, V. M. (2012). Applications of statistical mechanics to economics: Entropic origin of the probability distributions of money, income, and energy consumption. In: Taylor, L., Rezai, A., Michl, T. (eds): *Social Fairness and Economics: Economic essays in the spirit of Duncan Foley*, pp 53-82. In: *Proceedings of the symposium in honor of Duncan K. Foley on occasion of his 70th birthday at the Department of Economics, New School for Social Research, New York, 20-21 April 2012*. Routledge series, *Frontiers of Political Economy* (2012).
- PIKETTY, T. (2014) “*Capital in the Twenty First Century*”, President and Fellows of Harvard College.

Empirical Studies



**US Family
Income Tax
data, for 1996,
compared to
model curve.**

SOURCE:

Drăgulescu and Yakovenko (2001)
Evidence for the exponential
distribution of income in the USA“,
The European Physical Journal B,
20: 585-589.

What About Normative Issues?

As “naturalists” we train ourselves to see natural processes as **GOOD**, and want to “let nature take its course”.

The creation of vast inequity of wealth is clearly a “natural” process.

The reality is this: Mother nature is relentless, remorseless, and amoral.

What About Normative Issues?

Should we, then, embrace this natural process, and endorse the relentless march back to massive social inequity?

OR, should we resist mother nature to achieve this desired goal of distributive social justice?

A MORAL DILEMMA?

Types of Distributive Norms

Five types of distributive norm are defined by Forsyth:

- **Equity:** Members' outcomes should be based upon their inputs. Therefore, an individual who has invested a large amount of input (e.g. time, money, energy) should receive more from the group than someone who has contributed very little. Members of large groups prefer to base allocations of rewards and costs on equity.
- **Equality:** Regardless of their inputs, all group members should be given an equal share of the rewards/costs. Equality supports that someone who contributes 20% of the group's resources should receive as much as someone who contributes 60%.
- **Power:** Those with more authority, status, or control over the group should receive more than those in lower level positions.
- **Need:** Those in greatest needs should be provided with resources needed to meet those needs. These individuals should be given more resources than those who already possess them, regardless of their input.
- **Responsibility:** Group members who have the most should share their resources with those who have less.

Forsyth, D. R. (2006). Conflict. In Forsyth, D. R. , Group Dynamics (5th Ed.) (P. 388 - 389) Belmont: CA, Wadsworth, Cengage Learning. (Online source: https://en.wikipedia.org/wiki/Distributive_justice)

What About Individual Human Characteristics?

What roles do greed, talent, skill and education play?

- It has long been known that the empirical distributions have a slightly “fat tail”, meaning there are a few more rich people than there “should” be, based on such “gas models”.
- However, for the most part, such human qualities only help to determine your place in the distribution, and **DO NOT CHANGE THE SHAPE** of the distribution **VERY MUCH**.